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# The effect of milled rumble strips versus virtual rumble strips on sleepy drivers

## A driving simulator study

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vti

FINDING A BETTER WAY

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**Title:**
The effect of milled rumble strips versus virtual rumble strips on sleepy drivers – a driving simulator study

**Abstract (background, aim, method, result) max 200 words:**

This report describes the method, results and conclusions from a driving simulator experiment with the aim to evaluate the effect of two scenarios of importance selected on a theoretical framework within IN-SAFETY. One additional aim was to investigate consequences of driver state (alert/sleepy) on system effectiveness.

One out of two scenarios was related to lane departure warning in terms of milled rumble strips or as a driver support system. In relation to "lane departure warning", the experiment considered possibilities and consequences of replacing the infrastructure element milled rumble strips with a haptic in-vehicle system. The case of centre and shoulder line rumble strips on a two-lane highway was studied and compared with a baseline.

The second scenario was focusing on the effect of an in vehicle warning system about school bus ahead simulating a system based on vehicle to vehicle information. In-vehicle "School bus ahead warning" was considered as an example of in-vehicle information used to inform the driver of upcoming events.

In total 20 (10 male and 10 females) participated in the experiment. Two conditions were used: one after a night sleep (alert) and one after a night awake (sleepy). The alert condition was after a night sleep; the sleepy condition was after a night awake. The order was balanced for gender and condition.

The results showed that there is a potential to substitute the infrastructure measure rumble strips with an in-vehicle assistance system. Moreover, in-vehicle information was found to be an effective way of reducing the subjects' speeds during temporary safety critical situations.

**Keywords**:
Driver sleepiness, milled rumble strips, virtual rumble strips, driving simulator

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Effekten av frästa räfflor jämfört med virtuella på pigga och sömniga förare – en simulatorstudie

**Referat (bakgrund, syfte, metod, resultat) max 200 ord:**

Föreliggande rapport beskriver metod, resultat och slutsatser från ett simulatorförsök där syftet var att utvärdera effekten av två olika scenarion som på teoretisk basis valts ut inom projektet som potentiella lösningar i framtida transportsystem. Syfte var vidare att utvärdera betydelsen av förarens tillstånd (pigga och sömniga) för givna situationer.

Sammanlagt deltog 20 försökspersoner lika fördelade på män och kvinnor och i balanserad ordning. Två scenarion ingick. Det ena scenariot var ”lane departure warning” i termer av frästa räfflor jämfört med motsvarande åtgärd, men som förarstöd. Syftet var att utreda om den infrastrukturbaserade räfflan har samma effekt på förares beteende som den fordonsbaserade varningen, i vilka räfflan inte syns. I försöket var vägen försedd med räfflor både i mitten av vägen och på vägkanten. Jämförande scenario var inga räfflor alls. Det andra scenariot var ett fordonsbaserat varningssystem som varnar om det finns en stillastående skolbuss längre fram. Systemet var tänkt att utgå från en kommunikation mellan fordon. Skolbussen var tänkt som ett exempel på händelsebaserad information i fordonet.

Resultaten visade att det finns en potential i att byta infrastrukturbaserade räfflor mot system som genererar samma effekt, men som ett förarstöd. Det kunde även konstateras att fordonsbaserad information om en händelse längre fram t.ex. stannad skolbuss reducerade förbipasserandes hastighet. Hastighetsreduceringen var ett faktum såväl när försökspersonerna var utvilade som när de led av sömnbrist.

**Nyckelord:**
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# Foreword

This study has been possible to perform thanks to the Swedish Road Administration and to the EU project IN-SAFETY.

I would like to thank Beatrice Söderström, Andreas Tapani and Anne Bolling for their excellent work in most of the topics related to the planning of the experiment. I would also like to thank Andreas Tapani and Albert Kircher for their valuable work during analysing and writing of the report. Last but not least I would like to thank all participants coming to VTI twice, once after a good night's sleep and once after a night without sleep. Without you the study had not been possible.

Linköping October 2008

*Anna Anund*



Cover: Photos.com and VTI/Hejdlösa bilder

## Quality review

Review seminar was carried out on Marsh 7, 2008 where Anne Bolling reviewed and commented on the report. Anna Anund has made alterations to the final manuscript of the report. The research director of the project manager, Lena Nilsson, examined and approved the report for publication on October 31, 2008.

## Kvalitetsgranskning

Granskningsseminarium genomfört 2008-03-07 där Anne Bolling var lektör. Anna Anund har genomfört justeringar av slutligt rapportmanus. Projektledarens närmaste chef, Lena Nilsson, har därefter granskat och godkänt publikationen för publicering 2008-10-31.

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## List of abbreviations

| | |
|---|---|
| ADAS | Advanced Driver Assistance Systems |
| EU | European Union |
| ESS | Epworth Sleepiness Scale |
| FRE | Forgiving Road |
| HMI | Human Machine Interface |
| RLS | Rest less legs syndrome – Questionnaire |
| IST | Information Society Technologies |
| ITS | Intelligent Transport Systems |
| IVIS | In Vehicle Information Systems |
| KSS | Karolinska Sleepiness Scale. A self rated sleepiness score. |
| LCD | Liquid crystal display |
| NRS | No rumble strips |
| RRS | Real milled rumble strips (visible) |
| SER | Self Explaining Roads |
| TH | Time headway (time necessary to reach the point where the car ahead is when keeping constant speed with actual distance to car ahead. |
| TMIC | Traffic Management Information Centre |
| TTC | Time to collision (time necessary to touch car ahead when both are keeping actual speed and distance). |
| V2V | Vehicle to Vehicle |
| VRS | Virtual rumble strips (not visible) |
| VMS | Variable Message Signs |

**The effect of milled rumble strips versus virtual rumble strips on sleepy drivers – a driving simulator study**

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## Executive summary

The aim of the EU project IN-SAFETY is to create effective combinations of traditional infrastructure measures combined with new technology to increase the self-explanatory and forgiving nature of the road traffic system.

This report describes the method, results and conclusions of a driving simulator experiment with the aim to evaluate the effect of two scenarios of importance selected on a theoretical framework within IN-SAFETY: lane departure warning in terms of milled rumble strips or as a driver support system, and the effect of an in-vehicle warning system informing there is a school bus ahead, simulating a system based on vehicle to vehicle information.

Concerning the “lane departure warning”, the experiment considered possibilities and consequences of replacing the infrastructure element milled rumble strips with a haptic in-vehicle system. Both centre and side line rumble strips on a two-lane highway were studied and compared with a baseline. In-vehicle “School bus ahead warning” was considered as an example of in-vehicle information used to inform the driver of upcoming events. Both rumble strips and school bus warning was studied for drivers after not having slept the night before driving as well as after a night’s sleep in order to investigate consequences of driver state on system effectiveness.

The results showed that there is a potential to substitute the infrastructure measure rumble strips with an in-vehicle assistance system. Moreover, in-vehicle information was found to be an effective way of reducing the subjects’ speeds during temporary critical situations concerning traffic safety.

**Effekten av frästa räfflor jämfört med virtuella på pigga och sömniga förare – en simulatorstudie**

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## Sammanfattning

EU projektet IN-SAFETY hade som syfte att genom att kombinera traditionella infrastrukturella åtgärder med ny teknik få en väg som är mer självförklarande och förlåtande jämfört med dagens vägar.

Föreliggande rapport beskriver metod, resultat och slutsatser från ett simulatorförsök där syftet var att utvärdera effekten av två olika scenarion som på teoretisk basis valts ut inom projektet som potentiella lösningar i framtida transportsystem. Det ena var ”lane departure warning” i termer av frästa räfflor jämfört med motsvarande åtgärd men som förarstöd. Det andra var ett fordonsbaserat varningssystem som varnar om det finns en stillastående skolbuss längre fram. Systemet var tänkt att utgå från en kommunikation mellan fordon.

Avseende “lane departure warning”, så fokuserade försöket på att utreda om den infrastrukturbaserade räfflan har samma effekt på förares beteende som den fordons-baserade varningen, i vilka räfflan inte syns. I försöket var vägen försedd med räfflor både i mitten av vägen och på vägkanten. Jämförande scenario var inga räfflor alls. Skolbussen var tänkt som ett exempel på händelsebaserad information i fordonet. Såväl ”lane departure” som skolbuss studerades då förarna var dels pigga, dels sömniga. Syftet var att utvärdera betydelsen av förarens tillstånd för givna situationer. Sammanlagt deltog 20 försökspersoner lika fördelade på män och kvinnor och i balanserad ordning.

Resultaten visade att det finns en potential i att byta infrastrukturbaserade räfflor mot system som genererar samma effekt, men som ett förarstöd. Det kunde även konstateras att fordonsbaserad information om en händelse längre fram till exempel, stannad skolbuss reducerade förbipasserandes hastighet. Hastighetsreduceringen var ett faktum såväl när försökspersonerna var utvilade som när de led av sömnbrist.

# 1 Introduction

Over 42,000 road users are killed in European Union (EU) countries annually and around 3.5 million are injured, when under-reporting is taken into consideration. This accounts for an annual cost of over 160 billion Euros and untold pain and suffering of the victims and their relatives. Looking at fatality numbers, car occupants are the largest single casualty group. They comprise 57% of total EU road deaths, with the majority of car occupant casualties sustained in side and frontal impacts. Looking at fatality risk however, the traffic system is less safe for the more vulnerable road users, where the risk of death on EU roads is substantially higher than for car occupants. Indeed, for pedestrians and cyclists the risk is 8–9 times higher and for motorcyclists it is 20 times higher than for car drivers.

Thus, infrastructure improvements and enforcement campaigns are not expected to significantly contribute towards the 50% reduction of road fatalities, as is the target by the EU for 2010. The use of new technologies may become the catalyst towards achieving this goal, especially since the combination of new technologies with existing infrastructure, or with limited improvements of it, may lead to much more cost-effective solutions. However, the rather high cost of traditional infrastructure construction / adaptations is a prohibiting factor. The combination of new technologies with existing infrastructure may lead to much more cost-efficient solutions.

IN-SAFETY project aims to use intelligent, intuitive and cost-efficient combinations of new technologies and traditional infrastructure best practice applications, in order to enhance the forgiving and self-explanatory nature of roads, by:

- Building consensus on priorities for regulation and standardisation processes and assessing the potential and cost-effectiveness of combined use of such new technologies (ADAS, IVIS) and innovative HMI concepts.
- Developing and testing new simulation models (micro- and macro-) and risk analysis tools, in order to estimate the safety of road environments.
- Developing training tools and curricula for road and TMIC operators, focusing on the use of new technologies.
- Harmonising / optimising vertical and horizontal signing and adapting their information to the specific needs and wants of each user.
- Issuing priority implementation scenarios, guidelines for further research and policy recommendations for cost-efficient road environment development, road safety assessment and inspection, including new technological elements.

Except for two work packages focusing on Administration and Dissemination/Exploitation the EU project IN-SAFETY has five work packages focusing on:

- Implementation scenarios and concepts towards forgiving road environments
- Implementation scenarios and concepts towards self-explaining road environments
- New models, tools and guidelines for road safety assessment
- Pilots implementation and tests
- Implementation priorities and policy recommendations.

Here a self-explaining road was defined as: “A road designed and built is such a way as to induce adequate behaviour and thereby avoid driving error”. An example is: roads have a recognisable road layout dependent on the road category [in accordance to CROW, 1997]. The definition of a forgiving road was a road designed and built in such a way as to interfere with or block the development of driving error, to avoid or mitigate negative consequences of driving error, therefore allow the driver to regain control and either stop or the return to the travel lane without injury or damage. For instance:: roads have structural layout elements that reduce the consequences of accidents once they happen [in accordance to CROW, 1997]

Within the IN-SAFETY a categorisation of errors (resulting in accidents) was made in order to establish a transparent estimation of the effects of a forgiving road environment on the basis of these errors. A total of 18 alternative systems contributing to the creation of a forgiving road (FOR) and a self-explaining road (SER) environment have been identified. These 18 systems were obtained by combining the six most important causes of errors identified in accident statistics (excessive speed in unexpected sharp bends, speeding in general, violation of priority rules, wrong use of the road, failure when overtaking and insufficient safety distance), with three dimensions along which systems can be developed (the vehicle, the infrastructure and the coordination between the vehicle and the infrastructure). From this a final selection of scenarios was done. Within the IN-SAFETY project these would be in focus at four different test sites: Germany (Stuttgart), Italy (Torino), Greece (Athens) and in a moving based driving simulator in Sweden (Linköping).

**Scenario 1:** VMS information into vehicle (e.g. speed)

- Description: Self-explaining system that assists drivers with special information (here for example speed)
- Referred error: inappropriate speed where VDS/VMS is implemented
- Type of system: Warning is displayed on VMS at roadside and information is emitted into car.

**Scenario 2:** School bus ahead warning

- Description: Self-explaining system that informs about e.g. school buses ahead
- Referred error: when there are unprotected road users
- Type of system: Warning is displayed in vehicle only.

**Scenario 3:** Safe curve speed warning

- Description: Self-explaining system that aids drivers when driving too fast in curves
- Referred error: Exceeding safe speed in curves
- Type of system: Vehicle autonomous.

**Scenario 4: Lane Departure Warning**

- Description: Forgiving system that assists drivers when leaving the road unintended
- Referred error: Wrong use of the road
- Type of system: Vehicle autonomous
(in addition, also with roadside beacons emitting local conditions (e.g. road works).

**Scenario 5: Overtaking Assistant with lane separation (Blind spot)**

- Description: Forgiving system that assists drivers while overtaking
- Referred error: Failure while overtaking
- Type of system: Vehicle autonomous.

**Scenario 6:** Overtaking Assistant without lane separation (rural roads)

- Description: Forgiving system that assists drivers while overtaking
- Referred error: Failure while overtaking
- Type of system: Vehicle autonomous.

This report will describe the results from the moving based driving simulator experiment. Forgiving Road Environment (FRE) – scenario group 2 and Self-Explanatory Road Environment (SER) – scenario group 4 was evaluated.

# 2 Aim and Hypotheses

## 2.1 Aim

*Rumble strips*

The aim of this driving simulator study was to study the effects of haptic in-vehicle HMI as a substitute for installed infrastructure elements to increase the forgiving and self-explanatory nature of rural road environments. The infrastructure elements considered are milled rumble strips. The effects of milled rumble strips and in-vehicle “virtual” rumble strips was studied for both *night sleep* (alert) and *no sleep* (fatigue) drivers since there is a need for knowledge taking into account the differences between driver status. This information will be used in order to improve the rural simulation model RutSim (Tapani, 2005) and take into account different driver behaviour when overtaking.

*In vehicle information – in order to reduce speed*

The aim was also to evaluate the effectiveness of in-vehicle information about temporarily oncoming events, for example when a school bus stops for taking on or leaving children at the road side.

## 2.2 Hypotheses

The aim of the driving simulator experiment was to test the following hypotheses.

**Rumble strips:**

Overtaking – Visible rumble strips will reduce the number of overtakings more than virtual non-visible (virtual) rumble strips.

Speed – Visible rumble strips will reduce speed and increase the speed variance more than non-visible rumble strips.

Vehicle position – Visible rumble strips at centre line will force vehicles more to the right with increased variance than non-visible rumble strips.

**No sleep vs. night sleep:**

Overtakings – *No sleep* drivers make fewer overtakings than *night sleep* drivers

Overtakings – When overtaking, *No sleep* drivers have reduced safety margins compared to night sleep drivers.

Speed – *No sleep* drivers have increased speed variance compared to night sleep drivers.

**In vehicle information about school bus ahead**

Speed – when drivers receive an in vehicle warning about school bus ahead he/she will reduce speed more than without warning.

Lateral position – when drivers receive an in-vehicle warning about school bus ahead he/she will increase the safety distance to the bus when passing compared to without warning.

# 3 Method

## 3.1 Subjects

**Recruiting**

In total 20 subjects participated in the study, they were equally distributed between men and female. All were shift workers recruited by advertisement. The subjects drove twice; once after having worked during the night (no sleep) and driving just after getting of the night shift (5 am–8 am), and once after a night's sleep (alert) (9 am–4 pm). For the night sleep condition the subjects should not have been working night shift the last 5 days, this to make sure they were in alert conditions. At the no sleep condition the subjects were picked up and driven home by taxi. The subjects' reward was set to 220 Euro.

**Subject description**

In total 10 male and 10 female participated. Average age was 43.5 years (sd 7), average weight 76 kg (sd 13.8) and average height 173.4 cm (sd 9.6). In average the drivers had have their driving licences for 23.7 years (sd 7.12). They reported that they have been driving 2 273 km (sd 1 597 km) last year.

Medicine was used by three of the subjects. They used Levaxin or Bricanyl/Pulmicort. Most of the subjects (12 out of 20) reported that they use alcohol 2–4 times per month, 5 subjects reported a usage less than that and 3 subjects more (2–3 times per week). The majority of the drivers were none tobacco users (14 out of 20), 3 were smokers and 3 used snuff (smokeless tobacco). Most of the drivers drink coffee (19 out of 20), 40% (8 subjects) reported drinking 5 cups or more during working days. During their days off all reported taking coffee, the majority (70%) less then 4 cups per day.

The majority of the subjects did not have problems falling asleep (75%). Five subjects reported that they sometimes have problems falling asleep. Most of the subjects did not found it difficult to wake up (90%). Two subjects found it almost always difficult to wake up.

There were five subjects that self reported snoring, one subject reported having nightmare. Two subjects reported that they often sleep less than 6 hours, 11 subjects reported that they sometimes or always do not feel rested when waking up. Among the subjects 12 reported that they sometimes feel sleepy during daytime. In total three subjects reported that they have problems to keep awake while driving. The majority of the drivers report high sleep quality (19 out of 20), 4 subjects reported that they do not sleep enough. In total 7 out of 20 (35%) drivers had experience of sleep related incidents, however none of the drivers had been involved in a sleep related crash.

The experiment was approved by an ethical committee. (Regionala etikprövnings-nämnden i Linköping (EPN), 2006 dnr 179-06).

## 3.2 Experimental design

The design was a within subjects design. The order between no sleep condition and night sleep condition were balanced for sex.

The road scenario consisted of total 9 laps of 9.4 km each. The laps were divided into groups of 3. For each of those groups there was a balanced order of no rumble strips, real milled rumble strips and virtual rumble strips. The order was the same for each subject during both conditions, see Table 1.

*Table 1 Experiment design table.*

| | | | Baseline=0 (20 minutes)<br>Real rumble strips =1 (20 minutes)<br>Virtual rumble strips=2 (20 minutes) | | |
|---|---|---|---|---|---|
| subject | Gender<br>1=male<br>2=female | Condition<br>1=Night sleep<br>2=No sleep | 1st | 2nd | 3rd |
| 1 | 1 | 1 | 0 | 1 | 2 |
| 1 | 1 | 2 | 0 | 1 | 2 |
| 2 | 1 | 1 | 0 | 2 | 1 |
| 2 | 1 | 2 | 0 | 2 | 1 |
| 3 | 1 | 1 | 1 | 2 | 0 |
| 3 | 1 | 2 | 1 | 2 | 0 |
| 4 | 2 | 1 | 1 | 0 | 2 |
| 4 | 2 | 2 | 1 | 0 | 2 |
| 5 | 1 | 1 | 2 | 0 | 1 |
| 5 | 1 | 2 | 2 | 0 | 1 |
| 6 | 2 | 1 | 2 | 1 | 0 |
| 6 | 2 | 2 | 2 | 1 | 0 |
| 7 | 2 | 1 | 0 | 1 | 2 |
| 7 | 2 | 2 | 0 | 1 | 2 |
| 8 | 2 | 1 | 0 | 2 | 1 |
| 8 | 2 | 2 | 0 | 2 | 1 |
| 9 | 2 | 1 | 1 | 2 | 0 |
| 9 | 2 | 2 | 1 | 2 | 0 |
| 10 | 1 | 1 | 1 | 0 | 2 |
| 10 | 1 | 2 | 1 | 0 | 2 |
| 11 | 2 | 1 | 2 | 0 | 1 |
| 11 | 2 | 2 | 2 | 0 | 1 |
| 12 | 1 | 1 | 2 | 1 | 0 |
| 12 | 1 | 2 | 2 | 1 | 0 |
| 13 | 1 | 1 | 0 | 1 | 2 |

| | | | Baseline=0 (20 minutes)<br>Real rumble strips =1 (20 minutes)<br>Virtual rumble strips=2 (20 minutes) | | |
|---|---|---|---|---|---|
| subject | Gender<br>1=male<br>2=female | Condition<br>1=Night sleep<br>2=No sleep | 1st | 2nd | 3rd |
| 13 | 1 | 2 | 0 | 1 | 2 |
| 14 | 2 | 1 | 0 | 2 | 1 |
| 14 | 2 | 2 | 0 | 2 | 1 |
| 15 | 1 | 1 | 1 | 2 | 0 |
| 15 | 1 | 2 | 1 | 2 | 0 |
| 16 | 2 | 1 | 1 | 0 | 2 |
| 16 | 2 | 2 | 1 | 0 | 2 |
| 17 | 1 | 1 | 2 | 0 | 1 |
| 17 | 1 | 2 | 2 | 0 | 1 |
| 18 | 2 | 1 | 2 | 1 | 0 |
| 18 | 2 | 2 | 2 | 1 | 0 |
| 19 | 2 | 1 | 0 | 1 | 2 |
| 19 | 2 | 2 | 0 | 1 | 2 |
| 20 | 1 | 1 | 0 | 2 | 1 |
| 20 | 1 | 2 | 0 | 2 | 1 |

## 3.3 Experimental setting – moving base driving simulator

The experiment was carried out using VTI's third generation moving base driving simulator (VTI driving Simulator III), which consists of:

- Cut-off passenger car cab
- Computerised vehicle model
- Large moving base system
- Vibration table
- PC-based visual system
- PC-based audio system.

The driving simulator is shown in Figure 1 the driving simulator provides a realistic experimental driving condition which is fully controllable and with a high internal validity (same conditions for all subjects). Furthermore, the simulator makes it possible to carry out safety critical experiment which might very difficult to do as field studies. The external validity has been found to be very good in previous experiments carried out at VTI (Törnros, 1998).

*Figure 1  Moving base driving simulator at VTI.*

The simulated passenger car had a manual gearbox with 5 gears. The time delay introduced in the simulator is very short (40 ms), which is important when focusing on the control and manoeuvring aspects of driving. The noise, infra-sound and vibration levels inside the cabin corresponded to those of a modern vehicle. The car body used in this experiment was a Volvo 850. For technical specifications see Table 2.

*Table 2  Technical data about the VTI Driving simulator III.*

| **Technical data** | **Specification** |
|---|---|
| **Vibration table** | |
| vertical motion | ±6 cm |
| longitudinal motion | ±6 cm |
| roll | ±6° |
| pitch | ±3° |
| **Motion system** | |
| pitch | -9° to +14° |
| roll | ±24° |
| lateral motion | ±3.75 m |
| max. lateral acceleration | 0.8 g |
| max. lateral speed | 4 m/s |
| **Visual system** | Real time PC-based graphic projection system |
| field of view | 3 channels forward view 120° x 30° |
| resolution | 1 280 x 1 024 pixels per channel at 60 Hz |
| **Computer system** | PC |
| program language | Fortran, C and C++ |
| transport delay time | <45 ms |

## 3.4 Scenario, driving task

**Driving scenario**

The road was a two-lane rural road (9 m wide), each lane was 3.75 m wide, the rumble strips were 0.35 m wide and located 0.175 m outside the lane marking, and between the two lanes. Guard rails alternatively poles were present on the road. Before the start of the experiment all subject had to drive 10 minutes as training. During the drive overtaking was allowed and there was oncoming traffic. Theoretical three different scenarios were designed;

- Free driving: no slower vehicle on the road ahead
- Catching up a slower vehicle with and without visible oncoming vehicles
- Car following: following a slower vehicle.

Each group of 3 laps (~ 9.4 km each) consisted of approximately 20 minutes driving. As mentioned the drivers came once after a night awake (*no sleep*) and once after a night with sleep *(night sleep).* During one drive, which took approximately one hour, around 90 km were driven. A scene with free driving is shown in Figure 2.


*Figure 2 Base line and scenario without rumble strips.*

Furthermore a bus parked on the right hand side was passed twice. The first time with no information at all and the second time with an in-vehicle information beforehand. The in-vehicle information was received in the end of the first hour driven both after a night sleep and after no sleep. The information was presented in the dashboard, as shown in Figure 3. The subject did not receive information about this before the experiment started. The warning was presented before the driver could see the bus (570 meters before the bus was passed), seeing the bus was possible 447 meters before passing it. The warning was visible until overtaking the bus. As control condition a bus without driver information (warning) was at the road side earlier, and in a different rumble strip condition.


*Figure 3  Information on LCD display about school bus ahead.*

## 3.5 Measures

This chapter describes the data collected. Following data were recorded.

- Driving behaviour (see Chapter 3.5.1)
- Karolinska Sleepiness Scale (KSS) (see Chapter 3.5.2)
- General questionnaire as background, sleep and wake diaries
- Electrophysiological measures: EOG (see Chapter 3.5.3)
- Epworth Sleepiness Scale (see Chapter 3.5.4)
- DVD recording (4-split screen, see Figure 7).

### 3.5.1 Driving behaviour data

During the test the following variables were recorded with 10 Hz sampling frequency:

*Table 3 Recorded basic measurements.*

| **Variable** | **Unit** | **Description** |
|---|---|---|
| Time | msec | Time on route |
| Lap | | Lap driven (9+2 training laps) |
| Distance | | Distance driven |
| Speed | km/h | Speed of car |
| Lateral position | m | Lateral position of car relative to road middle – negative values to the left of centre line. |
| On rib | | Indicates if any wheel of the car is on the rumble strips |
| Rib | | Rumble strip mode (visible, not visible, not present) |
| Steering wheel angle | deg | Steering wheel angle |
| Longitudinal acceleration | m/s^2 | Longitudinal acceleration, forward positive |
| Lateral acceleration | m/s^2 | Lateral acceleration, left positive |
| Yaw | deg | Yaw (angle) related to road tangent |
| Yaw velocity | deg/s | Yaw velocity related to road tangent |
| Brake | n | Brake force |
| Acceleration pedal | | Acceleration pedal position (0 to1) |
| Curve | m | Road curve radius. Negative number indicates right turn |
| Slope | deg | Road slope |
| Dy | m/s | Speed in road radial direction |
| Ddy | m/s^2 | Acceleration in road radial direction |
| Rpm | 2pi/min | Engine revolution |
| Event | | Event identifier |
| Mode | | Mode within the event (ex: car following situation) |
| Distance car ahead | m | Distance to car ahead |
| Speed car ahead | km/h | Speed of car ahead |
| Side position car ahead | m | Side position of car ahead |
| Distance oncoming car | m | Distance to oncoming car |
| Left grip | V | Left grip sensor, rising voltage with pressure |
| Right grip | V | Right grip sensor, rising voltage with pressure |

Based on these measured data additional variables were calculated, see Table 4

*Table 4 Calculated measures.*

| Variable | Unit | Description |
|---|---|---|
| Overtaking | | 0 if not overtaking, 1 if overtaking |
| Overtaking start | | 0 if not overtaking, 1 if starting to overtake |
| Car following | | 0 if free driving, 1 if in car following situation with time head way < 3 sec |
| Car following start | | 0 if free driving, 1 if starting car following situation |
| Bus | | 0 if no bus, 1 if warning visible, 2 if bus visible, 3 when passing the bus |
| Hit left | | 1 when any wheel hits the left rumble strips |
| Hit right | | 1 when any wheel hits the right rumble strips |
| Average speed | km/h | Average speed, ±1 sec unweighted timeframe centred around s-point |

A detailed description of the algorithms used to calculate the variables can be found in Annex 2. For details about lateral position see

Annex 3.

All measures in Table 4 were aggregated, in addition data calculated from the EOG was added as well (all with 10 HZ sampling frequency and synchronized). Calculated measures analyzed were:

- Number of overtakings
- Mean time for overtakings
- Max speed during free driving (no overtaking or car following)
- Mean speed during free driving (no overtaking or car following)
- Max speed only during overtaking (for each overtaking separately)
- Max speed only during car following situation(for each overtaking separately)
- Mean speed only during overtaking
- Mean speed only during car following situation
- Speed variance in car following situation
- Speed variance without overtaking or car following situation
- Mean lateral position without overtaking or car following situation
- Lateral position variance without overtaking or car following situation
- Min lateral position own car (to the right side of the lane)
- Min distance to car ahead
- Lateral distance to car ahead during overtaking (point when passing car ahead)

- Min distance to oncoming car while overtaking
- Distance to oncoming car when entering own lane after overtaking
- Number of times with wheel on left rumble strips (middle line) without overtaking.

Event data for bus passing were:

- Speed (control bus without warning) at different distances from bus
- Mean speed (control bus without warning) when passing bus
- Max speed (control bus without warning) when passing bus
- Speed (warning visible) at different distances from bus
- Mean speed (warning visible) when passing bus
- Max speed (warning visible) when passing bus
- Min lateral position when passing bus (control bus without warning)
- Average lateral position when passing bus (control bus without warning)
- Min lateral position when passing bus (warning visible)
- Average lateral position when passing bus (warning visible).

### 3.5.2 Karolinska sleepiness scale

Subjective rating of sleepiness was obtained using the Karolinska Sleepiness Scale (KSS) (Åkerstedt & Gillberg, 1990). The scale consists of a 9-point scale with verbal anchors for every second step. However, the version used in this pilot was a modified version with verbal anchors for each step, see Table 5.

*Table 5 Karolinska sleepiness scale (KSS).*

| Rate | Verbal descriptions |
|---|---|
| 1 | extremely alert |
| 2 | very alert |
| 3 | Alert |
| 4 | fairly alert |
| 5 | neither alert nor sleepy |
| 6 | some signs of sleepiness |
| 7 | sleepy, but no effort to keep awake |
| 8 | sleepy, some effort to keep awake |
| 9 | very sleepy, great effort to keep awake, fighting sleep |

The participants rated their sleepiness before and after the drive and each 5th minute during the drive. They were instructed to select a score that corresponds to how they have been feeling in average during the last 5 minutes.

The self reported sleepiness differed between night sleep and no sleep condition ($F_{(1,18)}$= 114.8 ; p<0.01) see Figure 4.

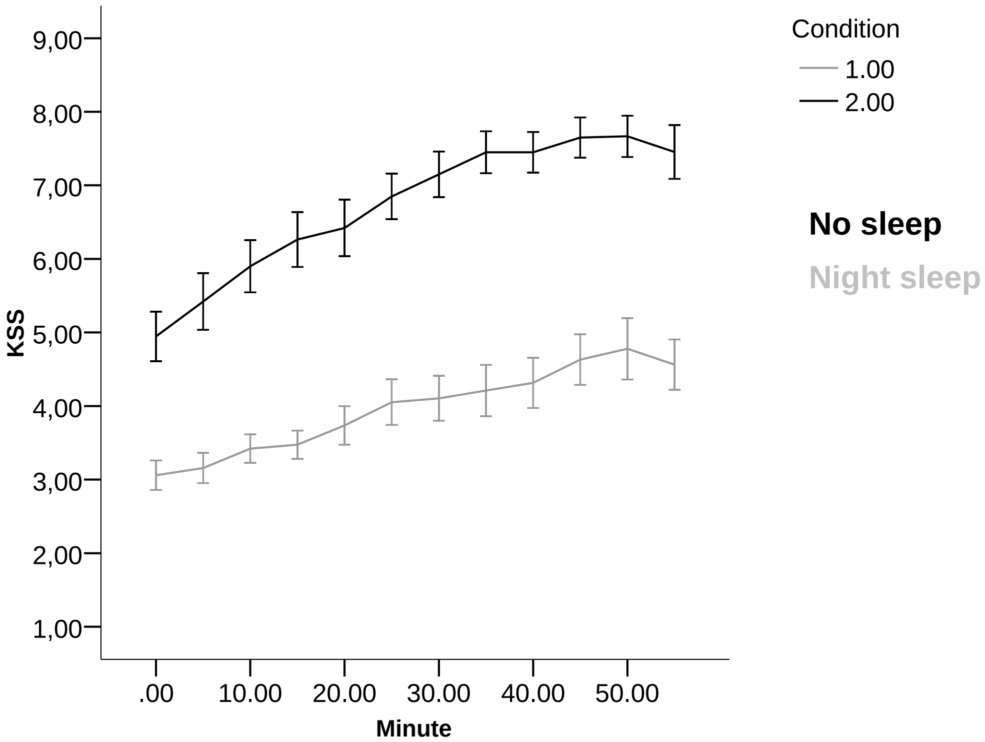


*Figure 4  Mean scored KSS for each 5 minutes during drive (bars represent SE of mean). The first score represents the KSS-value when starting to drive.*

### 3.5.3 EOG data and blink behaviour

EOG was measured by a portable recoding system called Vitaport 2 from Temec Instruments BV (see www.temec.com). Vitaport 2 is digital recorder with a software-configurable number of channels for physiological measurements. The VTI Vitaport 2 has 17 individually configurable (software) channels for physiological measurements including a marker channel for data synchronisation. To the Vitaport the electrodes were connected (see Figure 5) as well as a marker signal used for synchronisation of data.

*Figure 5 The Vitaport 2 digital recorder.*

The analysis of EOG data was done with a Matlab script developed by CNRS/LAAS in SENSATION WP4.4. This analysis provides several blink parameters per each identified blink (see Sensation Deliverable 4.4.2).

Horizontal and vertical electrooculogram (EOG) were measured through three channels. see Figure 6. The sampling frequency was 512 Hz, DC recording mode.

*Figure 6 Placement of EOG electrodes.*

### 3.5.4 Epworth sleepiness scale (ESS)

The ESS consists of 8 statements regarding different situations in daily life (Johns, 1991). Subjects were asked to rate on a scale from 0-3 how likely they would be to doze off or fall asleep in those eight situations, based on their usual way of life recently. The situations they were asked to rate were the following;

- Sitting and reading
- Watching television
- Sitting inactive in public place (e.g. theatre, meeting)
- As passenger in a car (more than one hour driving without pause)
- Lying down to rest in the afternoon when circumstances permit
- Sitting and talking to someone
- Sitting quietly after lunch (no alcohol)
- In a car, while stopped for a few minutes in the traffic.

This was used in order to describe if the subjects sleep pattern was normal or not.

### 3.5.5 DVD recordings

To make it possible to recall what happened during the drive e.g. looking for signs of fatigue, or to determine if a rumble strip hit was due to fatigue or something else, all driving sessions were recorded onto a DVD (one for each subject). The DVD recorder used was a Philips DVD-R 70 recorder. The screen was split into four windows showing the road, the driver’s face, a lateral view of the driver, and the LCD display (see Figure 7).

The subjects were asked to sign an agreement about being recorded on DVD while driving and that the recording could be used in the research.


*Figure 7  4-split DVD-screen.*

## 3.6 Procedure

This chapter describes the procedure that the drivers went through, this includes both before arriving, at the laboratory before and after driving and of course the procedure during the drive.

### 3.6.1 Preparation before arriving at the laboratory

About one week before arriving at the laboratory the subject received documents describing how the experiment will be done and how they should prepare before arriving. The drivers were asked **not to**:

- drink alcohol 72 hours before the experimental days
- eat, drink coffee or tee 3 hours before arriving at the laboratory
- use make-up.

This was done in order to minimize individual differences caused by external confounding factors. The drivers also received a sleep diary that they were asked to fill out the three days before the experiment day. Furthermore participants were asked to fill out the Epworth sleepiness scale (ESS) (see Annex 4) and Restless legs syndrome (RLS) questionnaire (see Annex 5). This is used in order to have knowledge of the drivers sleep habits and sleep behaviour, but mostly to control that the drivers did follow the instructions above.

### 3.6.2 Before driving

At arrival the drivers were taken to the laboratory in order to fill out pre-questionnaires and to put on electrodes for measuring EOG (see Figure 8).

*Figure 8 At the laboratory putting on electrodes for the EOG before driving.*

The background questionnaires (see

Annex 6) and informed consent (see Annex 7) were filled out at the laboratory before driving

### 3.6.3 Driving

The drivers were taken to the simulator, physiological measurement equipment was connected and instructions read to the driver. The driver was informed to:

- Adjust the seat
- Put on safety belt
- The vehicle is a Volvo 850 with manual gear box and front wheel drive
- Before the experiment starts there will be 10 minutes training
- Each 5 minutes they will receive a written question displayed at the screen asking “sleepy”. They should rate their sleepiness with help of the KSS. A reminder was visible in the centre of the steering wheel
- They are going to drive from Västervik to Linköping – in total 90 kilometres
- They should drive in correspondence to the law
- The test leader will observe the driver but not speaking to the driver during the experiment
- Finally that the driver has the right to stop the experiment when ever he/she wants to.

*Figure 9 Driver seated and ready to drive the 90 km.*

### 3.6.4 After driving

When 90 kilometres were driven the test ended. The subject went to the laboratory, electrodes where taken off and post-drive questionnaires filled out (see Annex 8). The aim with the questionnaires was to capture the drivers’ experience of the drive and especially overtakings and rumble strips. They also filled out the forms necessary for the reimbursement. During the no sleep condition the subjects were, for safety reasons, driven home by taxi after finishing.

## 3.7 Statistical analysis

The design was a within subject design. For the analysis related to sections with no rumble strips, milled real rumble strips and virtual rumble strips Anova – repeated measure design have been used. Huynh-Feldt correction for sphericity was used. This was also true for between effects test amid night sleep and no sleep conditions.

For the bus situation the speed for each driver was analyzed using the factor warning or no warning, and no sleep or night's sleep in the distance 9 800, 10 000 and 10 321 meters. 9 800 meters is after receiving the warning but before seeing the bus, 10 000 m is after seeing the bus, but before passing it, and 10 321 m is just when starting to pass the bus. Since the data distribution was approximately normal parametric tests were used. First paired samples t-test was used to get a general overview. The lateral position when passing the bus was also analyzed. Here absences/presence of rumble strips (RRS/VRS) was used as between factor, and normal sleep vs. no sleep and warning as within factor. A repeated measure analysis for the minimal lateral position when passing the bus with the factors warning and normal sleep vs. no sleep was performed.

For test related to the questionnaires Friedmans' non parametric test was used. All analysis have been done at a significant level of 5% ($\alpha$=0.05).

# 4 Results

## 4.1 Rumble strips

One main factor in the study design was the presence or absence of rumble strips on the road in order to make the driver aware of a lane departure. The rumble strips could have the form of a real milled rumble strips (RRS), which as well produced vibration and sound when hitting them, or of invisible (virtual) rumble strips (VRS), which only produced vibration and sound, and finally road stretches without rumble strips were present. The design was full factorial and balanced. The results are divided into section corresponding to the hypothesis about overtaking, speed and vehicle position.

### 4.1.1 Overtaking

In total 12 out of 20 subjects did overtake in both conditions (night sleep/no sleep) and on all three designs, see Table 6. Out of 20 subjects, 18 did overtake both after a night's sleep and after no sleep condition and 19 subjects did overtake in each design level.

*Table 6 Number of overtaking separated for subject, condition and design.*

| Subject | Night sleep condition | | | No sleep condition | | |
|---|---|---|---|---|---|---|
| | No rumble strips | Real rumble strips | Virtual rumble strips | No rumble strips | Real rumble strips | Virtual rumble strips |
| 1 | 5 | 6 | 6 | 1 | 1 | 0 |
| 2 | 0 | 0 | 0 | 1 | 6 | 3 |
| 3 | 2 | 0 | 0 | 6 | 5 | 6 |
| 4 | 3 | 3 | 3 | 6 | 5 | 6 |
| 5 | 6 | 6 | 6 | 6 | 5 | 6 |
| 6 | 6 | 5 | 5 | 4 | 5 | 6 |
| 7 | 1 | 3 | 3 | 3 | 3 | 3 |
| 8 | 2 | 1 | 1 | 2 | 3 | 4 |
| 9 | 5 | 3 | 3 | 5 | 5 | 5 |
| 10 | 6 | 6 | 6 | 6 | 5 | 5 |
| 11 | 2 | 1 | 0 | 2 | 3 | 0 |
| 12 | 6 | 6 | 6 | 5 | 5 | 3 |
| 13 | 3 | 5 | 5 | 2 | 3 | 4 |
| 14 | 7 | 7 | 8 | 1 | 2 | 0 |
| 15 | 6 | 6 | 4 | 6 | 5 | 5 |
| 16 | 3 | 3 | 3 | 1 | 0 | 1 |
| 17 | 3 | 3 | 3 | 1 | 1 | 1 |
| 18 | 5 | 6 | 6 | 5 | 6 | 4 |
| 19 | 1 | 2 | 1 | 0 | 0 | 0 |
| 20 | 1 | 0 | 1 | 5 | 3 | 6 |

The driver performed approximately seven overtakings for each rumble strip condition and approximately 20 overtakings for the complete driving session (and the same amount in the second driving session where the sleep deprivation factor was different). The range for the number of overtakings ranged from a minimum of zero overtakings to a maximum of 22 overtakings for a drive. Table 7 shows the number of overtaking for the rumble strip factor (without accounting for sleep deprivation). Note that each rumble strip condition was on 1/3 of the route distance.

*Table 7 Number of overtakings.*

| Rumble strips | Mean | Std. Deviation | N |
|---|---|---|---|
| NRS – Number of overtakings without rumble strips | 7.05 | 3.605 | 20 |
| RRS – Number of overtakings with real rumble strips | 7.15 | 3.200 | 20 |
| VRS – Number of overtakings with virtual rumble strips | 6.90 | 3.323 | 20 |

The analysis showed no significant differences in the number of overtakings when driving without rumble strips, with milled real rumble strips or with virtual rumble strips ($F_{(2,19)}$ =.182, p>.05). The average time needed for the overtakings was analyzed as well. No significant differences in the time needed for overtakings, which could be attributed to the presence or absence of rumble strips, were found ($F_{(2,19)}$ =1.003, p>.05). In general, the time for an overtaking manoeuvre (as defined in the mentioned algorithm) was approximately 17 seconds (see Table 8). There was a weak trend that the visible rumble strips led to a shorter overtaking time compared to the virtual rumble strips or no rumble strips.

*Table 8 Average time for overtaking manoeuvre in the three rumble strip modes.*

| Rumble strips | Mean | Std. Deviation |
|---|---|---|
| Average overtaking time no rumble strips | 17.8758 | 3.45341 |
| Average overtaking time real rumble strips | 16.6100 | 2.61977 |
| Average overtaking time virtual rumble strips | 18.2092 | 3.18192 |

**Lateral space to car ahead during overtaking**

In order to find safety critical behaviour the lateral space between own car and car being overtaken was calculated for each overtaking manoeuvre. This space is calculated from the outer margin of the own car to outer margin of the car overtaken, and represent the space between the cars; if this space is zero the cars would touch each other. For all overtakings the one with minimum value was extracted for each driver and each condition (night sleep and no night's sleep, and for groups NRS, RRS and VRS). The analysis revealed that rumble strips did not have effect on the space between the two cars while overtaking. In average the drivers left about 1.5 meter between their car and the car they overtook (lateral space between the cars). Minimal values of 0.77 meters were found, which is not considered safety critical.

### Distance to car ahead while not overtaking

The distance to the car ahead during the drive was studied. Here only the driving when not in overtaking procedure was analyzed, thus situations where the drivers “prepared to overtake” were included. It has to be noted that estimating distances is difficult for a driver in a driving simulator. There was no significant effect on the minimum distance to car ahead during free driving when driving without rumble strips (NRS), with real rumble strips (RRS) or with virtual rumble strips (VRS). Minimal values of 4.8 to 1.6 meters were observed for various cases. A video analysis of the situations showed that indeed the drivers came very close to the vehicle ahead, trying to overtake it. In Figure 10 one of these situations, which can be considered safety critical is shown as example.


*Figure 10  Very low distance to car ahead before overtaking.*

### Distance to oncoming car while overtaking

The distance to oncoming cars while overtaking is considered safety critical, as the extreme case of distance zero is equal to a collision with the oncoming car. All overtaking situations in which an oncoming car was present while the subject’s car was still as much in the opposite lane to lead to a collision with an oncoming car were analyzed. The analysis showed no effect on the distance to oncoming car while overtaking when comparing driving in the three different rumble strips situation. While the mean values ranged about 190 meters, some minimal values of distance to oncoming car of 50 meters were found. In a similar manner the distance to oncoming car when finishing to overtake (re-entering the own lane, but still with left side of the car in the opposite lane) could be analyzed, however, the low number of valid cases here disallow proper statistical analysis. Qualitative investigation led to a single value of distance to oncoming car being 12.8 meters while re-entering the own lane.

### Centre line crossing being in a car following situation

This variable counts each occurrence of crossing the middle line of the road with at least the left car wheel before overtaking, but without concluding the overtaking manoeuvre.

It is explained as attempts to overtake which were not concluded for some reason (for example there was an oncoming car which was judged as being to close to allow safe overtaking). Repeated measures analysis showed no effect of NRS, RRS and VRS in the number of centre line crossings before overtaking. A trend towards less centre line crossing with visible rumble strips (VRS) was observed. The mean number of centre line crossing before overtaking was approximately four, with maximum count for the whole drive ranging up to 10.

### 4.1.2 Speed

**Speed while not in overtaking chance or not during overtaking**

First the maximal speed on route during free driving (not in car following condition with possibility to overtake or during overtaking) was examined: Maximal speed in free driving was approximately 120 km/h. The presence or absence of rumble strips did not have any significant effect on maximal speed, but there was an interaction between no sleep/night sleep and NRS, RRS and VRS (($F_{(2,19)}$ =4.197, $p<.05$). A similar analysis for average speed in free driving condition led to comparable results: no effect on presence/absence of rumble strips on average speed; here no interaction between rumble strips and sleep deprivation was found. The average speed was approximately 96 km/h in free driving. Speed variation on route was thought to be affected by presence or absence of rumble strips. The analysis did not support this. Standard deviation of speed during not overtaking chance or during not overtaking was unaffected by rumble strip design.

**Speed while overtaking**

In this chapter speed while overtaking is analyzed. Since the participants performed a different number of overtakings in the experiment (some had over 18 overtakings per drive, others no overtakings at all), the analysis was somehow less straightforward than for the free driving condition. Here the maximum speed for all overtakings for a single participant was analyzed for sections with NRS, RRS and VRS. For all overtakings the one with highest speed were used. The analysis showed that presence or absence of either real or virtual rumble strips did not have an effect on the maximum speed while overtaking. It has to be noted that a high variance in maximum speed, together with the relatively low number of observations is a challenge in the statistical analysis. A trend towards higher maximum speed with virtual rumble strips, and lowest with no rumble strips was observable. The speed variation in car following situations was analyzed as well, but no effect of the rumble strip factor on speed variance was found.

### 4.1.3 Lateral position

**Lateral position while not in overtaking chance or not during overtaking**

The lateral position of the vehicles was recorded and analyzed in situations where the driver was in situations other than preparing to overtake and actually overtaking. First the free driving is looked at, i.e. when not overtaking and when not in car following situation with chance to overtake. There was no significant effect of the presence or absence of either real or virtual rumble strips on average lateral position of the car. Average lateral position was approximately -1.8 meters during free driving. The minimal lateral position to the right (closer to the outside lane of the road) was not significantly affected by the rumble strip factor, although a trend towards keeping the vehicle further away from the right lane margin for the visible rumble strip road stretches could be seen. Minimal lateral position values ranged around -2.5 meters. Variation in lateral position in free driving was not affected by presence/absence of either real or virtual rumble strips.

Cases were observed where drivers had lateral position values well outside the road margins during free driving. A subsequent analysis of the video recordings showed that the drivers had fallen asleep several times during the drive. Two of the cases were for the same person, which was driving after a not having slept during the night, and showed clear signs of sleepiness. For this driver two road departures were while driving on visible rumble strips, and three departures while driving without rumble strips (note: the sequence here was first virtual rumble strips, then visible rumble strips, and finally no rumble strips). The driver was about -3.9 meters to the right, which means well outside the road with the right wheel, but not with the whole car. In two cases the driver had hit the guard rail. The driver departed as well to the opposite lane several times because of falling asleep. There was no collision with other vehicles, but in real traffic this drive could have been fatal.

#### 4.1.4 Questionnaire

After the driving session all subjects were asked to fill in a questionnaire related to acceptance and usefulness of milled real rumble strip and virtual rumble strips. This was done both after driving after a night sleep and after a no sleep. There were no significant differences between these two conditions. The results are consequently based on the answers given after the drive when the drivers had slept normally during the night.

Among the 20 subjects driving in a night sleep condition 19 were sure they had experienced rumble strips, one driver was unsure. In total 9 subjects (45%) found that the sound had been the main factor for the impression of driving on real rumble strips, 6 subjects (30%) found that it was a combination between sound and vibration and 2 subjects (10%) found the vibrations as the main source. One subject did not answer the question. The vibrations were sent to the drivers through the simulator vibration table and therefore they should be experienced in the entire vehicle. The majority (80%) of the drivers experienced the vibrations in the entire car.

The sound was heard by the driver from the left side if the lane departure was on the left and from the right if the lane departure was on the right side. This was noticed by 13 (65%) of the subjects. The subjects were asked about their "*general opinion about the sound and the vibrations*?" (See Figure 11 and Figure 12.) More than half of the drivers found the sound annoying, the majority found it realistic but not scary. Almost all drivers thought the sound will be an effective way of warning a sleepy driver.

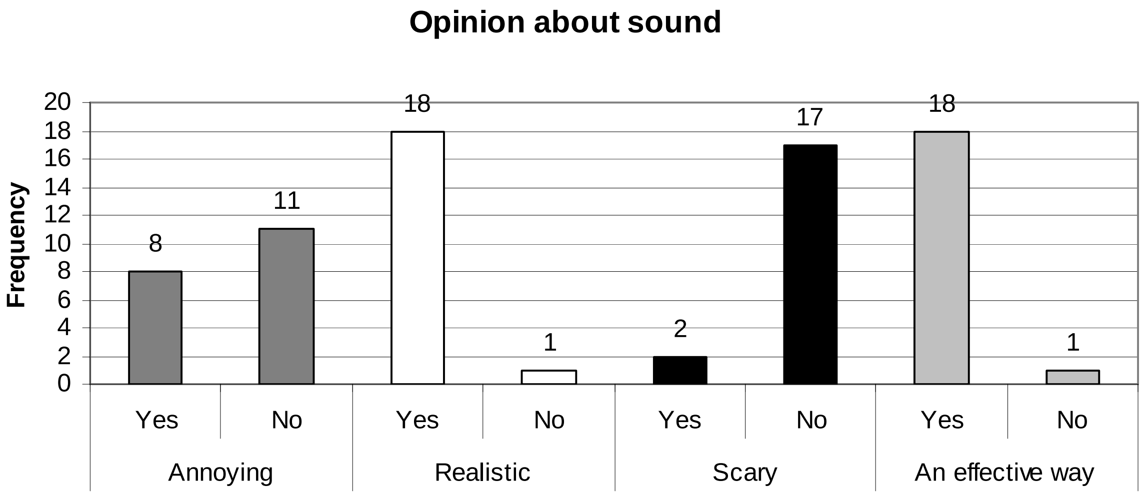


*Figure 11 Subjects opinion about the sound (n=20). One subject did not answer the question.*

About 50% of the drivers did not found the vibrations annoying, the majority found them realistic but not scary. Almost all drivers thought the vibration will be an effective way of warning a sleep driver.

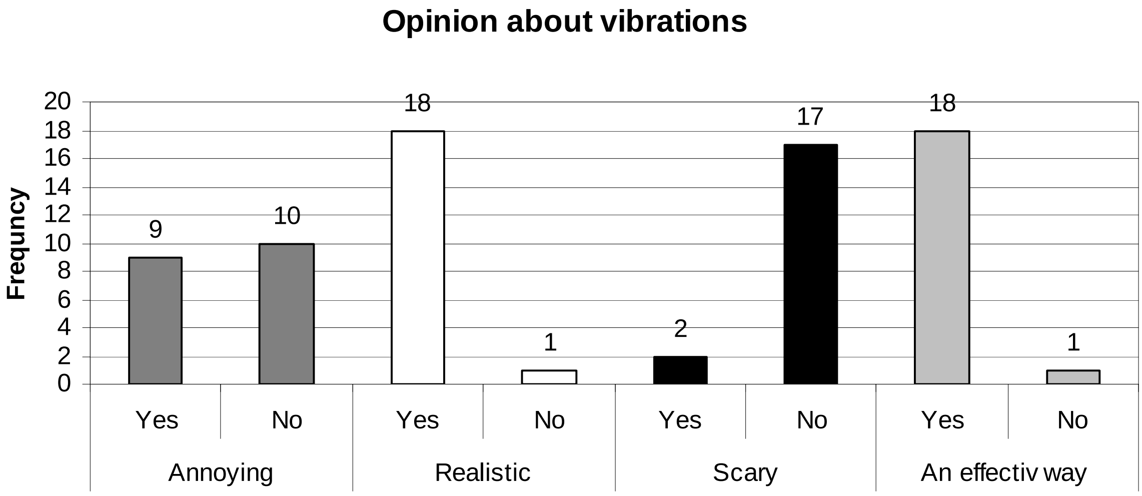


*Figure 12 Subjects opinion about the vibrations. There was one subject that did not answer the question.*

There is an interest to find out if there is a difference in opinion about the usefulness and acceptance between milled real rumble strips and virtual rumble strips. There is a special interest to analyse the differences regarding the potential of rumble strips in order to *"...call for attention*", "*…to motivate the driver to do something about the situation*" but also the driver thoughts related to "*…if the drivers will accept rumble strips*", *"...if there is a risk that the rumble strips will scare the driver"*, *"…cause risky situations"*, "*….if it they will make the drivers drive longer"* or "*…if the drivers will do less overtakings or more carefully choose situation for overtaking"*.

The results are presented separately for milled rumble strips (Figure 13) and virtual rumble strips (Figure 14).

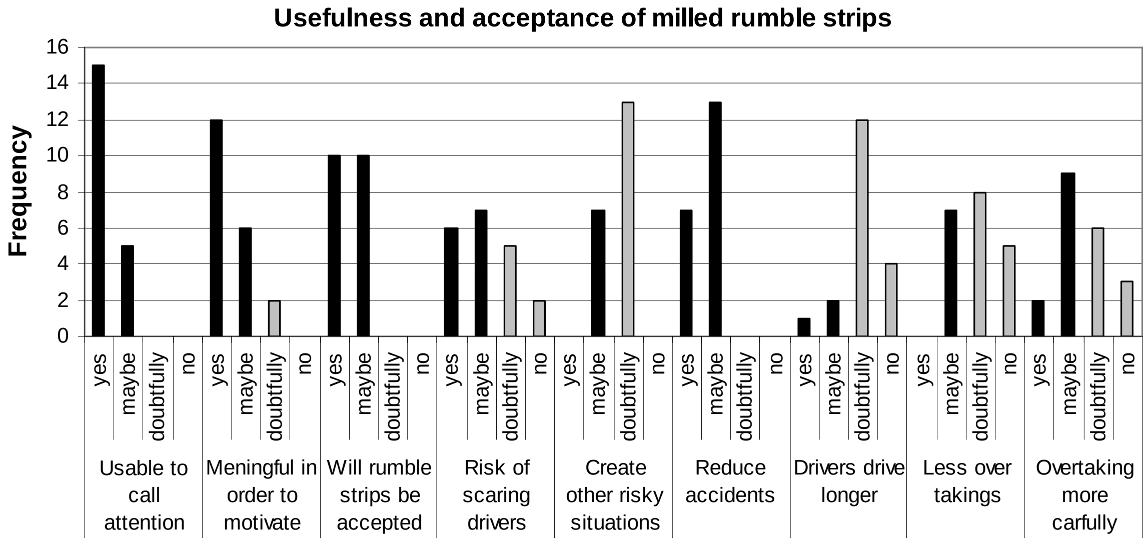


*Figure 13 Usefulness and acceptance of milled rumble strips.*

There was a high acceptance for real milled rumble strips. All subjects found it more or less useful to call attention; almost all found it meaningful in order to motivate the driver. There were drivers that thought the rumble strip could be scaring and also some that thought it could create other risky situations. However, all drivers believed real milled rumble strips will reduce the number of accidents. There were no consensuses if the real milled rumble strips will lead to less overtakings and more carefully overtakings.

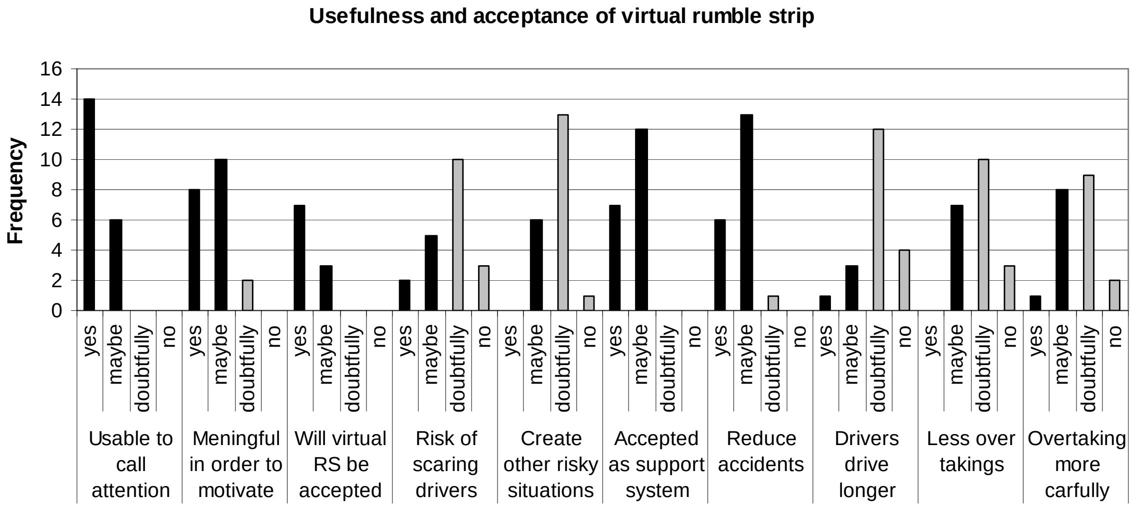


*Figure 14 Usefulness and acceptance of virtual rumble strips.*

The acceptance for virtual rumble strips was high as well. All subjects found it more or less useful to call attention; almost all found it meaningful in order to motivate the driver, there were drivers that thought the rumble strip could be scaring. The difference was not significant. However, all drivers except one believed virtual rumble strips will reduce the number of accidents. Also for virtual rumble strips there was no consensus if the virtual rumble strips will lead to less overtakings and more careful overtakings.

*Overtaking*

The subjects were asked about their willingness to overtake in relation to milled or virtual rumbles strips, see Figure 15. The question was divided for situations being alert/sleepy and rumble strips being milled or virtual.

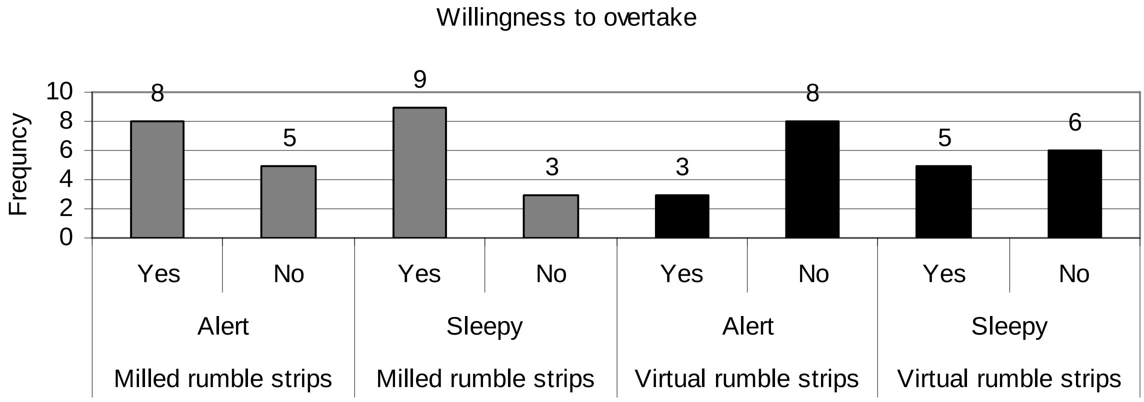


*Figure 15 Results of question: "Do you think that your willingness to overtake will be influenced during the described conditions (alert/sleepy-milled rumble strips/virtual rumble strips)?"*

The reason for the high missing values could be explained by practical problems with the questionnaires (wrong version of the questionnaire was used).

*Usefulness of different warning signals*

The subjects were asked to *"…rate on a five graded scale (1=not useful at all to 5=very useful) their opinion regarding the usefulness of…"* vibrations in seat, sound of rumble strips and the visual impression of rumble strips, see Figure 16.

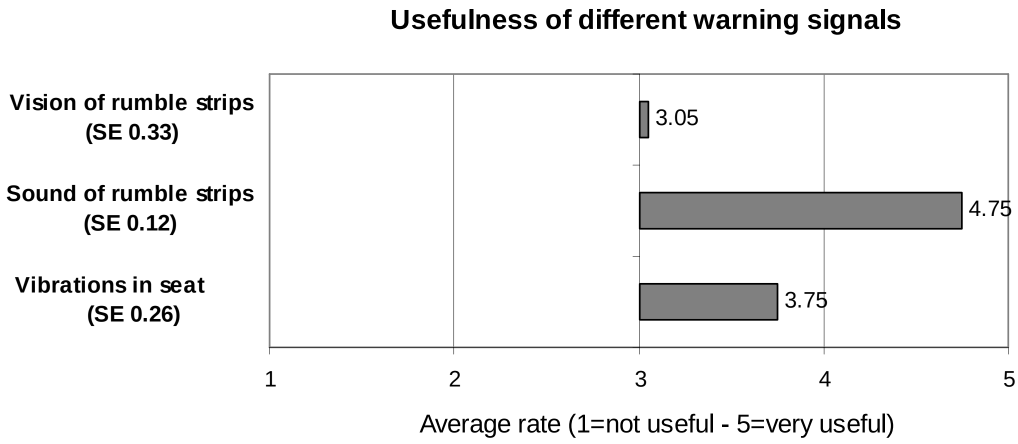


*Figure 16 The subjects' average rate of usefulness for different warning signals related to real rumble strips or virtual rumble strips. SE=standard error of mean.*

The sound and vibrations in the seat were rated as useful. The difference in usefulness between seeing the rumble strips, hear the sound from them or feel vibrations in the seat was significant (Friedmans $X^2_{(2)} = 18.698$; $p<0.001$). The most useful signal was seen to be the sound.

## 4.2 Normal night with sleep vs. not having slept during the night

One main factor in the study design was the driver's condition: no sleep (sleepy) and night sleep (alert). The design was full factorial and balanced.

The results are divided into section corresponding to the hypothesis about overtaking, speed, vehicle position.

### 4.2.1 Overtakings

This chapter deals with the overtakings. The hypothesis was that the overtaking behaviour was different between the condition alert and sleepy.

The different indicators that are looked at are:

- Number of overtakings
- Average time used for overtakings
- Number of centre line crossings before overtaking
- Safety distance to car ahead when overtake
- Safety distance to oncoming car when overtake.

In total there were 422 overtakings, see Figure 17.

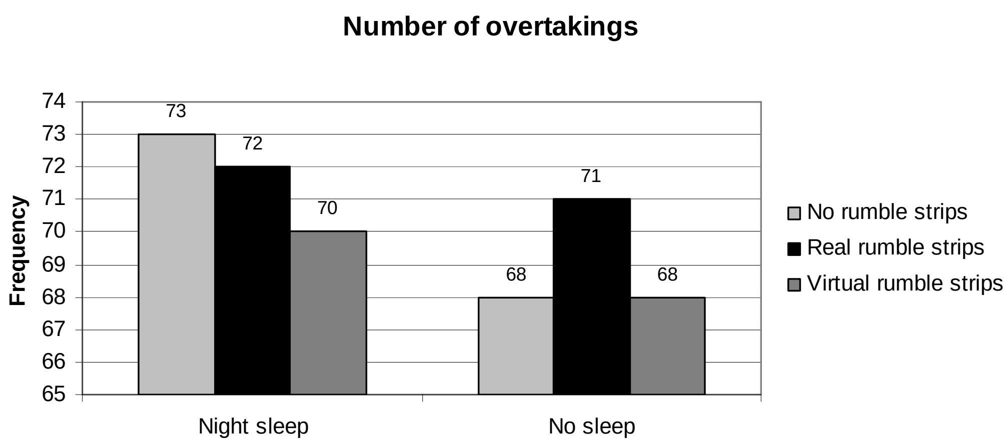


*Figure 17 Number of overtakings distributed over sections with no rumble strips, real rumble strips and virtual rumble strips (All overtakings included – n=20).*

There were 12 out of 20 subjects that did overtake both after night sleep and after no sleep condition. The average number of overtakings (with standard deviation - sd) is presented in Table 9.

*Table 9 Average number of overtakings and sd (n=12).*

| | NRS | RRS | VRS |
|---|---|---|---|
| Night sleep | 4.33 (sd 1.83) | 4.42 (sd 1.73) | 4.25 (sd 1.66) |
| No sleep | 4.25 (sd 1.82) | 4.25 (sd 1.42) | 4.33 (sd 1.50) |

There was no significant difference in number of overtakings after night sleep condition compared to no sleep condition ($F_{(1,19)}$=0.05; p>0.05), neither on different types of rumble strips (($F_{(2,38)}$=0.18; p>0.05). There was no interaction between condition and presence/absence of real/virtual rumble strips. In Figure 18 the average time used for overtakings is presented.

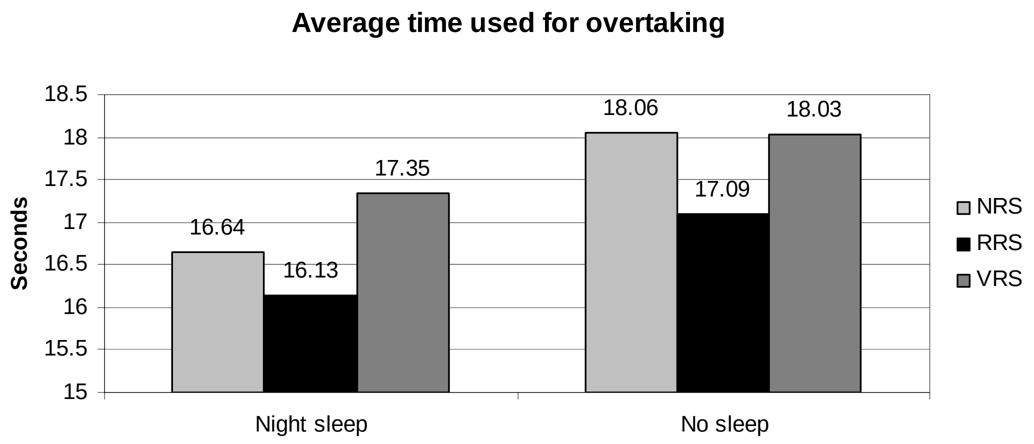


*Figure 18 Time used for overtaking. Design: 1= no rumble strips (NRS); 2=real rumble strips (RRS) and 3= virtual rumble strips (VRS); condition: 1= Night sleep; 2=no sleep (n=20).*

In total there were 12 subjects that performed overtakings in each condition. The average time and sd is presented in

*Table 10 Average time for overtaking (n=12).*

| | NRS | RRS | VRS |
|---|---|---|---|
| Night sleep | 18.27 (sd 4.34) | 16.89 (sd 3.79) | 18.59 (sd 3.62) |
| No sleep | 18.57 (sd 2.66) | 17.73 ( sd 1.83) | 18.03 ( sd 2.60) |

There was no significant difference in time used for overtakings after night sleep compared to after the no sleep condition ($F_{(1,11)}=0.09$; $p>0.05$). There was no significant interaction between condition and design.

### Distance to car ahead when not being in an overtaking situation

The distance to car ahead is a safety critical measure, as low distances leave less time to react for critical situations.

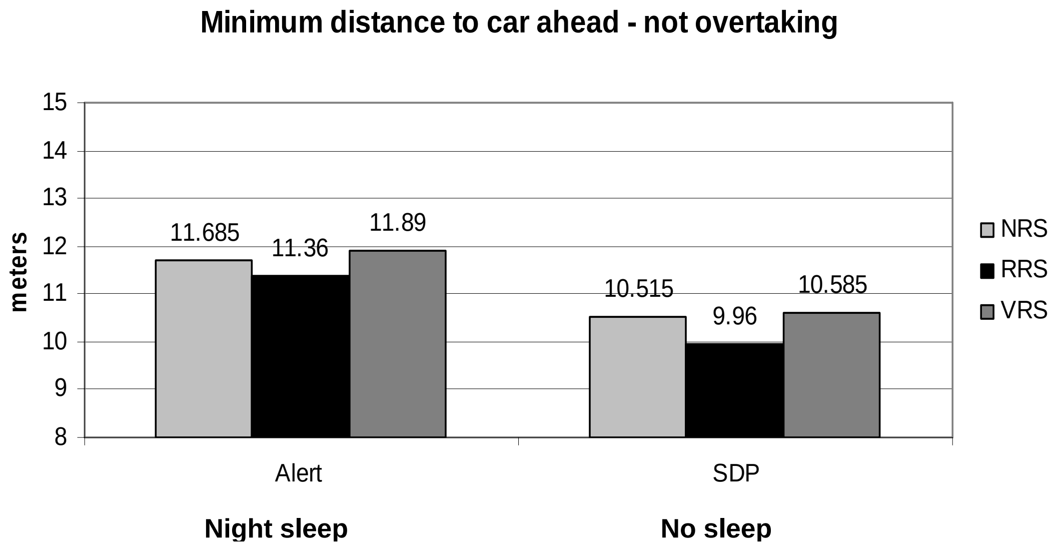


*Figure 19 Minimum distance to car ahead – while not overtaking.*

In Figure 19 it can be seen that there is a trend that after a no sleep (being sleepy) the driver have shorter distance to car ahead compared to driving after a night sleep. However, the difference was not significant ($F_{(1,19)}$=2.766; p=0.113).There was no interaction between condition and design.

### Minimum distance to oncoming when starting to overtake

In the analysis only the first overtaking on each design for each driver are included. Overtakings without visible oncoming vehicles are not included. There were no critical interactions between the drivers and oncoming vehicles during overtaking. In average the minimum distance to oncoming vehicles when starting to overtake was 638 meter (sd 70.0) in no sleep condition; and 626 meter (sd 71.5) in night sleep condition. The difference was not significant ($F_{(1,7)}$=2.16; p>0.05). An oncoming vehicle was possible to recognize at a distance of about 600 meter.

### Distance to oncoming car when entering the own lane again

In the analysis only the first overtaking on each design and for each driver are included. Overtakings without visible oncoming vehicles are not included. Distance to oncoming vehicle when entering the own lane could be a more sensitive event than average of minimum distance. Driving after night sleep condition the distance was 470 meter (sd 196 m); and after no sleep condition it was 418 meters (sd 206 m). The difference between the conditions was not significant ($F_{(1,3)}$=4.88; p>0.05).

### Minimum lateral distance to car ahead

The lateral distance to car ahead when passing the car (value when the driver's car front bumper just passed the rear bumper of the car overtaken) was calculated and analyzed.

There was a significant difference in lateral distance to car ahead when overtaking during night sleep and no sleep condition ($F_{(1,11)}$=7.163; p>0.022). There was also a significant interaction between condition and presence/absence of real/virtual rumble strips ($F_{(2,22)}$=5.045; p>0.016).

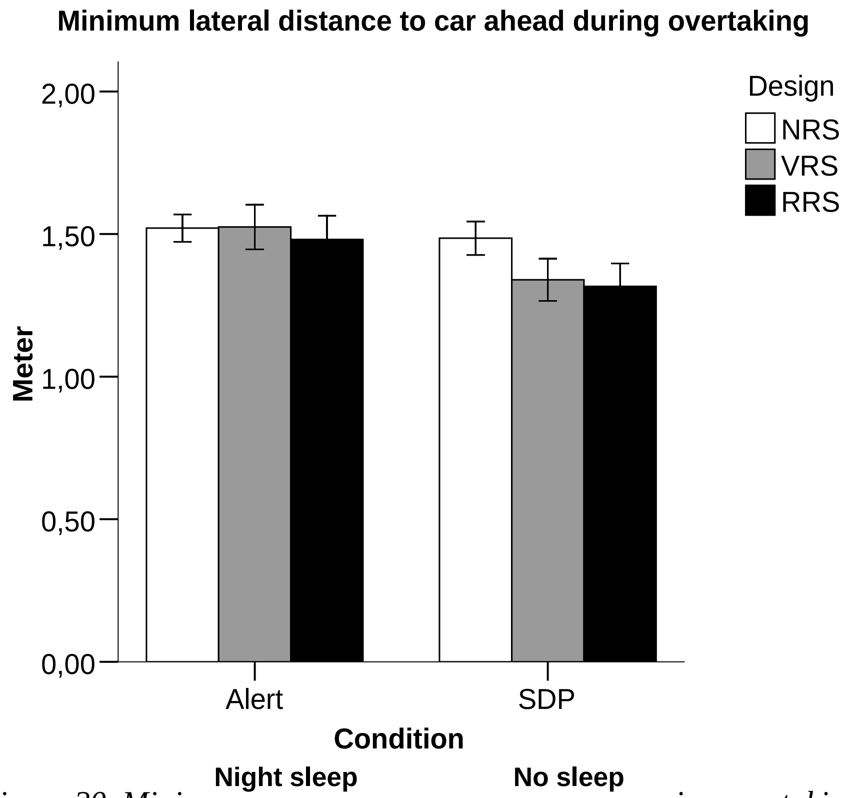


*Figure 20  Minimum lateral distance to car ahead during overtaking.*

**Number of centre line crossings being in an overtaking chance**

One indicator of interest is the number of centre line crossings before overtaking. This is an indicator that may describe the process before the actual decision to overtake. No significant difference in the number of centre line crossings before overtaking was seen comparing night sleep vs. no sleep condition ($F_{(1,19)}$=0.37; p>0.05). However, we would like to underline that all overtaking situations did not end up with an overtaking. In this analysis we have not taken into account if the overtaking was completed or not.

### 4.2.2 Speed

This chapter describes the speed of the vehicles during different situations. The hypothesis is that: a driver chose a different speed in a no sleep condition compared to in a night sleep condition. The different situations in focus are the following:

**No overtaking chance or not during overtaking**

- Average speed
- Maximum speed
- Standard deviation of average speed.

**During overtaking**

- Average speed
- Maximum speed.

**Only during overtaking chance**

- Average speed
- Standard deviation of average speed.

**Speed in no overtaking chance or not during overtaking**

In Figure 21 average speed when not being in overtaking chance or not during overtaking is presented.

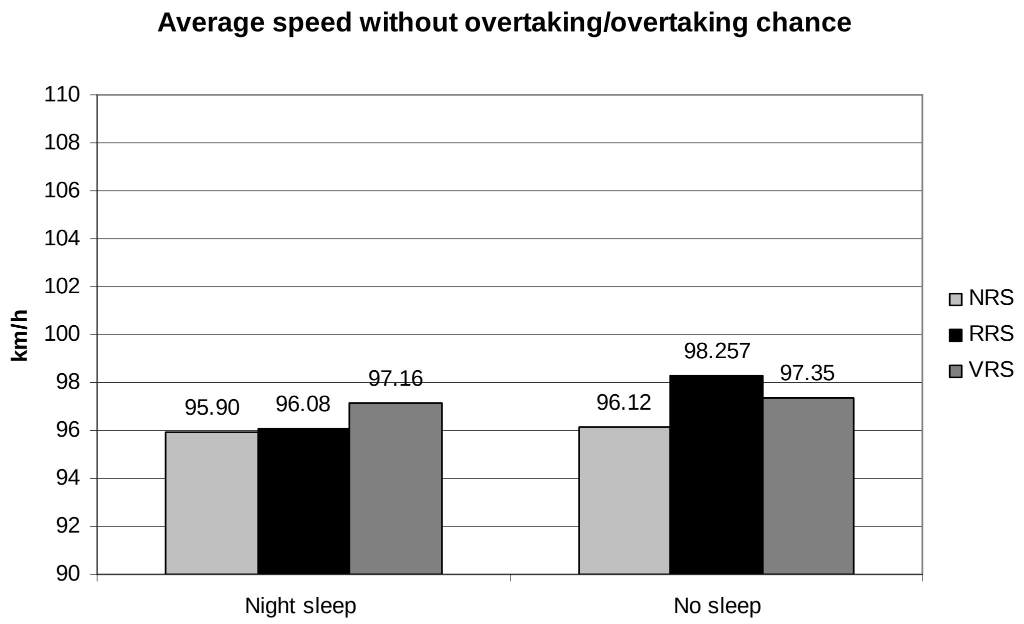


*Figure 21  Average speed – no overtaking chance or no overtaking (n=20).*

There was no significant difference in average speed during night sleep and no sleep condition ($F_{(1,19)}$=0.15; p>0.05). There was no interaction between condition and absences/presence of rumble strips.

In Figure 22 the maximum speed when not being in an overtaking chance or not during overtaking is presented.

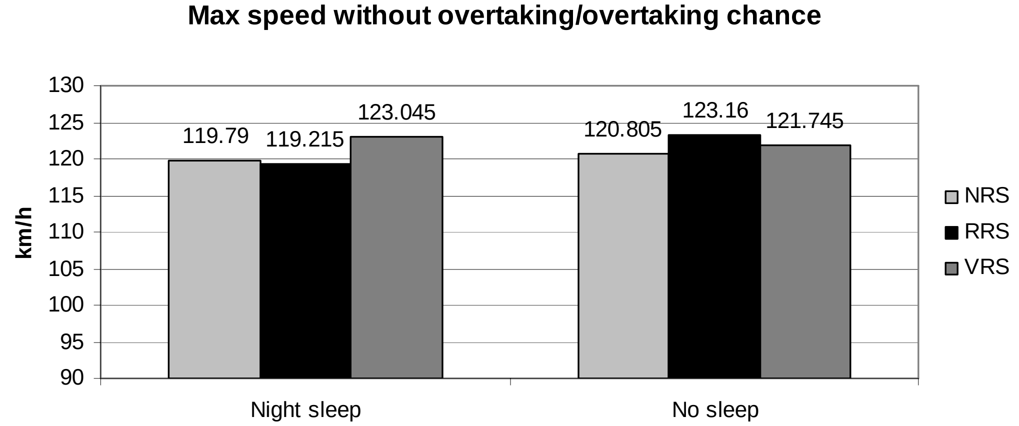


*Figure 22  Maximum speed – no overtaking chance or no overtaking (n=20). Night sleep and no sleep condition.*

There was no significant difference in maximum speed during night sleep and no sleep condition ($F_{(1,19)}$=0.26; p>0.05). There was an interaction between condition and absences/presence of rumble strips (RRS/VRS) ($F_{(2,38)}$=4.20; p=0.03).

In Figure 23 the standard deviation of speed when not being in an overtaking chance or not during overtaking is presented.

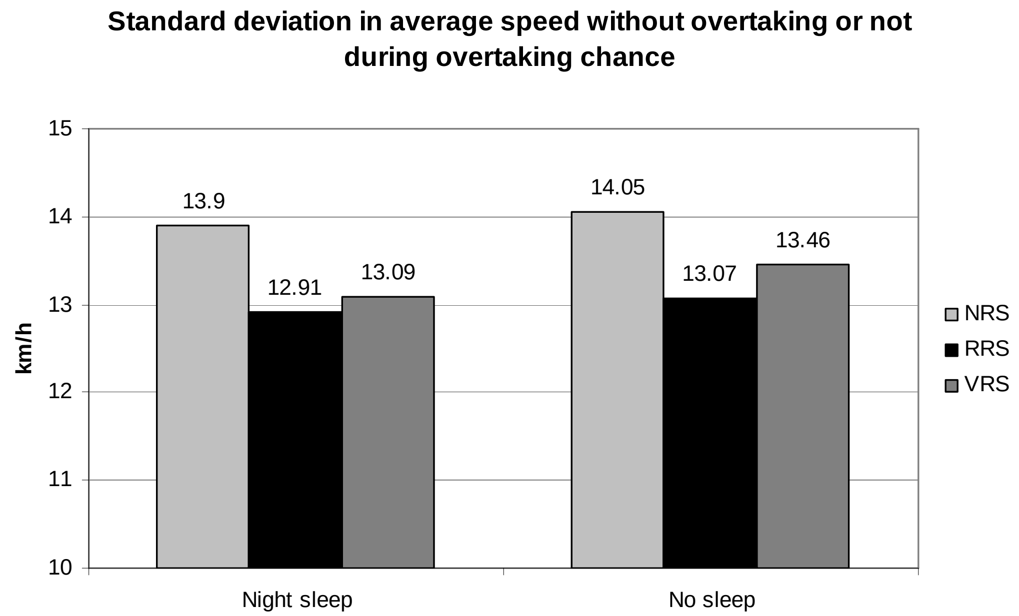


*Figure 23  Standard deviation in average speed without overtaking/overtaking chance.*

There was no significant difference in standard deviation of speed during free driving between night sleep and no sleep condition ($F_{(1,19)}$=0.13; p>0.05). There was no significant interaction between condition and absences/presence of rumble strips (RRS/VRS).

### Speed only during overtaking

### Average speed

There was no significant difference in average speed during overtaking between night sleep and no sleep condition ($F_{(1,11)}$=0.30; p>0.05). There was no interaction between condition and design, see Figure 24. The tendency is however a higher speed during no sleep condition.

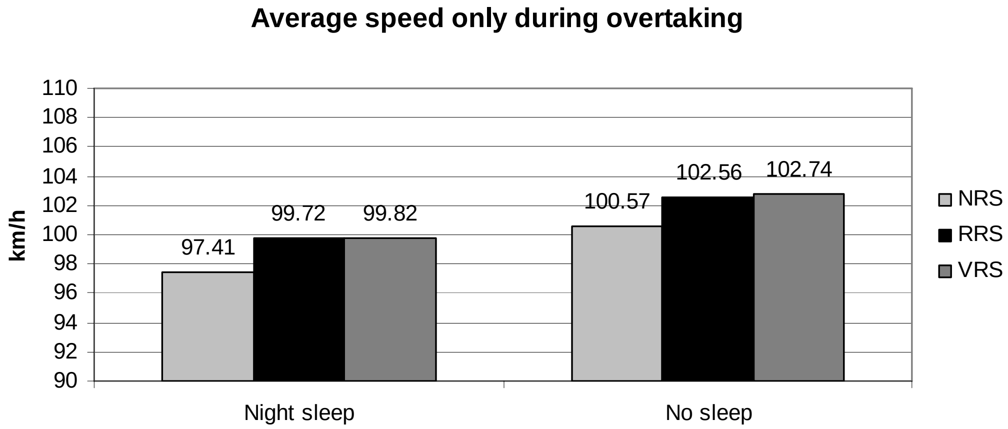


*Figure 24  Average speed only during overtaking.*

### Maximum speed during overtaking

There was no difference in maximum speed during overtaking between night sleep and no sleep condition ($F_{(1,11)}$=2.64; p>0.05).

### Speed only during overtaking chance

There was no significant difference in average speed during overtaking between night sleep and no sleep condition ($F_{(1,19)}$=0.09; p>0.05). There was no interaction between condition and absences/presence of rumble strips (RRS/VRS), see Figure 27.

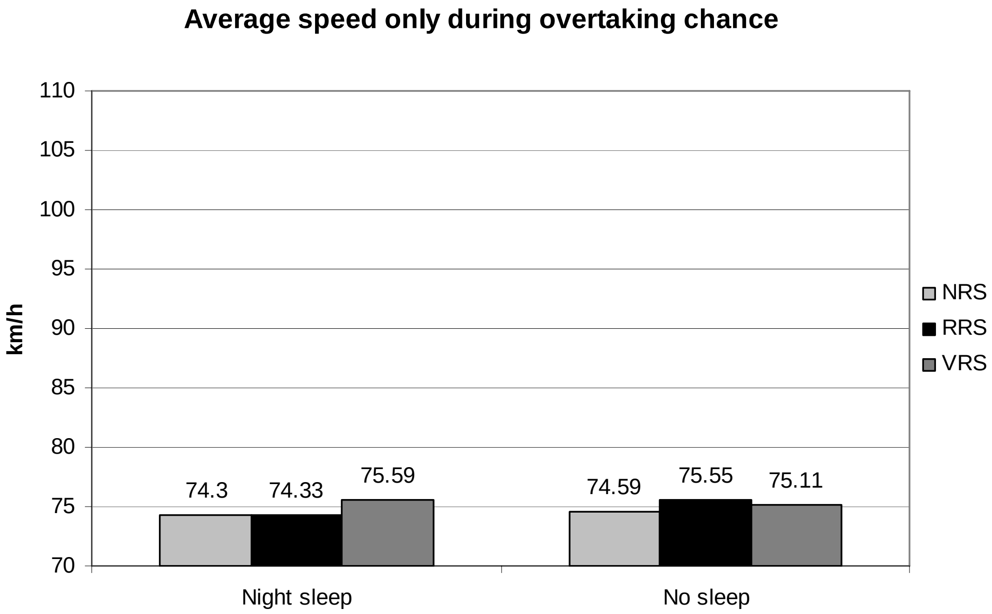


*Figure 25 Average speed only during overtaking.*

There was no significant difference in speed variance during overtaking between night sleep and no sleep condition ($F_{(1,19)}$=0.12; p=0.73). There was no significant interaction between condition and absences/presence of rumble strips (RRS/VRS),

### 4.2.3 Lateral position

This chapter describes the lateral position of the vehicles during different situations. The hypothesis is that lateral position when driving after no sleep and night sleep condition differ. We only focus on the situations when the drivers are not in an overtaking chance or not doing overtakings.

- Average lateral position
- Standard deviation in lateral position.

Additionally, there are also results about the minimum lateral position measured during the total drive.

- Minimum lateral position.

**Average lateral position without overtaking chance or overtaking**

There is a possibility that real milled rumble strips will reduce the variation in lateral position but also change the driver's preferences about lateral position. This could lead consequences related to maintenance. Figure 26 show differences between night sleep and no sleep condition. Drivers being in a no sleep condition drove closer to the centre line.

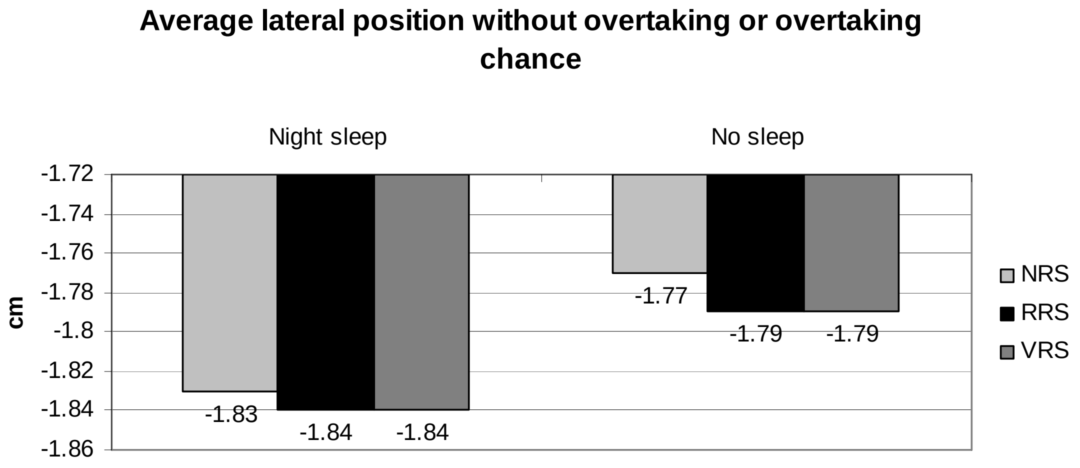


*Figure 26  Average lateral position without overtaking or not during overtaking chance.*

There was a significant difference in lateral position when not overtaking or being in an overtaking situation between night sleep and no sleep condition ($F_{(1,19)}$=14.31; p=0.001). There was no significant interaction between condition and absences/presence of rumble strips (RRS/VRS). Figure 27 show the standard deviation of lateral position.

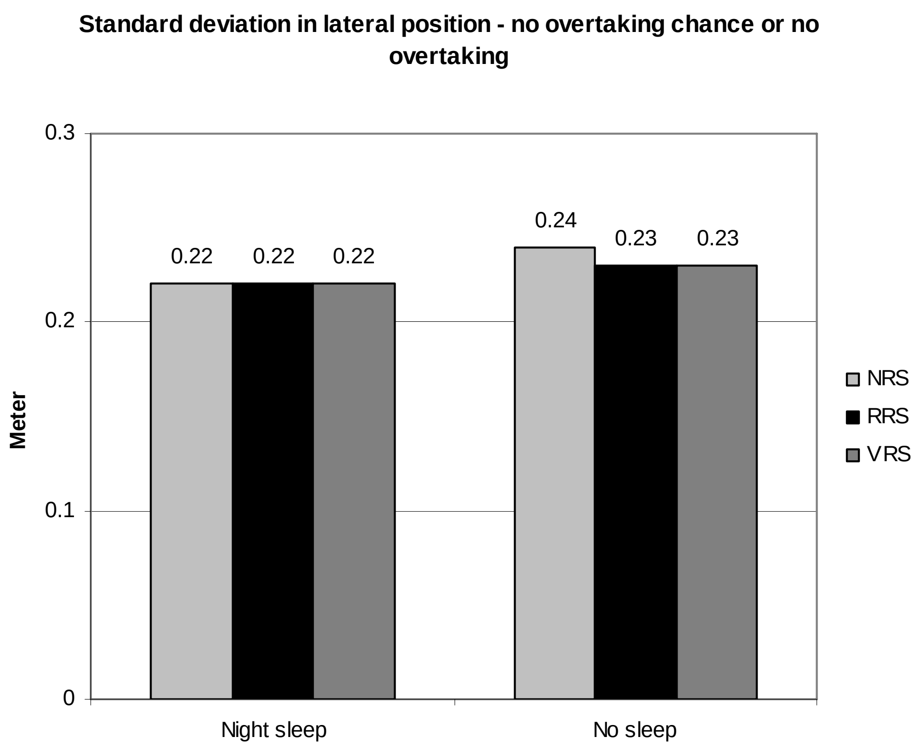


*Figure 27  Standard deviation in lateral position – no overtaking/overtaking chance.*

There was a significant difference in standard deviation of lateral position between night sleep and no sleep condition ($F_{(1,19)}$=5.79; p=0.03). There was no significant interaction between condition and absences/presence of rumble strips (RRS/VRS).

**Minimum lateral position – right road margin**

There was no significant difference in minimum lateral position between night sleep and no sleep condition ($F_{(1,19)}$=0.63; p>0.05). There was no significant interaction between condition and absences/presence of rumble strips (RRS/VRS). However, there was a tendency that after the no sleep condition drivers were closer to the outer road margin, see Figure 28.

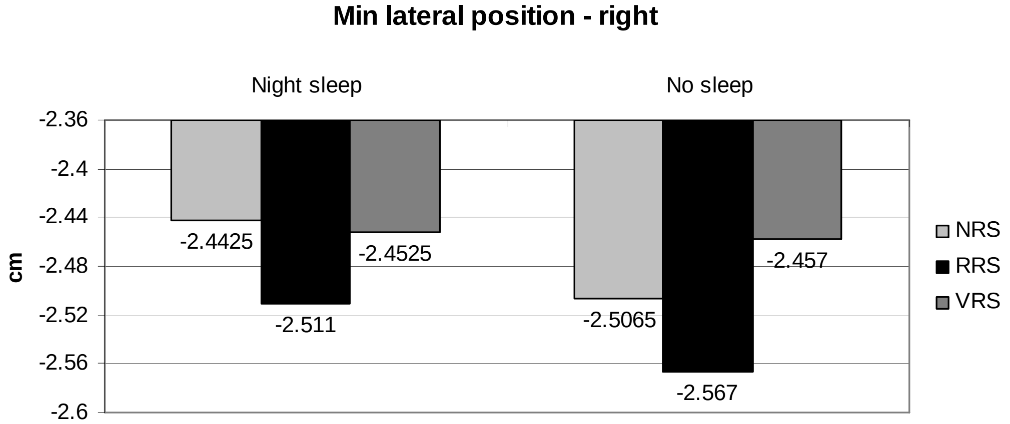


*Figure 28  Minimum lateral position during the total drive (closest to outer margin of the road).*

### 4.2.4 Summary of difference between no sleep and night sleep

The results focus on comparison between driving in two conditions: after a night sleep (alert) and after a no sleep (sleepy). Three main aspects were analyzed: speed, lateral position and overtaking behaviour.

**Speed**

There was no significant difference in *speed, standard deviation of speed or maximum speed* between the conditions.

**Lateral position**

***Lateral position*** was significantly closer to the centre line during no sleep condition. ***Standard deviation of lateral position*** was significantly increased during no sleep condition, but the difference in meters is small. *Minimum of lateral position* (close to the edge) was not significant different.

**Overtaking**

In total 12 out of 20 subjects did *overtakings* in both conditions and on sections with absences/presence of rumble strips (RRS/VRS). In average a driver made around 4 overtakings in night sleep condition. There was no significant difference in *overtaking frequency* between conditions. Average time for overtaking was about 17 seconds in night sleep condition. There was no significant difference between conditions. Minimum *distance to car ahead* was between 10–12 meters. There was no significant difference between conditions. Distance to oncoming vehicles when starting to overtake was between 626–638 meters. When re-entering the own lane after overtaking the distance was around 418–470 meter. There was no significant difference between conditions.

## 4.3 School bus – in vehicle information system

The subjects were confronted with two bus situations in each drive: A bus was parked on the right side of the road in a parking lot, and before passing the bus the participants received a visual warning, alternatively no visual warning. The warning before encountering the bus was believed to increase awareness about the oncoming situation, and lead to appropriate action. Again the factors “no rumble strips” versus “virtual rumble strips” versus “real milled rumble strips” and “warning received” versus “no warning received” were analyzed, in addition the night and no sleep condition went into the analyses.

Main hypothesis was that the drivers would drive more carefully when provided with the warning before passing the bus. This can display in decreased speed and increased lateral distance from the bus. This behaviour changes will probably be different for no sleep versus night sleep condition.

### 4.3.1 Speed when passing bus

First the speed development for the bus situation with and without warning is plotted. Figure 29 and Figure 30 below show the speed development in the bus situation for each participant. Figure 29 displays only the situations where the driver received no warning that a parked bus was imminent, while Figure 30 shows the situations when the warning was given to the driver. The thick blue line in both figures show the average speed for all participants. Cleary most drivers slow down when passing the bus, but there are as well a number of drivers who did not slow down.

The effect of the warning on speed development is evident: looking at the average speed in Figure 30, speed is reduced shortly after the warning is received (and already before seeing the bus), but the drivers who did not receive the warning started to decelerate only after seeing the bus (Figure 29). The speed when passing the bus physically (distance 10 321 to 10 337) was as well lower when having received the warning before. Please note that the bus pictured in the graphs below is not to scale, only symbolic.

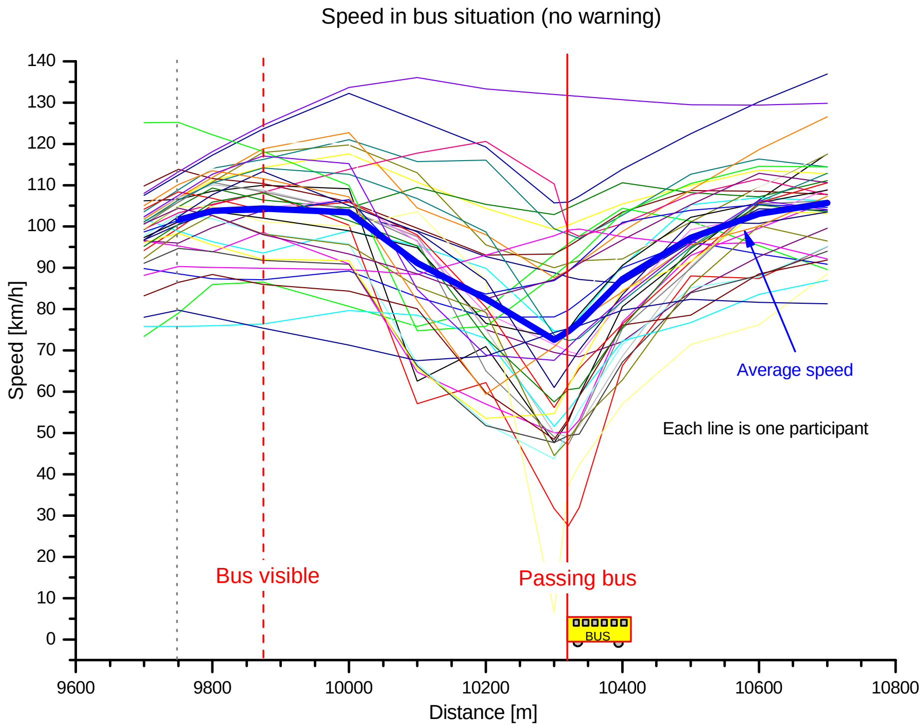


*Figure 29 Speed development in bus situation without warning.*

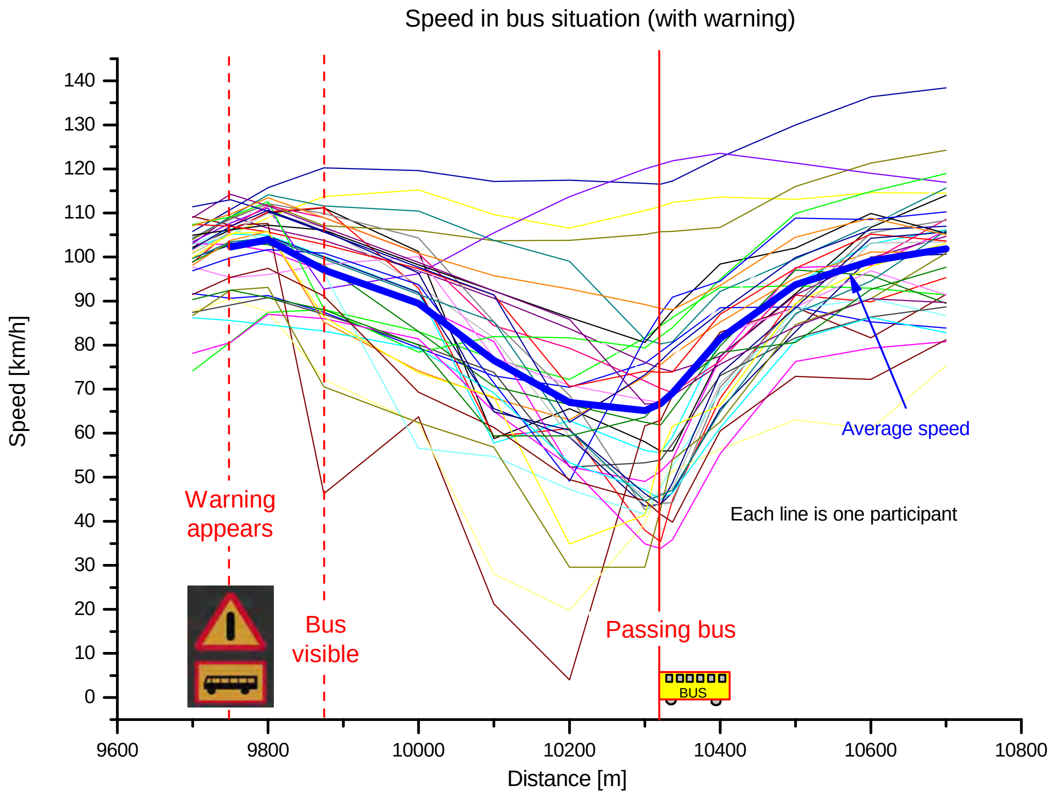


*Figure 30 Speed development bus situation with warning.*

Both average speed lines are compared in Figure 31. The red line is the speed for the situation when a warning was presented in before, the black line is when no warning was given. The effect of the warning is evident. The speed when a warning was presented flattens already approximately 100 meters before passing the bus physically. This would give the driver time to react in case a passenger would cross the road. For the situation without warning this is not the case: the speed is higher, and the drivers seem to prepare less for a possible dangerous situation.

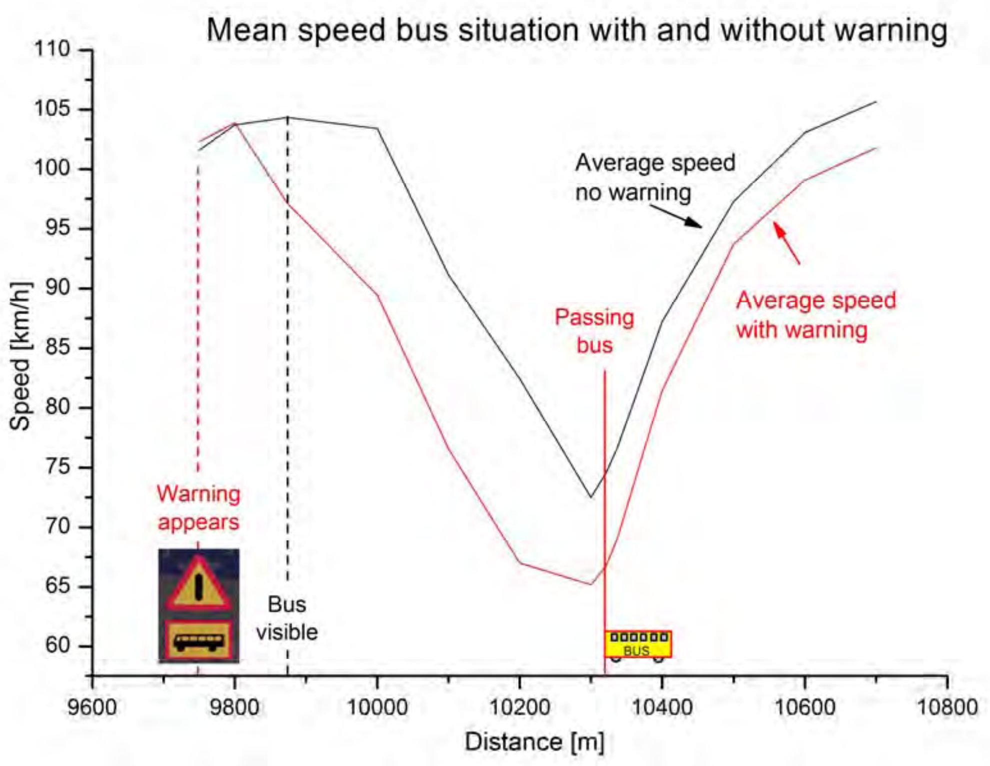


*Figure 31 Comparison average speed in bus situation with and without warning.*

Figure 29 and Figure 30 show the speed development in the bus situation for night sleep and no sleep condition. Figure 32 show the average speed for the four groups (night sleep with and without warning, and no sleep with and without warning). The effect of night/no sleep on speed are visible for the situations when a warning was given: here the drivers after a night sleep reduced the speed more than after the no sleep. In fact the ”optimal” speed development for encountering a situation with a parked bus seems to be after the night sleep condition receive a warning, which is consistent with common traffic safety sense.

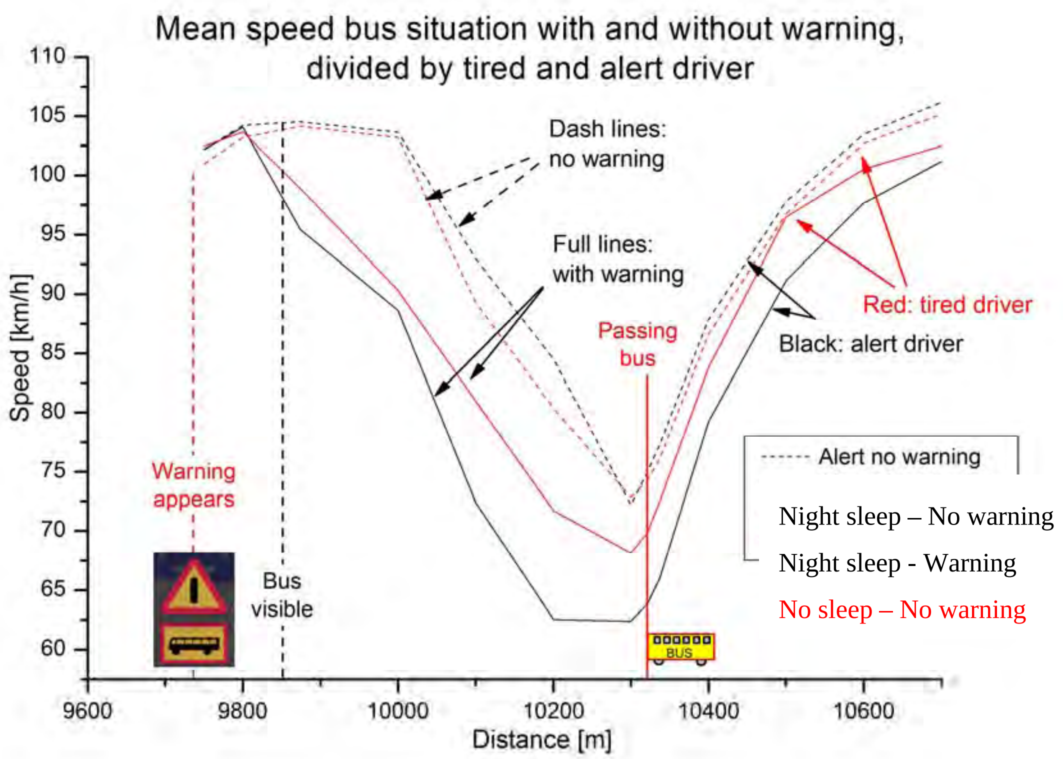


*Figure 32  Speed development for night sleep and no sleep condition in bus situation with and without warning.*

Comparison between night sleep and no sleep condition did not reveal significant differences. Analyzing for the factor with warning versus without warning showed significant differences in the point 10 000 meters and 10 321, which means that the warning did have an effect on speed here. In the point when passing the bus (10 321 meters) the night sleep drivers had statistically significant lower speed with warning, the speed after a no sleep was not statistically significantly lower, se Table 11.

*Table 11  Paired samples t-test results for speed in warning versus no warning condition.*

| Point (m) | Speed night sleep no warning | Speed night sleep with warning | Speed no sleep no warning | Speed no sleep with warning | t-test result night sleep | t-test result no sleep |
|---|---|---|---|---|---|---|
| 9800 | 104.225 | 104.060 | 103.200 | 103.668 | ns | ns |
| 10000 | 103.640 | 88.640 | 103.185 | 90.300 | t(19)=4.7, p<.05 | t(18)=5.2, p<.05 |
| 10321 | 74.915 | 63.820 | 74.215 | 69.779 | t(19)=3.3, p<.05 | ns |

A repeated Anova for speed using distance 9 800, 10 000 and 10 321 meters as repeated factor, as well as warning/no warning and no sleep/not no sleep was done. The effect of warning, night/no sleep and distance were analyzed. The results above were confirmed, warning had a strong effect on speed development ($F(1)=19.4$, $p<.05$), while no significant effect was found for night sleep versus no sleep condition. Distance itself was the main contributing factor for speed reduction ($F(1.245)=58.29$, $p<.05$). The estimated marginal means for warning/no warning were 86.8 (sd 1.66) and 94.3 (sd 1.64) km/h.

The maximal speed when passing the bus (10321 to 10337 meters) was calculated for each subject and level (night sleep/no sleep and warning/no warning). A repeated measures analysis showed that night sleep versus no sleep did not have an effect on the maximal speed when passing the parked bus, but the warning had an effect ($F(1)=5.1$, $p<.05$). There was no interaction effect between night/no sleep condition and warning. The estimated marginal mean for maximal speed without warning was 76.7 (SE=4.5) km/h and with warning 69.5 (SE=4.5) km/h. This shows again that the speed (in this case the maximal speed) was significantly reduced as an effect of the warning! The average speed when passing the bus was as well higher when no warning was given to the participants (8 km/h higher).

### 4.3.2 Lateral position of car when passing bus

Neither warning or condition showed an effect on the minimal lateral position. The results were similar for the average lateral position when passing the bus. The absence/presence of rumble strips (RRS/VRS) did not have an effect on lateral position (minimal or average), anyway, a trend were visible. Without rumble strips the lateral position (average and minimal) while passing the bus was more to the right (closer to the bus), while with rumble strips it was more to the left (higher lateral distance to the bus). It should be noted that the differences in lateral position are not large, the mean values for average lateral position without rumble strips is -1.45 (sd 0.24) with real milled rumble strips $-1.34\pm0.34$ m and with virtual rumble strips -1.28 (sd 0.27). The difference is only 17 centimetres. Anyway, in “normal driving” (no bus, no overtaking) the average lateral position is around -1.8 meters, therefore the average lateral position values while passing the bus are about half a meter further left (away from the bus): clearly the drivers keep a “safety distance” to the parked bus.

# 5 Discussion and conclusions

## 5.1 Method

The overall aim of the experiment was to study the effects of two prioritized scenarios within IN-SAFETY: "Lane departure warning" and "School bus ahead warning". In relation to "Lane departure warning", the pilot considered possibilities and consequences of replacing the infrastructure element milled rumble strips with a haptic in-vehicle system. The case of centre and side line rumble strips on a two-lane highway was studied and compared with a baseline. In-vehicle "School bus ahead warning" was considered as an example of in-vehicle information used to inform the driver of upcoming events. Both rumble strips and school bus warning was studied for no sleep as well as night sleep condition in order to investigate consequences of driver state on system effectiveness. This is a very complex design and even if the scenario was based a repeated road section of 9.4 km consisting of different situation it was not always the case that the drivers act as planned in the scenario. The consequence will be, for example, that even if all subjects on all 9 repeated laps of 9.4 km each will have situations suitable for overtakings, not all subjects will do overtakings. This will result in an unbalanced design or lack of observations. There is often a problem when trying to focus on more than one or two issues. A clean design is most often to prefer – this was not the case here.

From a survey of school bus related injury events in Sweden during 1994–2001, data from 361 injured or killed children in 256 school bus related events were analysed and their injury mechanisms identified (Anund, Falkmer et al., 2003). In total 74% of the injury events took place while the child was outside the bus. The predominant reason for being killed or injured when travelling with school transportation was when crossing the street, running in front of the bus (21%) or behind the bus (30%), both of them related to the child being outside of the bus. During 1994–2001 in total 361 children were killed or injured when going by school transportation. In order to enhance safety and security in school transportation for children outside of the school transportation vehicle, the Swedish Road Administration (SRA) is currently studying the effects of a speed limit of 30 km/h (~20 mph) for drivers passing a bus at standstill (Kircher et al., 2007; Vägverket, 2007). However, the speed limit is only considered for drivers passing a bus at standstill at roads with 70 km/h or less, why other measures need to be investigated for children with "bus stops" at high speed roads. The idea of using in vehicle information could be one of those. The driving simulator is well suited to investigate this type of potential solutions.

The experiment was carried through in the VTI moving base driving simulator using a simulated environment representing a Swedish two-lane highway. The simulator is used in many studies with the benefit of a high degree of repetition of the same situation for all subjects and with a possibility to reduce confounding effects coming from uncontrolled factors. The simulator environment also makes it possible to look into effects caused by driver impairments in this case being sleepy. Earlier studies show the benefit of this (Anund, Hjälmdahl, Sehammar, Palmqvist, & Thorslund, 2005). For parameters possible to compare the results seem to be in line with earlier studies (Åkerstedt, Peters, Anund, & Kecklund, 2005; Anund et al., 2005).

Based on the data from the subjects drives, statistical analysis was conducted to test hypotheses regarding the effect of milled versus in-vehicle rumble strips and school bus warning. Hypotheses regarding the consequences of driver sleepiness were also tested. As before, one major problem is the very complex design with too many hypothesis to test. For some of the drivers there is not enough data in order to make correct assumptions from a statistical point of view. Even if a repeated design were used based on 20 subjects and the comparison is not made between individual but within individual there is not enough observations for all individuals for all events of interest. This is especially true for overtakings.

## 5.2 Results

*Rumble strips*

Real milled" rumble strips was assumed to reduce the number of **overtakings** more than in-vehicle "virtual" rumble strips. No significant difference in the number of overtakings for different rumble strip mode was found. There was however a weak trend towards shorter overtaking duration with visible rumble strips. Another interesting finding is that the overtaking duration for female drivers was shorter than for male drivers. One possible explanation for this result is that the female subjects were more careful when overtaking and therefore completed the overtakings quicker in order to reduce the time spent in the opposite lane. Observations of overtaking behaviour in real traffic are a very difficult to do. Normally this is done either by road side observations or by car following. In a study from 2005 (Anund, 2005) tried the latter one. Before milled rumble strips at centre line 48% of the 120 drivers that were followed did at least one overtaking. The after measure showed that among the 154 cars followed, 40% did at least one overtaking. The difference was not significant. This is in line with the results from this experiment.

In relation to speeds, visible rumble strips were assumed to reduce **speed** more than virtual rumble strips. No evidence in support of this assumption was found. The same result was found for speed variance; no impact of rumble strip mode could be established. Those results are in line with road side interviews done at a test site in Sweden (Anund, 2005). The majority of the drivers do not report reducing their speed because of milled rumble strips at centre line. However, measuring the speed among passing vehicles a speed reduction of 1.8 km/h was observed. This is not observed in the driving simulator experiment. The reason for this is unknown. One explanation could be related to the selection of subjects and to the instruction given that they should drive according to the speed limit.

The fact that virtual rumble strips led to similar driver behaviour as real milled rumble strips speaks in favour of their effect. On the other hand there were few differences between absence and presence of rumble strips at all was observed. It could also be noticed that evaluations of the acceptance of lane departure system also show very positive results.(Thorslund, Anund, & Hjälmdahl, 2006). Field studies with a higher number of participants or of driven kilometres could help to disclose dissimilarities here.

**Lateral position** is an important issue in relation to rumble strips since shifted average and reduced variance in lateral position has implications for maintenance costs. No significant shift in lateral position was found. However, there was a trend towards keeping the vehicle further away from the right margin when the rumble strips were visible. This is a difference compared to traffic measures done at the same type of roads(Anund, 2005). The hypotheses regarding corrective actions in relation to unintended rumble strip hits were not possible to test based on the collected data. Some extreme cases of lateral position were found, but in these cases the driver had fallen asleep and the vehicle was outside the road margins before corrective action was taken. This is in line with a study comparing different types of rumble strips and one of the strips was not visible for the drivers(Anund et al., 2005). No collision occurred during these lane departures, but the situations could have been fatal in real traffic. Even when looking qualitatively at the data (i.e. video recordings and experience from the simulator personnel), corrective actions, if present at all, could not be related to presence of rumble strips.

The questionnaire results displayed high acceptances of both milled and virtual rumble strips and there was no significant difference between the acceptances of the two rumble strip types. Most subjects believed that rumble strips would be an effective way to reduce the number of accidents. No significant difference in the usefulness of virtual compared to visible milled rumble strips was found. This observation was further supported by the high usefulness rating of sound and seat vibration warning signals. These observations together with the similar driving data observed for milled and virtual rumble strips suggest that there is a potential to substitute the infrastructure element milled rumble strips by an in-vehicle assistance system.

*No sleep vs. night sleep condition*

Drivers were assumed to make fewer **overtakings** in fatigued condition than in night sleep condition. This assumption was not supported by the data. No significant differences in the number of overtakings or in the overtaking duration were found. One reason for this could be the unbalance between overtakings done by subjects. It was also assumed that the variance in speed of fatigue drivers would be higher than the variance for night sleep drivers. This difference was also not supported by the data. However, there was a slight tendency that no sleep drivers drove faster during overtakings than night sleep drivers. During overtaking the driver in no sleep condition showed at short lateral distance to oncoming compared to being in a night sleep condition.

The results with respect to the **lateral position** during night sleep and no sleep condition did not support the assumption that the variance in lateral position is higher when drivers being sleepy. In addition, after no sleep condition the drivers drove closer to the centre of the road than after the night sleep condition. These results can be important for the design of future sleepiness warning systems since there will be a potential to use lateral position as an indicator of driver fatigue. The measurement of driver sleepiness normally involves indicators such as the standard deviation of the lateral position (O'Hanlon & Kelly, 1974; Otmani, 2005). It is worth mentioning that cases were observed where drivers fell asleep during the simulator drive. Qualitative analysis of their behaviour in relation to rumble strip presence could give further clues on effect of rumble strips.

*School bus ahead – in vehicle information*

The subjects were confronted with two situations with a parked school bus during each drive. One situation without prior warning and one situation with an in-vehicle warning before the school bus became visible. The results of this part of the pilot supported the hypothesis that an in-vehicle warning results in lower speeds when passing the bus compared to a no prior warning situation. Especially the speed development shortly before passing the parked bus was more favourable in terms of traffic safety when the drivers had received the information before passing. There is consequently a potential to use in-vehicle information to reduce speeds during temporary safety critical events. No difference in lateral position for the warning compared to the no warning situations was found. However, all subjects kept a safety distance to the bus. A tendency towards increased safety distance for the rumble strip scenarios compared to the no rumble strip scenario was also found. Possible adaptation effects on such a warning strategy should be examined in a long time study.

*Conclusion and further research*

The aim of IN-SAFETY project was to create effective combinations of traditional infrastructure measures combined with new technology to increase the self-explanatory and forgiving nature of the road traffic system. This experiment has contributed to this objective by showing that there is such a potential to substitute the infrastructure measure rumble strips with an in-vehicle assistance system. Moreover, in-vehicle information was found to be an effective way of reducing the subjects' speeds during temporary safety critical situations.

No significant effects with respect to overtaking and speed behaviours for different rumble strip modes and driver conditions were found. One contributing factor behind this result can be a difference between driving in the simulator and real driving. An important issue for future research is differences between real driving and simulator driving. Another issue for further research is the implications of the findings at the traffic system level. These impacts would be studied using traffic simulation models like RutSim (Tapani, 2005).

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Vägverket. (2007). *Utvärdering av 30 rekommendationen på Gotland – försök med rekommenderad 30 km/tim vid passage av stillastående skolskjutsskyltad buss* (No. 2007:152). Borlänge: Vägverket.

*Annex 1. An overview of the description of lateral position.*

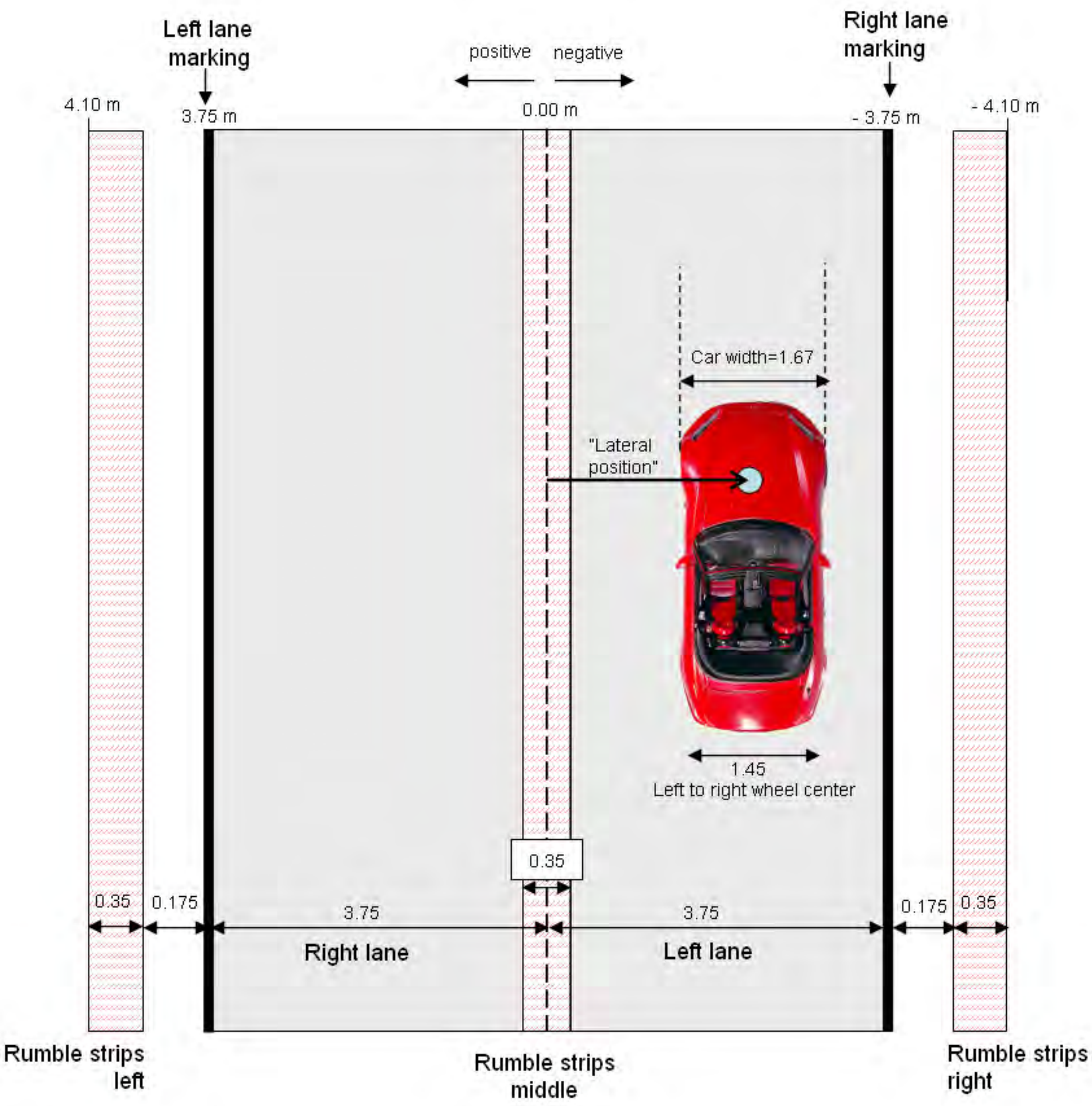


*Figure 33 Lateral position is measured from the middle lane to the centre of the car. Lateral position= 0 means car is driving exacly on the middle line. When driving normally in the right lane the lateral position is approx. -2 meters.*

*Annex 2 – Algorithms to extract data in Table 4*

## Overtaking algorithm

To extract the data in Table 4 the following algorithms were applied. Here they are noted in a simplified form. This algorithms turned out to work very well, as all overtakings were automatically found. A graphical representation of a typical overtaking will help to understand the algorithm (see Figure 34 and Figure 35). A more detailed graph with points used in the algorithm is shown in Figure 36.

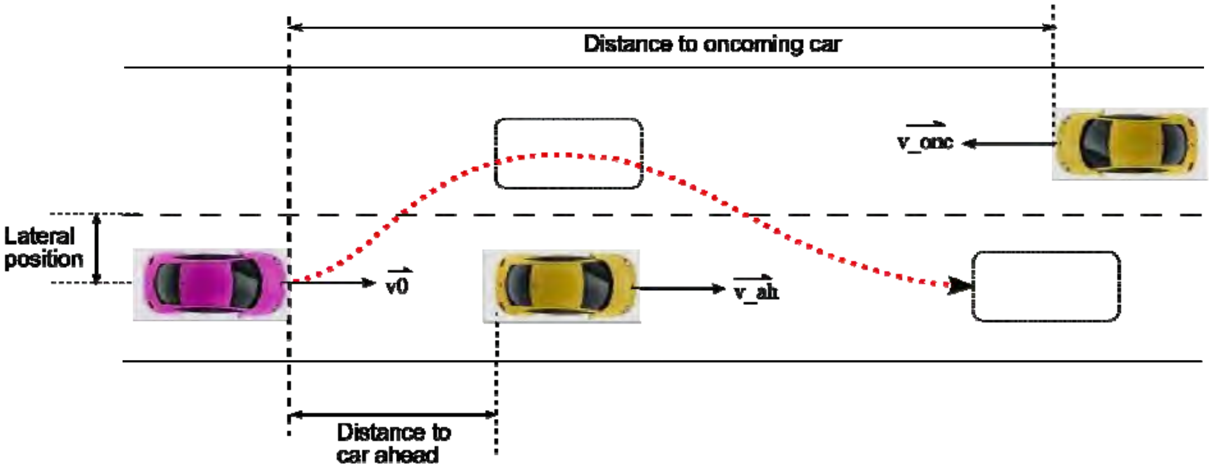


*Figure 34  Overtaking a car ahead.*

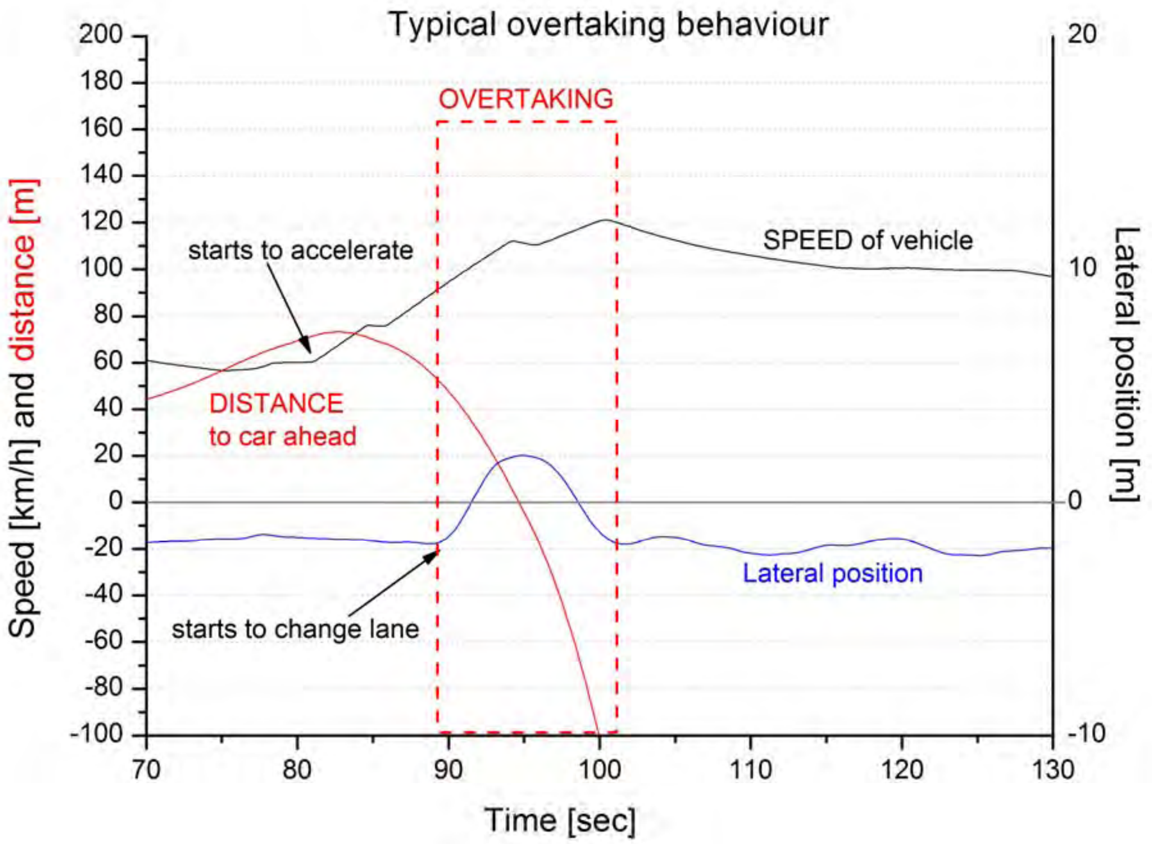


*Figure 35 Typical overtaking plotted. Lateral position of own car, distance to car ahead and speed of own car are shown.*

A normal overtaking manoeuvre is shown in, speed, lateral position and distance to car ahead are plotted in Figure 36. The purple car overtakes the yellow car. Overtaking has usually the following pattern: Check that distance to oncoming car is sufficient, consider road curvature, speed and distance to car ahead, start to accelerate, change lane, pass car *ahead, enter own lane again, slowly decelerate.* Here we simplified this and used the algorithm below.

**Overtaking algorithm:**

IF speed > 40 km/h AND distance to car ahead >0 m AND <80 m:

Find first middle lane crossing, from this point find the global maxima of lateral position (must lie maximally 25 seconds after middle lane crossing)

Find first local minima of lateral position left of first middle lane crossing(lateral position must be <-0.835 m, meaning car still in right lane).

Find first local minima after global maxima of lateral position (found above), lateral position must be <-0.835, meaning car is again in the right lane.

Overtaking variable is set to “1” from the first minima of lateral position left to the first minima of lateral position right of the lateral position maxima.

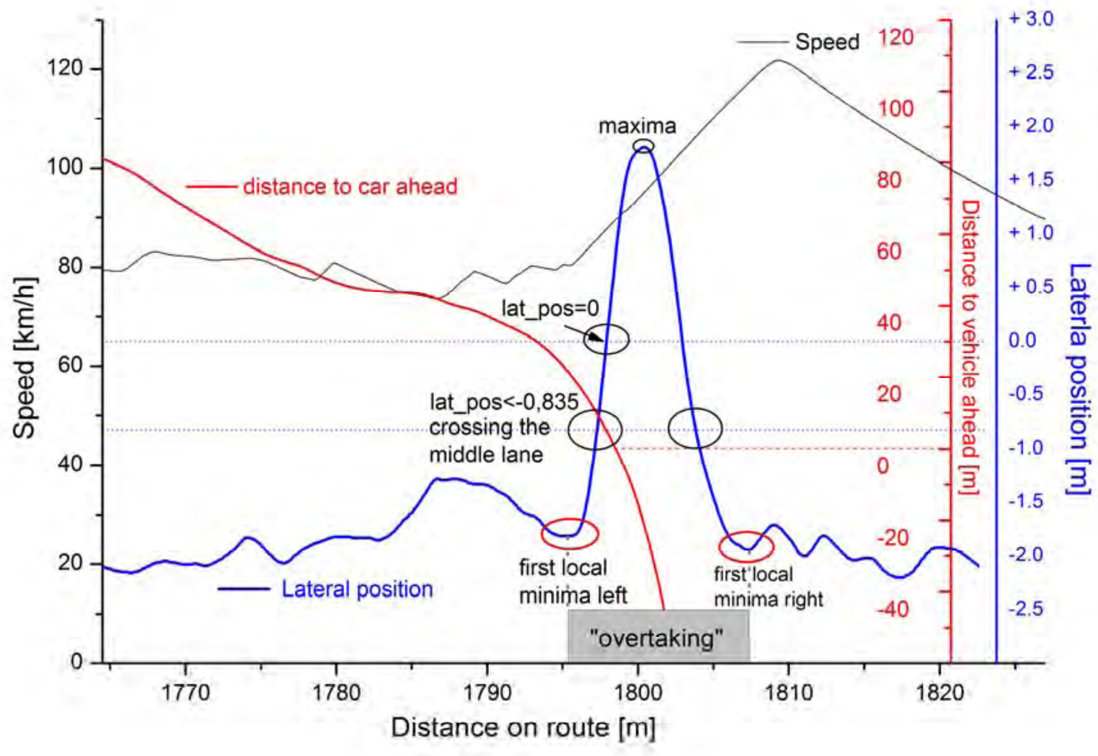


*Figure 36 Overtaking algorithm with points used.*

### Overtaking start algorithm

This was simple: when the “overtaking” variable gets “1”, the “overtaking start” variable gets “1” as well, but only for one sample point, then it returns zero. This means the “overtaking start” variable denotes only when the overtaking starts.

### Car following algorithm

The car following algorithm aims at finding situations were overtaking is potentially possible, but without considering oncoming traffic. Basically it sets the “overtaking start” variable to 1 when a car is ahead and the time headway is less than 3 seconds. It cannot be “1” while overtaking.

“Car following start” is simply set to “1” each time the “car following” variable is 1, but only for one sample.

### Bus variable algorithm

This variable is dependent of the distance to the parked bus: when no bus is present it is 0, when the warning shows up (at 571 meters distance from the bus) it gets “1”, when the bus becomes visible (at 447 meters distance from the bus) it gets “2”, when passing the bus (distance to bus =0 to -16 meters) it is “3”, and then returns 0. Clearly for the situation with control bus (no warning) the “1” is not present.

### Time to collision (TTC)

TTC is calculated by dividing the distance to the car ahead with the speed difference between own car and car ahead). Overtakings lead to not defined values (empty cell).

### Hitting rumble strips zone

The “hit left” and “hit right” variable shows when a wheel is on the rumble strips zone. Only one sample is set to “1” when hitting rumble strips (not for the whole duration when a wheel is on the rumble strips). Lateral position and lateral velocity (for the direction of lateral movement) are used to extract the variable.

*Annex 3 Explanation of selected point data*

Most of the point data in the point data files in page 24 are pretty straight forward, here just a few are explained.

| | |
|---|---|
| Mean time for overtakings | The average time when “overtaking” is 1. |
| Min distance to car ahead | Situations when overtaking are taken out. |
| Lateral distance to car ahead during overtaking | This is the lateral space to the car ahead just when passing the car (own front bumper passing rear bumper of car overtaken), one value for each overtaking. |
| Min distance to oncoming car while overtaking | Distance to oncoming car when overtaking, only when “overtaking” is 2 and when the own car is still in a lateral position when collision is possible. |
| Distance to oncoming car when starting to overtake. | When starting to overtake, just in the moment when the middle lane is crossed. One value for each overtaking. |
| Distance to oncoming car when entering own lane again. | After the overtaking, when the left wheel of the car is again in the own lane. One value for each overtaking. |

*Annex 4 Epworth sleepiness scale*

# ESS

Namn:

Dagens datum:

Hur troligt är det att du skulle slumra till eller somna i följande situationer, till skillnad från att bara känna dig trött? Det avser ditt vanliga levnadssätt på senaste tiden. Även om du inte gjort allt detta nyligen, så försök att komma på hur det skulle ha påverkat dig. Använd följande skala för att välja den lämpligaste siffran för varje situation.

0 = skulle *aldrig* slumra
1 = *liten* risk att slumra
2 = *måttlig* risk att slumra
3 = *stor* risk att slumra

| ***Situation*** | ***Risk att slumra*** |
|---|---|
| Sitter och läser | ______ |
| Tittar på TV | ______ |
| Sitter overksam på allmän plats (t ex teater eller ett möte) | ______ |
| Som passagerare i en bil i en timme utan paus | ______ |
| Ligger ner och vilar på eftermiddagen om omständigheterna tillåter | ______ |
| Sitter och pratar med någon | ______ |
| Sitter stilla efter att ha ätit lunch (utan alkohol) | ______ |
| I en bil som stannat några minuter i trafiken | ______ |

**Tack för din medverkan**

Ref.: Johns MW. A new method for measuring daytime sleepiness: the Epworth Sleepiness Scale. Sleep 1991;14:540-545.
Svensk översättning gjord av Jan-Erik Broman, Uppsala 2000 och antagen av Svensk förening för sömnforskning, 2001.

*Annex 5 Restless legs Syndrome*

# Svensk översättning av epidemiologiska frågor och diagnostiska kriterier för Restless Legs Syndrom

## EPIDEMIOLOGISKA FRÅGOR

1. Har du obehagliga förnimmelser (myrkrypningar) i benen kombinerat med ett starkt behov av att röra på benen? ☐ Ja ☐ Nej

2. Uppträder dessa besvär huvudsakligen eller endast vid vila och avtar de när du rör på dig? ☐ Ja ☐ Nej

3. Är dessa besvär värre på kvällen eller under natten, jämfört med på morgonen? ☐ Ja ☐ Nej

4. Hur ofta uppträder dessa besvär?
   - ☐ mindre än en gång om året
   - ☐ minst en gång om året men mindre än en gång i månaden
   - ☐ en gång i månaden
   - ☐ 2-4 gånger i månaden
   - ☐ 2-4 gånger i veckan
   - ☐ 4-5 gånger i veckan
   - ☐ 6-7 gånger i veckan

## DIAGNOSTISKA KRITERIER

1. Ett starkt behov av att röra på benen, vanligtvis åtföljt eller orsakat av otrevliga och obehagliga förnimmelser i dessa (ibland uppträder rörelsebehovet utan obehagliga förnimmelser och ibland är även armarna eller andra delar av kroppen inblandade, i tillägg till benen).

2. Det starka rörelsebehovet eller de obehagliga förnimmelserna börjar eller förvärras under perioder av vila eller inaktivitet, såsom när man ligger eller sitter.

3. Det starka rörelsebehovet eller de obehagliga förnimmelserna lindras helt eller delvis vid rörelse, såsom när man går eller sträcker på sig, åtminstone så länge aktiviteten pågår.

4. Det starka rörelsebehovet eller de obehagliga förnimmelserna är värre på kvällen eller under natten, jämfört med under dagen, eller så uppträder detta bara på kvällen eller under natten. (När symtomen är mycket svåra, kan försämringen nattetid vara svår att uppmärksamma, men den måste ha förekommit på ett tidigare stadium.)

Originalreferens: Allen RP et al. Restless legs syndrome: diagnostic criteria, special considerations, and epidemiology. A report from the restless legs syndrome diagnosis and epidemiology workshop at the National Institutes of Health. Sleep Med. 2003;4:101-119.

*Annex 6 Background questionnaires*

Fpnummer: __________

Datum: ______________

Klockslag:__________

**Frågor före körning**

1. Markera den tid du arbetat/studerat eller sovit under det senaste dygnet. Markera även när du senast åt, drack kaffe/te/coladrycker, samt tog eventuell medicin.

nu

I går → I dag →

| Klockslag | 19 | 20 | 21 | 22 | 23 | 24 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arbete | | | | | | | | | | | | | | | | | | | | | | | | |
| Sömn | | | | | | | | | | | | | | | | | | | | | | | | |
| Mat | | | | | | | | | | | | | | | | | | | | | | | | |
| Kaffe/Te | | | | | | | | | | | | | | | | | | | | | | | | |
| Medicin | | | | | | | | | | | | | | | | | | | | | | | | |

Var vänlig skriv ned vad du åt senast, hur mycket kaffe/coladrycker du eventuellt drack och i de fall du tagit medicin vilken typ av medicin det var.

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
__________________________________________________

Tack för hjälpen!

Fpnummer: _________

Datum: ____________

Klockslag:_________

Med detta formulär hoppas vi få en uppfattning om din sömn, dygnsrytm, hälsa, och erfarenhet som förare. Vi ber dig att svara uppriktigt på alla frågor!

**1. När är Du född?** **år _______**

**2. Kön?**

- ❑ **kvinna**
- ❑ **man**

## Sömn och trötthet

**3. Har du haft känning av några av följande besvär under de <u>senaste 6 månaderna</u>?**

*(Markera med ett svarsalternativ för varje besvär!)*

| | **aldrig** | **sällan**<br>någon, några ggr/år | **ibland**<br>någon, några ggr/mån | **för det mesta**<br>någon, några ggr/vecka | **alltid**<br>i stort sett varje dag |
|---|---|---|---|---|---|
| Svårigheter att somna | ❑ | ❑ | ❑ | ❑ | ❑ |
| Svårigheter att vakna | ❑ | ❑ | ❑ | ❑ | ❑ |
| Kraftiga snarkningar (enligt omgivningen) | ❑ | ❑ | ❑ | ❑ | ❑ |
| Mardrömmar | ❑ | ❑ | ❑ | ❑ | ❑ |
| Ej utsövd vid uppvaknandet | ❑ | ❑ | ❑ | ❑ | ❑ |
| Störd sömn/orolig sömn | ❑ | ❑ | ❑ | ❑ | ❑ |
| För lite sömn (mindre än 6 timmar) | ❑ | ❑ | ❑ | ❑ | ❑ |
| Känsla av att vara utmattad vid uppvaknandet | ❑ | ❑ | ❑ | ❑ | ❑ |
| Sömnig under arbete eller fritid | ❑ | ❑ | ❑ | ❑ | ❑ |
| Irritation/trötthet i ögonen | ❑ | ❑ | ❑ | ❑ | ❑ |
| Svårigheter att hålla mig vaken i samband med bilkörning | ❑ | ❑ | ❑ | ❑ | ❑ |

**4. Hur bedömer du på det hela taget din sömnkvalitet?**

- ❑ mycket bra
- ❑ ganska bra
- ❑ varken bra eller dålig
- ❑ ganska dålig
- ❑ mycket dålig

**5. Anser du att du får tillräckligt med sömn?**

- ❑ ja, definitivt tillräckligt
- ❑ ja, i stort sett tillräckligt
- ❑ nej, något otillräckligt
- ❑ nej, klart otillräckligt
- ❑ nej, långt ifrån tillräckligt

Nu kommer några frågor som berör dina sömnvanor under arbetsdagar och lediga dagar.

**6. När brukar du vanligen gå upp respektive gå till sängs vid arbetsdagar samt vid lediga dygn? Hur lång tid tar det vanligen för dig att somna (efter det att du har släckt lampan)?**

*Om du regelbundet - åtminstone varannan dag – tar en tupplur, anteckna även tiden för denna.*

arbetsdagar (skoldag) lägger mig (släcker lampan) kl________ upp kl________

tid innan du somnar (efter att du har släckt lampan)?_____________ min.

regelbunden tupplur från kl___________ till kl____________

lediga dagar lägger mig (släcker lampan) kl________ upp kl________

tid innan du somnar (efter att du har släckt lampan)?_____________min.

regelbunden tupplur från kl___________ till kl____________

**7. Försök att ange i hur hög grad du anser dig vara morgonmänniska eller kvällsmänniska.**

- ❑ utpräglad morgonmänniska (dvs. morgonpigg och kvällstrött)
- ❑ i viss mån morgonmänniska
- ❑ i viss mån kvällsmänniska (dvs. morgontrött och kvällspigg)
- ❑ utpräglad kvällsmänniska

Vad har du för vanor avseende användning av tobak/kaffe/cola och alkohol

**8. Är du:** *(OBS! gäller även snusare)*

- ❑ icke rökare – har aldrig rökt/bara rökt vid något enstaka tillfälle
- ❑ icke rökare – men har tidigare rökt (uppehåll minst ett halvår)
- ❑ rökare → besvara även fråga 14
- ❑ snusare – men röker ibland
- ❑ endast snusare (röker eventuellt vid något enstaka tillfälle)

**9. Ungefär hur många koppar kaffe/coladrycker dricker du under en arbetsdag?**

*Markera ett kryss för arbetsdag och ett kryss för ledig dag!*

| | Ingen kopp | 1–2 koppar | 3–4 koppar | 5–6 koppar | 7 koppar eller mer |
|---|---|---|---|---|---|
| Arbetsdag | ❑ | ❑ | ❑ | ❑ | ❑ |
| Ledig dag | ❑ | ❑ | ❑ | ❑ | ❑ |

**10. Hur ofta dricker du alkohol ?** *(räkna ej med lätt- el. folköl)*

- ❑ aldrig
- ❑ vid enstaka tillfällen, 1 gång i månaden eller mer sällan
- ❑ 2–4 gånger i månaden
- ❑ 2–3 gånger i veckan
- ❑ 4 gånger/veckan eller mer

**11. Använder du någon medicin?**

- ❑ Nej
- ❑ Ja, nämligen ________________________________________

**12. Hur lång är du?** **______ cm**

**13. Hur mycket väger du? ______ kg**

## Körerfarenhet

**14. Hur många mil körde du förra året?_____________ mil**

**15. Hur många år har du haft körkort?______________ år**

**16. Har du som förare erfarenhet av incident beroende på trötthet i samband med körning?** **(***Med incident menas nära olycka, felaktigt beteende, avkörning, perioder av ouppmärksamhet etc***.)**

- ❑ Nej, aldrig
- ❑ Ja → Vilken typ av incident?_________________________
  Hur många gånger under de senaste 5 åren?_________
- ❑ Vet ej

**17. Har du som förare varit inblandad i en olycka beroende på trötthet vid körning?**

- ❑ Nej, aldrig
- ❑ Ja, utan att själv ha orsakat olyckan — Hur många gånger under de senaste 5 åren?____
- ❑ Ja, det var jag själv som orsakade olyckan — Hur många gånger under de senaste 5 åren?____
- ❑ Vet ej

TACK FÖR DIN MEDVERKAN!

*Annex 7 Informed consent*

## Informerat samtycke

Undertecknad har tagit del av den skriftliga och muntliga informationen angående studien ”INSAFETY – en studie med bilkörning i simulator” och accepterar att delta på angivna villkor. Jag accepterar även att dvd- inspelningarna från mättillfällena kan användas vid presentationer av studien. Jag vet att jag har rätt att när som helst avbryta studien utan närmare förklaring.

Datum: ______________

Underskrift: __________________________________

Namnförtydligande: __________________________

XXXXXX

Projektledare

*Annex 8 Post questionnaires*

Fpnummer: __________

Datum: ______________

Klockslag: ____________

**Frågor efter körning**

1. Markera med ett kryss på den 9 gradiga skalan hur du känner dig just nu, från 1=extremt pigg till 9=mycket sömnig.

☐ 1 extremt pigg
☐ 2 mycket pigg
☐ 3 pigg
☐ 4 ganska pigg
☐ 5 varken pigg eller sömnig
☐ 6 lätt sömnig
☐ 7 sömnig men ej ansträngande vara vaken
☐ 8 sömnig och något ansträngande att vara vaken
☐ 9 mycket sömnig, mycket ansträngande att vara vaken, kämpar mot sömnen

2. Hur presterade du under körning?

Mycket bra — Mycket dåligt

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

3. Hur ansträngande (inte alls – mycket) var det att hålla sig vaken under körningen?

| Inte alls ansträng-ande | | | | | | Mycket ansträng-ande |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

4. Hur lätt eller svårt tyckte du att det var att skatta din sömnighet?

| Mycket lätt | | | | | | Mycket svårt |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

5. Har du under körningen känt dig så sömnig att du varit tvungen att kämpa för att hålla dig vaken?

| Ja | Nej | Vet ej |
|---|---|---|
| ☐ | ☐ | ☐ |

6. Har du somnat (nickat till) under körningen?

| Ja | Nej | Vet ej |
|---|---|---|
| ☐ | ☐ | ☐ |

7. Hur realistiskt (inte alls – mycket) var det att köra i simulatorn?

| Inte alls realistiskt | | | | | | Mycket realistiskt |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

8. Kände du av något illamående (inte alls – mycket) när du körde i simulatorn?

| Inte alls illamående | | | | | | Mycket illamående |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

9. Kände du dig uttråkad (inte alls – mycket) under körningen?

| Inte alls uttråkad | | | | | | Mycket uttråkad |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

10. Kände du dig orolig (inte alls – mycket) under körningen?

| Inte alls orolig | | | | | | Mycket orolig |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

| Inte alls stressad | | | | | | Mycket stressad |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

Har du några kommentarer?

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

Tack för hjälpen!

Fpnummer: _________

Datum: _________

Klockslag: ___________

Nu kommer några frågor som handlar om din upplevelse av räfflorna som du kört på, vi är speciellt intresserade av dina åsikter kring ljud och vibrationer samt betydelsen av att räfflorna syns.

1. Upplevde du räfflorna i simulatorn som verklighetstrogna?

   Ja ☐

   Nej ☐

   Vet ej ☐

2. Vad var det som till störst del bidrog till din upplevelse av räfflan?

   Att du såg dem ☐

   Ljudet ☐

   Vibrationerna ☐

   Både ljud och vibrationerna ☐

   Ljud, vibrationer och synintrycket ☐

   Vet ej ☐

3. Var upplevde du vibrationer?

   I ratten ☐

   I sätet ☐

   I hela bilen ☐

   Vet ej/minns ej ☐

4. Varifrån upplevde du att ljudet kom?

| | |
|---|---|
| Från det håll du körde över linjen? | ☐ |
| I hela bilen | ☐ |
| Vet ej/minns ej | ☐ |

5. Vad är din <u>generella</u> uppfattning om ljudet och vibrationerna?

| **Vibrationer** | **Ja** | **Ja, ganska** | **Nej, tveksamt** | **Nej** |
|---|---|---|---|---|
| Var vibrationer störande? | ☐ | ☐ | ☐ | ☐ |
| Var vibrationerna verklighetstrogna? | ☐ | ☐ | ☐ | ☐ |
| Blev du skrämd av vibrationerna? | ☐ | ☐ | ☐ | ☐ |
| Är vibrationer ett bra sätt att varna en förare som är trött? | ☐ | ☐ | ☐ | ☐ |

**Övriga kommentarer avseende vibrationer från räfflor:**

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

| **Ljud av räfflor** | **Ja** | **Ja, ganska** | **Nej, tveksamt** | **Nej** |
|---|---|---|---|---|
| Var ljudet av räfflor störande? | ☐ | ☐ | ☐ | ☐ |
| Var ljudet av räfflor verklighetstroget? | ☐ | ☐ | ☐ | ☐ |
| Blev du skrämd av ljudet? | ☐ | ☐ | ☐ | ☐ |
| Tror du att ljud av räfflor är ett bra sätt att varna en trött förare? | ☐ | ☐ | ☐ | ☐ |

**Övriga kommentarer avseende ljud från räfflor:**

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

6. Var tycker du att en fräst räffla ska vara placerad på en väg av den typ som du kört nu (9-m, 90 väg)?

| | |
|---|---|
| Integrerad med mittlinjen | ☐ |
| Innanför mittlinjen (i ditt körfält) | ☐ |
| Integrerad med kantlinjen | ☐ |
| Utanför kantlinjen | ☐ |
| Vet ej | ☐ |

I följande frågor vill vi ta del av din åsikt kring räfflor frästa i vägen. Vi vill att du svarar dels utifrån att du omedvetet t.ex. i trött tillstånd kommer ut på räfflor, dels hur de påverkar dig då du inte är trött, dvs. vid "vanlig körning".

7. Vad är din uppfattning om nyttan och acceptansen av frästa räfflor i vägen?

| **Omedveten passering** | **Ja** | **Ja, kanske** | **Nej, tveksamt** | **Nej** |
|---|---|---|---|---|
| Är det användbart med frästa räfflor på vägen för att göra föraren uppmärksam på sitt tillstånd? | ☐ | ☐ | ☐ | ☐ |
| Är det meningsfullt i termer av att föraren motiveras att göra åtgärder? | ☐ | ☐ | ☐ | ☐ |
| Kommer det att finnas en acceptans hos förare för räfflor frästa i vägen? | ☐ | ☐ | ☐ | ☐ |
| Finns det en risk att trötta förare blir skrämda när de kommer ut på frästa räfflor? | ☐ | ☐ | ☐ | ☐ |
| Finns det en riska att trötta förare som kommer ut på räfflor agerar så riskfyllda situationer uppkommer? | ☐ | ☐ | ☐ | ☐ |
| Kommer frästa räfflor i vägen bidrar till att olyckor reduceras? | ☐ | ☐ | ☐ | ☐ |
| Tror du att konsekvensen av frästa räfflor i vägen kan vara att förare kör längre innan de stannar jämfört med om de inte hade ett system? | ☐ | ☐ | ☐ | ☐ |

**Medveten passering**

| | | | | |
|---|---|---|---|---|
| Kommer förare att göra färre omkörningar om det finns frästa räfflor i mitten? | ☐ | ☐ | ☐ | ☐ |
| Kommer frästa räfflor i mitten innebära att man väljer tidpunkt för omkörning med större säkerhetstänkande? | ☐ | ☐ | ☐ | ☐ |

8. Vad är din uppfattning om nyttan och acceptansen av <u>räfflor som ett förarstöd</u>?

| | **Ja** | **Ja, kanske** | **Nej, tveksamt** | **Nej** |
|---|---|---|---|---|
| Är det användbart att nyttja vibrationer och ljud som "virtuella räfflor" för att göra föraren uppmärksam på sitt tillstånd? | ☐ | ☐ | ☐ | ☐ |
| Är det meningsfullt i termer av att föraren motiveras att göra åtgärder? | ☐ | ☐ | ☐ | ☐ |
| Kommer det att finnas en acceptans hos förare för "virtuella räfflor"? | ☐ | ☐ | ☐ | ☐ |
| Finns det en risk att trötta förare blir skrämda när de får effekten av "virtuella räfflor"? | ☐ | ☐ | ☐ | ☐ |
| Finns det en riska att trötta förare som får "virtuella räfflor" agerar så riskfyllda situationer uppkommer? | ☐ | ☐ | ☐ | ☐ |
| Kommer det att finnas en acceptans hos förare för räfflor i form av ett förarstödssystem? | ☐ | ☐ | ☐ | ☐ |
| Kommer "virtuella räfflor" bidrar till att olyckor reduceras? | ☐ | ☐ | ☐ | ☐ |
| Tror du att konsekvensen av <u>räfflor som ett förarstöd</u> kan vara att förare kör längre innan de stannar jämfört med om de inte hade ett system? | ☐ | ☐ | ☐ | ☐ |

**Medveten passering**

| | | | | |
|---|---|---|---|---|
| Kommer förare att göra färre omkörningar om de får en återkoppling i form av "virtuella räfflor"? | ☐ | ☐ | ☐ | ☐ |
| Kommer "virtuella räfflor" att innebära att man väljer tidpunkt för omkörning med större säkerhetstänkande? | ☐ | ☐ | ☐ | ☐ |

9. Markera på en femgradig skala i vilken utsträckning du anser att de olika varningssignalerna var 1=inte användbara till 5=mycket användbara.

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Vibrationer i sätet | ☐ | ☐ | ☐ | ☐ | ☐ |
| Ljud av räfflor | ☐ | ☐ | ☐ | ☐ | ☐ |
| Synen av räfflor | ☐ | ☐ | ☐ | ☐ | ☐ |

10. Har du tidigare erfarenhet av att ha kört på frästa räfflor?

Ja ☐ **Nämligen**______________

Nej ☐

Vet ej ☐

**Tack för din medverkan!**

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