



# D43.1: Eco driving in the real-world: behavioural, environmental and safety impacts: Chapter 11 - Annexes

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**Abstract**

This document contains the annexes parts of the D43.1: Eco driving in the real-world: behavioural, environmental and safety impacts. It contains the following sections:

- Annex A: VMC summaries
- Annex B: Situational variables definitions
- Annex C: Segment definitions
- Annex D: Events definitions
- Annex E: Detailed results per hypothesis (Energy)
- Annex F: Detailed results per hypothesis (Driver attention)
- Annex G: Detailed results per hypothesis (Driver behaviour)

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## Glossary of terms

Term	Description
App	In general: application software that causes a computer to perform tasks for computer users. In ecoDriver: the ecoDriver App.
Baseline period / phase	The part of the data collection during which the function(s) operate in "silent mode", that is, they collect data, but do not give any signals to the driver. From the viewpoint of the driver the function(s) is/are off.
CAN bus	A CAN bus (Controller Areas Network) is a vehicle bus standard designed to allow microcontrollers and devices to communicate with each other in applications without a host computer.
Controlled study	Study where the effect of a system is assessed based on a Baseline/Treatment comparison where pre-determined routes are scheduled for all participants.
Embedded system	An ecoDriver system that uses detailed vehicle data (CAN bus or OBD), i.e. an OEM system or a FeDS.
Event	An event is something that happens in a specific period of time which is individuated combining (pre-processed) measures according to predefined rules.
FeDS	The Full EcoDriver System.
FOT	A FOT (Field Operational Test) is a study undertaken to evaluate a function, or functions, under normal operating conditions in environments typically encountered by the host vehicle(s) using quasi-experimental methods.
Function	Implementation of a set of rules to achieve a specified goal.
Haptic system / feedback	In ecoDriver: using (variations in) gas pedal force as an HMI.
HMI	Human-Machine Interface. In ecoDriver, the HMI can have haptic, visual and auditory components.
HuD	Head-up-display
Hypothesis	A specific statement linking a cause to an effect and based on a mechanism linking the two. It is applied to one or more functions and can be tested with statistical means by analysing specific performance indicators in specific scenarios. A hypothesis is expected to predict the direction of the expected change.
Naturalistic Driving (ND)	Refers to studies undertaken using unobtrusive observation when driving in a natural setting.
ND	Naturalistic Driving.
NOx	Nitrogen oxides.
OBD	On Board Diagnostics.
OEM	Original equipment manufacturer.



Term	Description
Performance Indicator (PI)	Quantitative or qualitative indicator, derived from one or several measures, agreed on beforehand, expressed as a percentage, index, rate or other value, which is monitored at regular or irregular intervals and can be compared to one or more criteria.
PI	Performance Indicator.
PKE	Positive kinetic energy
Research question	A research question is a general question to be answered by compiling and testing related specific hypotheses.
RPM	Revolutions per minute is a measure of the frequency of rotation, in ecoDriver context: the engine's rotational speed.
Scenario	A scenario is a use case in a specific situation.
Situation	One specific level or a combination of more specific levels of situational variables.
Situational Variable (SV)	An aspect of the surroundings made up of distinguishable levels. At any point in time at least one of these levels must be valid.
SV	Situational Variable.
System	A system is a combination of hardware and software enabling one or more functions.
THW	time headway.
Treatment period / phase	The part of the data collection during which the function(s) are switched on by the experimental leader, such that they are either active all the time, or can be switched on or off by the driver.
TTC	Time To Collision.
VMC	Vehicle Management Centre.

## Acronyms

Acronym	Description
CRF	Centro Ricerche Fiat
BMW	Bayerische Motoren Werke
CTAG	Automotive Technology Centre of Galicia
IFSTTAR	French institute of science and technology for transport, spatial planning, development and networks
IKA	Institute for Automotive Engineering
TNO	Dutch Organisation for Applied Scientific Research
VTI	Swedish National Road and Transport Research Institute

# 1 Annex A: VMC summaries

## 1.1 CRF

Three vehicle prototypes hosted on Alfa Romeo Giulietta (1.4 T-Jet 120CV), Fiat Bravo (1.4 Multiair E5 Dynamic) and Lancia Musa (1.9 Multijet) with 3 different HMIs were developed and used during the on-field tests.

CRF ecoDriver prototypes are based on proprietary systems that allow:

- to evaluate in real time the eco-driver behaviour (acceleration, deceleration, gear and speed)
- to provide real time suggestions on eco-driving style improvement, through a self-learning tool that works on recurrent trips without using digital maps

The three developed HMIs are always visual ones and shown on instrument cluster or on a central stack display; moreover on the prototype hosted on Alfa Romeo Giulietta there is, beyond the visual interface, a haptic feedback too, provided to the driver by a counterforce gas pedal.

Each trial vehicle and HMI data were logged for all trips, thanks to a specific in vehicle unit.

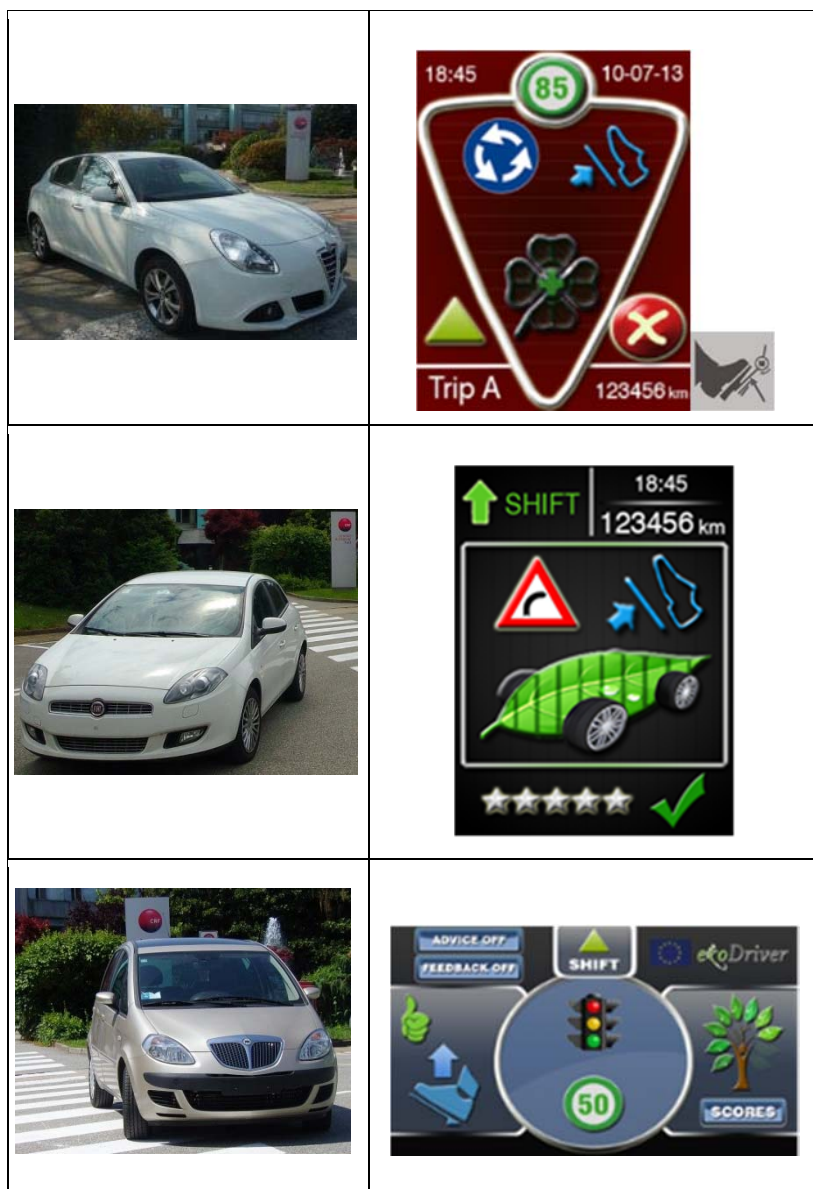


Figure 1: CRF prototypes hosted on Alfa Romeo Giulietta, Fiat Bravo and Lancia Musa (from top to bottom) and their HMIs.

The following table shows the system features in CRF prototypes hosted on Alfa Romeo Giulietta (A), Fiat Bravo (B), and Lancia Musa (C).

Table 1: System features of the CRF vehicles, Alfa Romeo Giulietta (A), Fiat Bravo (B), and Lancia Musa (C).

Prototype	Feed-forward (curve, traffic light, ...)	Gear Shift Indicator	Green Speed	Driving advice (pedal release)	Feedback (correct or wrong pedal release)	Visual HMI	Haptic HMI
A	YES	YES	YES	YES	YES	YES	YES
B	YES	YES	YES	YES	YES	YES	NO
C	YES	YES	YES	YES	YES	YES	NO

The on- field trials were conducted on a predefined track, starting and finishing at CRF, about 52 km long and with a travel time of about 1 hour and 10 minutes. Globally, more than 11.000 km were driven by participants involved in the real road test. The track consisted in a mix of urban, extra-urban and highway roads through several villages at an altitude variable from 270 to 500 m a.s.l., where the speed limits varied from 30 km/h to 90 km/h up to 110 km/h in the highway.

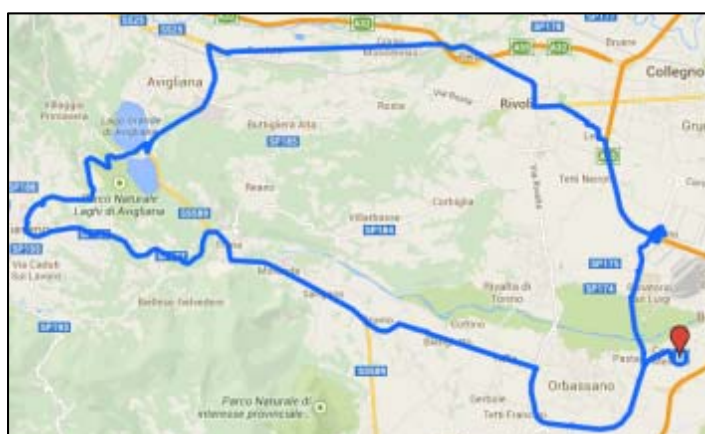


Figure 2: Trial track at CRF.

Twelve participants, recruited from CRF not technical areas employees, were involved in the on-field trials. All participants were required to own, beyond their valid driving license, a CRF driving license too, allowing them to drive vehicles prototypes with testing plates on public roads.

A within-subjects design was conducted. Each participant drove each of the 3 prototypes for a set of 6 drives (only one drive per day); each of the 6 drives set was composed by:

- 1<sup>st</sup> drive: baseline drive, with ecoDriver system off (visual and haptic HMIs deactivated)
- From 2<sup>nd</sup> to 6<sup>th</sup> drive: drives with ecoDriver system on (visual and haptic - if present - HMIs activated)
- For prototype hosted on Giulietta only, the 6<sup>th</sup> drive was done with the visual HMI activated as during the previous 4 drives but the haptic HMI deactivated.

The order of prototypes to be driven was randomized for each participant to avoid sequence and learning effects.

In the following lines the procedure is explained. Each participant was shortly briefed on the purpose of the trial by the experimenter and then asked to fill in the *Pre-Baseline* questionnaire.

The experimenter explained to the participant he would have been sitting on the passenger seat during all the drives, in order to take note of the variable events occurring throughout the drive using the Observer Protocol application installed on a tablet and also to give instruction about the track to be followed. Then the experimenter explained to the participant the guidelines to be observed during the drives (e.g. to drive according to the participant usual driving style, to respect the road and traffic rules). No explanation of the ecoDriver HMIs was done in that moment by the experimenter to the participant, since the participant didn't have to use any of them.

Thereafter the baseline drive started on the first prototype as sorted out by the randomisation.

At the end of the 1<sup>st</sup> drive the participant was asked to answer to the *Pre-Exposure* questionnaires.

Before the 2<sup>nd</sup> drive started, the experimenter activated the ecoDriver HMIs and explained the system to the participant and also the procedure to be followed in case of possible system problems. All these information were reminded to the participant before the beginning of other following drives.

After the end of 4<sup>th</sup> drive the participant was asked to answer to the *Mid-Exposure* questionnaires.

After the final drive the participant was asked to fill-in the *Post-Exposure* questionnaires.

Trials were conducted without problems, respecting the scheduling.

## 1.2 BMW

BMW's experimental setup is presenting of the ecoDriver application "ecoAssist". The forward looking ecoDriving system is connected to the digital map and inside vehicle communication with respect to the vehicle's longitudinal dynamics and the ecoDriver HMI to achieve a reduction of fuel consumption and CO<sub>2</sub> emission. The focus behind all is the 20% reduction of fuel and CO<sub>2</sub>.

BMW vehicle ecoDriver application was evaluated with acceptance test drives in 2014 and 2015. The acceptance test drives has been composed with 10 BMW BMW employees (male/female, 25-56 years) driving with a BMW 535i fuel (automatic powertrain) equipped with ecoDriver application prototype. Figure 3 shows the BMW 535i which has been used in the ecoDriver project.



Figure 3 BMW 535i equipped with ecoDriver application.



The test route has been located in the south of Germany: Munich – Wolfratshausen – Benediktbeuern with a length of 66 km includes a mostly hilly terrain with city traffic, motorway and small curvy rural roads around Wolfratshausen. The test drives has been driven three times: one without the ecoDriver application and two times with the ecoDriver application.

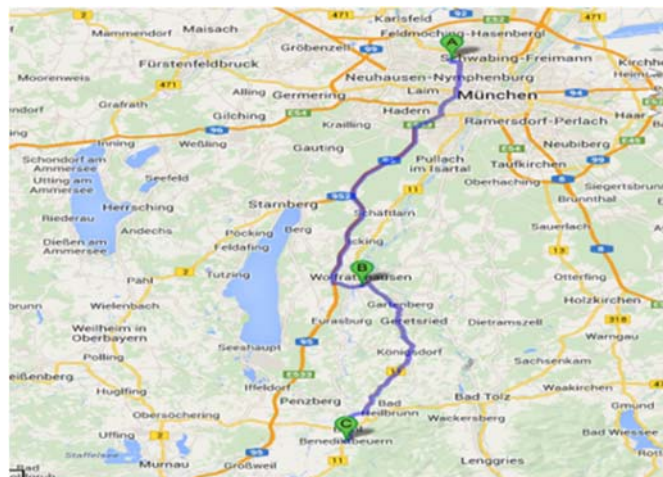


Figure 4 ecoDriver test route in the south of Munich.

The test route is shown in Figure 4. The test route is described by 11km city, 28 km motorway, 27km country roads (total 66km). The BMW drivers (BMW employees) were accompanied by observers which informed the drivers on the route only and took notes during trip. Test drivers were asked to answer questions from ecoDriver questionnaire during breaks and at the end of test trip. Vehicle and ecoDriver application data were logged for all trips.

BMW's ecoDriver application is based on the Navigation System with a new developed electronic horizon shown in the HuD and dashboard. Both are a new development of ecoDriver. All the mentioned systems are connected to the full driving dynamics and to the coasting function. The function of the costing function is given by means of: if the driver is not accelerating anymore the gearbox switches to the normal mode and if the driver accelerate again the gearbox switches back to the driving mode. There is a special feature: if we driving in the coasting mode and the driver is braking the gearbox switches back to the driving mode. A number of features are unique to the BMW HMI design that are different given by a modern HuD and dashboard connected to the driving dynamics showing an special electronic Horizon, e.g., in the electronic horizon are shown different colours dependent how eco-friendly the driver is driving (see Figure 5).

Further we are showing in the dashboard the CO<sub>2</sub> values that driver knows how eco-friendly the driver is driving.



Figure 5 Coasting sign shown in the dashboard together with the CO<sub>2</sub> values, eco-friendly driving (stars on the left side) speed and average CO<sub>2</sub> values in the middle and on the right side the fuel consumption as well as the “Last trip” values at the bottom of the dashboard (ecoDriver dashboard/stars, upper figure), full coloured HUD background (lower figure).

The instrument cluster of the eco-systems displayed information on the current fuel consumption and CO<sub>2</sub> production. Background colours of each display within the instrument cluster and on the HuD were according to Figure 3. Upper figure shows the dashboard and the lower figure shows the HuD.

### 1.3 Daimler

The experimental evaluation by Daimler was performed with an Actros 1851 (510 horsepower) as a test vehicle. To achieve typical heavy duty driving behaviour, the gross weight was setup up to 30 tons with an attached semitrailer loaded with gravel.

In total 24 test drivers were recruited for the evaluation. All drivers fulfilled the prerequisite of having the driver’s license for at least two years and driving at least ten thousand kilometres per year. The average age of the test drivers was 44 years with a standard deviation of 9.4 years. Of the participants were 23 male and 1 female persons who drove an average of 53 thousand kilometres per year with a standard deviation of 34 thousand kilometres.

All evaluation drives were performed with the same test vehicle in a period of six weeks total. The test drivers had to complete the test route three times with different system conditions, which were assigned in a randomized order. The system conditions were “baseline” with no system

recommendation activated, “treatment” with ecoDriver system activated and one condition “haptic” with an additional haptic acceleration pedal activated. The controlled study took place on a 34 kilometre long route near Münsingen (Germany) in urban and rural environments, which is shown on a satellite picture in Figure 6.

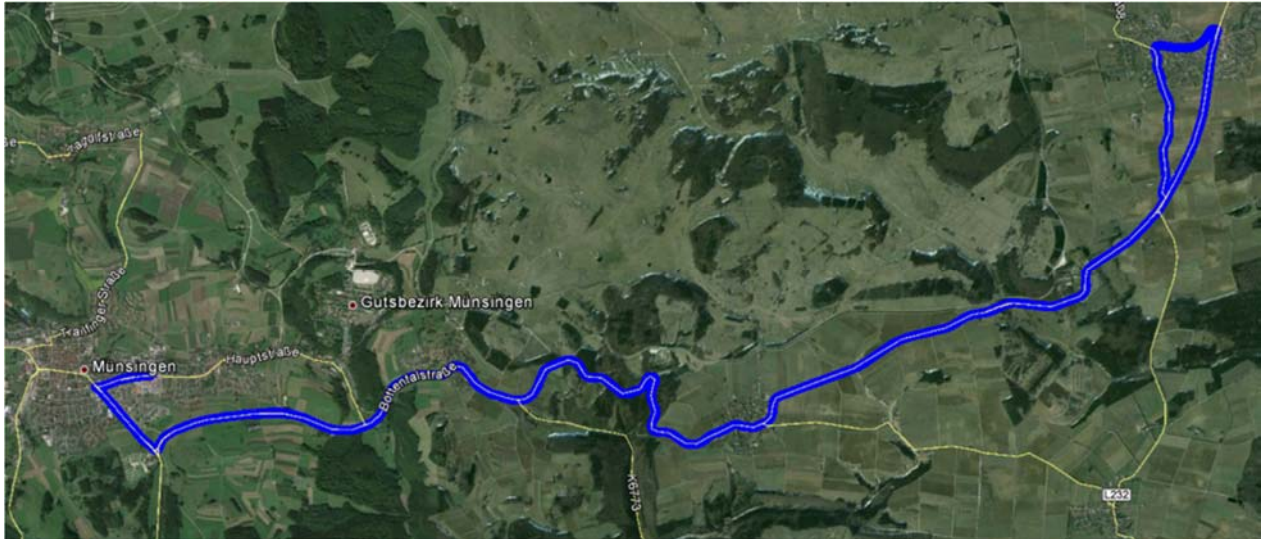


Figure 6: Daimler evaluation test route

The evaluation drivers also transferred the vehicle from the company site in Stuttgart (Germany) to the test route (approximately 90 kilometres) and also transferred the vehicle back to the start point (approximately 72 kilometres), which are considered as naturalistic data. The different participants had to drive different conditions for the transfer, which was also assigned randomly. As a result, some of drivers experienced the system before the controlled study and some did not.

## 1.4 TomTom Telematics

The TomTom Telematics (former TomTom Business Solutions) ecoDriver system is an aftermarket system, which is built on top of the TomTom Telematics platform. The advantage of such an aftermarket system is that it is not focusing on a specific vehicle model, but can be installed in the majority of vehicles available on the market. The disadvantage is that the system has little access to all the sensors already on-board of the vehicle. To retrieve the information necessary to properly support the driver, the TomTom Telematics ecoDriver system has access to vehicle data via the OBDII interface and derives predictive traffic information from the TomTom map using GPS location.

A more precise description of the system tested is presented at chapter 3.

### Release phases for testing

The process of the system development and the evaluation tests are shown in Figure 7. For the trials, first a baseline period and a period where the previous TomTom Telematics solution was tested were taken into account. The previous TomTom Telematics eco-driving solution was extended with the results from the ecoDriver research coming out of SP 1 and resulted into the TomTom Telematics ecoDriver system. The TomTom Telematics ecoDriver system trials started in June 2014. These tests were divided in three phases:

1. Phase 1: Contains the feedback and key performance indicators on fuel consumption, idling, speeding and driving events (harsh braking and harsh steering). Furthermore, the driver can see in the menu the tips & tricks on how to drive eco-friendly. The phase 1 tests provide feedback and debug results for the firmware upgrade in phase 2. The firmware of phase 1 can be seen as a first proof of concept version that is tested in the field.
2. Phase 2: Contains the improved TomTom Telematics ecoDriver version of phase 1 plus additional advice and key performance indicators on coasting, constant speed, gear shifting and green speed (recommended speed to decrease fuel consumption).
3. Phase 3: In this phase the ecoDriver system will be extended with additional eco-driving functionality in the back-office, i.e. KPI reports and dashboards, so that the fleet manager can monitor his drivers and their driving behaviour. Furthermore, some UI elements were changed, e.g. the coasting advice was changed from just a pop-up message to advice in the routebar, where the driver would already see upcoming coasting areas and the reason (e.g. approaching an intersection or roundabout or speed limit drop).

This 3-phased approach was taken to introduce not all the features at once and to improve the system step-by-step in an iterative process. The drivers drove the final TomTom Telematics ecoDriver system in phase 3.

After the baseline condition, the condition where the drivers tested the previous TomTom eco-driving solution and after testing the final TomTom Telematics ecoDriver system the drivers were asked to fill in the ecoDriver questionnaire to retrieve subjective driver acceptance information about the system.

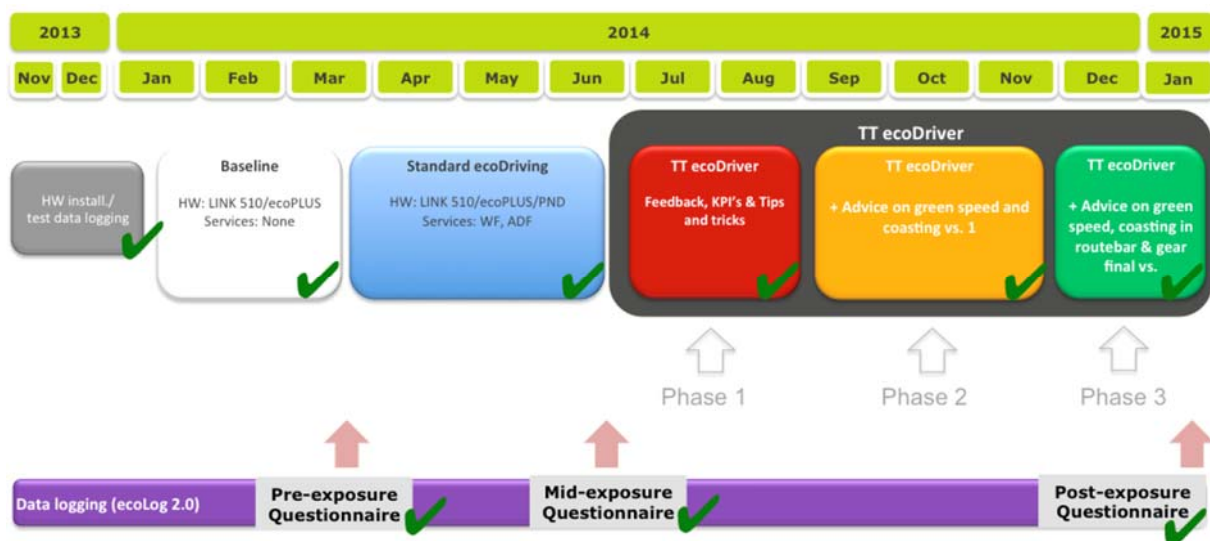


Figure 7: Process of firmware integration and testing

### Participants

The Naturalistic Driving Study was conducted with two TomTom Telematics customers, one in Germany and one in The Netherlands. An overview of the 2 customers is shown in table 1.

The German company is a company in the building industry, delivering material for buildings and infrastructure. The Dutch company is a postal delivery company delivering across the whole of the Netherlands.

Although these customers decided to participate in the ecoDriver Naturalistic Driving study to test the TomTom Telematics ecoDriver system, there are a few factors that could influence the results of the



analysis, since the Naturalistic Driving study is really different from the controlled experiments done with the other ecoDriver systems.

Factors that could impact the results:

- Participation in the trial was not drivers' choice, but the choice of the company
- There was no direct contact with the drivers
- The focus of the driver is quick delivery, not the ecoDriver system or driving eco-friendly
- Drivers consider themselves as professional drivers and are less open towards feedback
- It was mainly a financial motivation of the company to participate
- Focus of the company was the daily operation
- Companies & drivers were not responsive - especially in Germany the drivers did not really collaborate: returned empty or quickly filled in questionnaires

Table 2 Overview of the two participating customers (\* The German customer did hardly cooperate during the trial. Especially at the end of the trial they were not responsive towards our request to fill in and send back the questionnaires. Some questionnaires were sent back un-answered.).

	German customer*	Dutch customer
Type of vehicle	LCVs and Trucks	LCVs
Number of vehicles	10	10
Vehicle models	Volkswagen Touran	"Mercedes Benz Citan
	Fiat Ducato	Mercedes Benz Vito
	Mercedes Benz Sprinter	Ford Transit
	Volkswagen Transporter	Ford Transit Connect
	Mercedes Benz Actros	Renault Trafic"
	Mercedes Benz Vario"	
Type of engine	ICE (Diesel)	ICE (Diesel)
Type of gearbox	Manual and automatic	Manual
ecoDriver system	TomTom system	TomTom system
Type of study	Naturalistic	Naturalistic
Experiment format	ACB <sub>1</sub> B <sub>2</sub> B <sub>3</sub> (these Bs are different versions)	ACB <sub>1</sub> B <sub>2</sub> B <sub>3</sub> (these Bs are different versions)
Experiment duration	13 Jan 2014 – 28 Feb 2015	13 Jan 2014 – 28 Feb 2015
Special focus	A comparison of three different systems against both a pure baseline and one with an existing fuel advice system.	A comparison of three different systems against both a pure baseline and one with an existing fuel advice system.
ADAS	CC	CC
Onboard energy efficiency	None	None

	German customer*	Dutch customer
<b>Data logging</b>	Data logging on backoffice server	Data logging on backoffice server
<b>Incentives</b>	None	None
<b>Number of drivers</b>	10	10
<b>Selection criteria</b>	Professional truck/LCV drivers	Professional LCV drivers
	Employees of the company selected for the trial	Employees of the company selected for the trial
<b>Traffic density</b>	Low to high	Low to high
<b>Routes</b>	Free	Free
<b>Landscape</b>	Bit hilly (Stuttgart)	Flat (Netherlands)
<b>Climate</b>	Full range (W-E)	Full range (W-E)

## 1.5 VTI

### Participants

Twelve participants were recruited with the ambition to have at least ten participants who complete all ten trials. A request sent to the registry of vehicle owners generated a list of 100 randomly selected Volvo-V70-owners. These people were invited by letter to sign up as participants, provided that their schedule would likely allow them to participate in all trials, which would extend over the course of approximately one year. Two participants did not complete all trials. The remaining ten participants were five women and five men. Their mean age was 41 years (sd = 7 years). They had held their driver's license on average for 15 years (sd = 6.5 years) and their mean annual mileage was 30000 km (sd = 16000 km).

### Experimental design

The participants drove the same route nine times over the course of approximately one year. The first two drives were baseline drives without FeDS, the next five drives were treatment drives with the FeDS in place, and the last two drives were after-exposure baseline drives without FeDS. The last drive was conducted at least four weeks after the next-to-last drive, to investigate the persistence of learning effects. For statistical analyses four of the nine drives will be used as specified in Table 3.

Table 3. Drives in the visual behaviour study, and motivations for why they are included in or excluded from the analyses.

Name	type of drive	motivation for inclusion in/exclusion from analysis
B1	Baseline 1 (excluded)	First time encounter with the car and first test day, therefore possibly less natural behaviour than during the second baseline.



Name	type of drive	motivation for inclusion in/exclusion from analysis
B2	Baseline 2 (included)	Pre-treatment baseline, more familiar with car and experimental setup.
O1	Off-line instruction 1 (excluded)	Not driving, therefore no eye tracking recorded.
T1	Treatment 1 (included in descriptives, excluded from inferential statistics)	First encounter with full ecoDriver system, therefore included for comparison in some analyses, but main research interest lies in more “standard” behaviour when familiar with the system.
T2	Treatment 2 (excluded)	Treatment 2 and Treatment 3 were planned for training with the FeDS, therefore not included in the study.
T3	Treatment 3 (excluded)	
T4	Treatment 4 (included)	Included as the “experienced” treatment trial. Some experience was gained during previous drives, while the current drive still was not the last with the system.
T5	Treatment 5 (excluded)	The participants knew that this was the last trial with the system, which may have prompted them to be extra attentive to the system in order to remember everything for the following drives.
B3	Baseline 3 (included)	Comparison to Baseline 2 and also to Treatment 4 to assess learning effects.
B4	Baseline 4 (included)	Comparison to Baseline 2, Baseline 3 and Treatment 4, to assess learning (and decay) effects after 1 month.

### Vehicle and equipment

The test vehicle was a Volvo V70 with manual transmission. It was equipped with a Controller Area Network (CAN) data logger (CTAG, Porriño, Spain) storing data from the vehicle, from a radar (UMRR Type 29, smart microwave sensors GmbH, Braunschweig, Germany) and a GPS sensor (Navilock 302U, Tragant Handels- und Beteiligungs GmbH, Berlin, Germany). A separate computer logged data from a remote five-camera eye tracking system with a panoramic forward view camera (SmartEye Pro 6.1, Smart Eye AB, Gothenburg, Sweden). GPS data were logged with 1 Hz, vehicle related data were logged with 10 Hz and gaze data were logged with 60 Hz. All data sources were synchronized by storing a common time stamp in both recording systems.

### Included data

The experimental route was approximately 96 km long, taking 94 minutes to drive on average, and was divided into segments. Within each segment the posted speed limit and the road type (urban, rural, motorway, 2+1 road) were constant. Segments shorter than 1 km were removed. The remaining

segments were bundled based on road type, resulting in the analysable road sections presented in Table 4. The location of the different segments is shown in Figure 8.

Table 4. Road segments included in and excluded from the analyses, per road type.

type	speed limits	distance of segment	mean time spent on segment	total distance and time	% of total distance	ca. % of total time
urban	40 km/h	1.7 km	2.7 min	9.1 km	9.5 %	18.0 %
	50 km/h	5.8 km	12.2 min	16.8 min		
	60 km/h	1.6 km	1.9 min			
rural	70 km/h	0.9 km	0.9 min	35.3 km	36.5 %	38.5 %
	70 km/h	6.1 km	5.5 min	36 min		
	70 km/h	24.1 km	25.6 min			
	70 km/h	4.2 km	4.0 min			
motorway	90 km/h	2.2 km	1.6 min	30.9 km	32 %	19.5 %
	110 km/h	2.2 km	1.4 min	18.5 min		
	110 km/h	26.5 km	15.5 min			
2+1 road	110 km/h	5.1 km	3.1 min	5.1 km 3.1 min	5.5 %	3.5 %
not included	Various	16 km	19.6 min	16 km no data	16.6 %	20.5 %

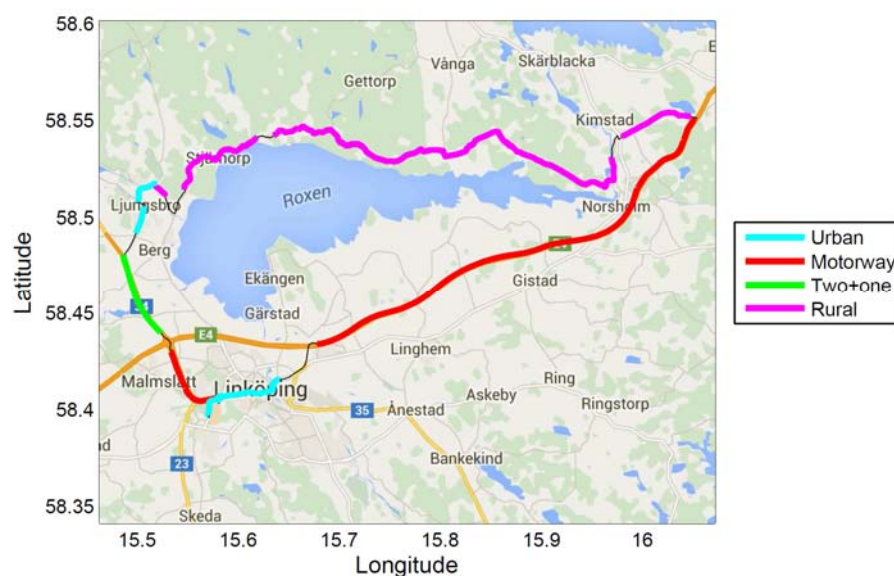


Figure 8: The location of the different segments along the VTI test route.

Data from segments with low quality data were excluded from further analyses. The criteria defining low quality were (i) more than 30 % missing values in the entire trip, (ii) more than 30 % missing values in the current segment, (iii) looking through the windscreen less than 40% in the current segment, and (iv), high frequency of lost tracking sequences, defined as more than 1 % of missing value sequence initialisations. The total number of useful segments, where GPS data were available and the eye tracking quality was sufficient, was 724 of 990. The availability of eye tracking data in the useful segments was  $93.3 \pm 4.9$  %.

### **Deviations from plan**

The delay in the FeDS delivery caused some issues for running the experiment as planned. The trial period had to be extended, and the last two baseline drives had to be moved closer together. This also caused one participant to leave the experiment prematurely.

Otherwise the setup was stable, and no major changes were implemented on the test route over the course of the experimental year. Only weeks later, speed limit changes were implemented. Fortunately this did not affect the trials, but if it had happened just a few weeks earlier (or if the trials had been further delayed), this change to speed limits would have had large influence on the data analysis.

While the decision to record eye tracking films instead of doing real-time tracking was well motivated, it turned out to be a real problem. The amount of data collected was immense, and the software still contained too many bugs for the tracking process to run smoothly. In hindsight it would have saved many hours to perform real time tracking instead. These problems could not be detected during the pilot phase, as an older version of the tracking software was implemented at the time, which did not exhibit the problems experienced with the newer version.

## **1.6 IKA**

### **Introduction**

In the real-world trials of the ecoDriver project, IKA conducted controlled test drives with the Full ecoDriver System (FeDS) in order to test the system in general as well as with a special focus on deceleration and coasting manoeuvres.

### **Test route**

The test route for the experiment has a distance of 45 km around the vicinity of Aachen. It contains sections of motorway, rural and urban areas and takes about 50 to 60 min time of driving depending on the traffic situation. While the roads of the northern part of the route (motorway and urban area) are rather flat, the southern part of the track (rural and urban roads) can be considered as hilly. The route is shown in Figure 9.

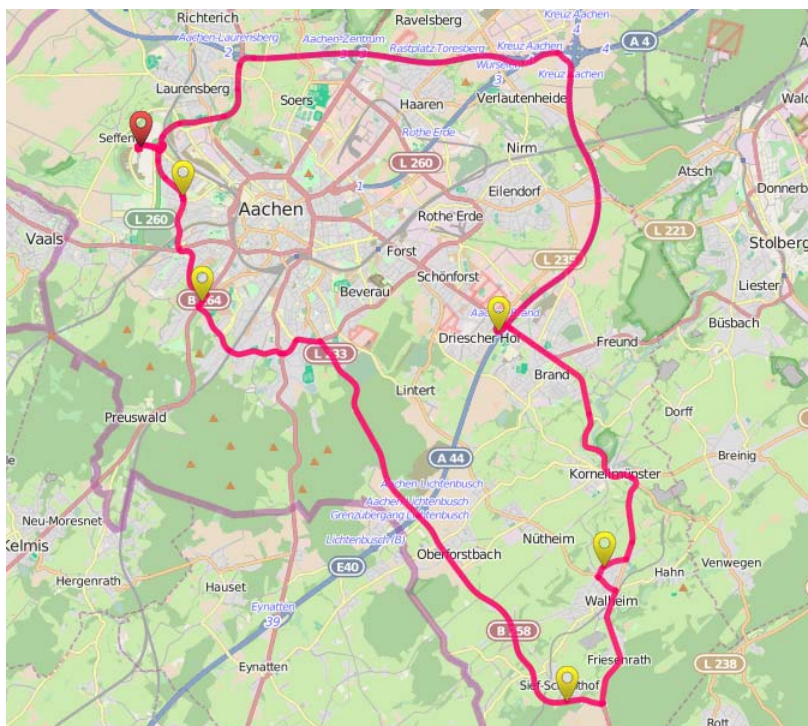


Figure 9: IKA's piloting test route (openstreetmap.org)

### Number and selection criteria of participants

Due to legal aspects only IKA employees holding a special driving permission to drive the test vehicle on public roads were allowed to participate in the study. All participants were aged between 20 and 40 years. For this study, two participants were taken from the available pool of test subjects in order to conduct the pilot test drives. Overall, 18 participants were tested. This number includes two pilot test persons (2 male) in A-B-A and 16 persons (2 female, 14 male) in A-B-B setup. Overall, data from over 2400 km of driving was recorded. For the experiment, 18 participants [2 female, mean age = 27.7 years, standard deviation (SD) = 4.0 years] with a mean driving experience of 9.8 years (SD = 3.8) were tested.

### Range of testing

Each participant is planned to undertake three drive sessions, totalling 135 km driven by each participant in total. The first drive without the system is considered as baseline drive followed by two drive sessions with the system active. Each drive session is conducted on consecutive days within the same time slot in order to eliminate daytime effects and traffic influences as far as possible. For IKA's VMC, two participants (3 days of driving each, 270 test km in total) were used as pilot testers in order to verify the test setup and the experimental design for the main study.

Table 5: IKA's test schedule for each participant

Day 1	Day 2	Day 3
<ul style="list-style-type: none"> <li>– Baseline instructions</li> <li>– Pre-drive and pre-baseline questionnaires</li> </ul>	<ul style="list-style-type: none"> <li>– System instructions</li> <li>– Pre-drive and pre-exposure questionnaires</li> </ul>	<ul style="list-style-type: none"> <li>– System instructions</li> <li>– Pre-drive questionnaire</li> </ul>

Day 1	Day 2	Day 3
<i>Baseline drive (A)</i> <i>Driving session 1</i>	<i>System drive 1 (B)</i> <i>Driving session 2</i>	<i>System drive 2 (B)</i> <i>Driving session 3</i>
– Post-baseline questionnaire	– Mid-exposure questionnaire	– Post-exposure questionnaire – Incentives

### Observer's task

Each participant was accompanied by an observer in all drives of the controlled field test. Simultaneously, the observer also acted as an instructor handing out instructions and questionnaires before and after the drive sessions. While driving, the observer used the observer protocol application in order to log additional data that could not be recorded by the system itself, Figure 10.



Figure 10: Scene from IKA's pilot test drive.

### Test vehicle

IKA's implementation of the FeDS uses the existing hardware of IKA's test vehicle, a Volkswagen Passat CC with a 3.6l TFSI gasoline engine. The car is equipped with several sensors, actuators as well as computers and programmable control units with interfaces to the test vehicle's CAN bus. The configuration is shown in Figure 11.



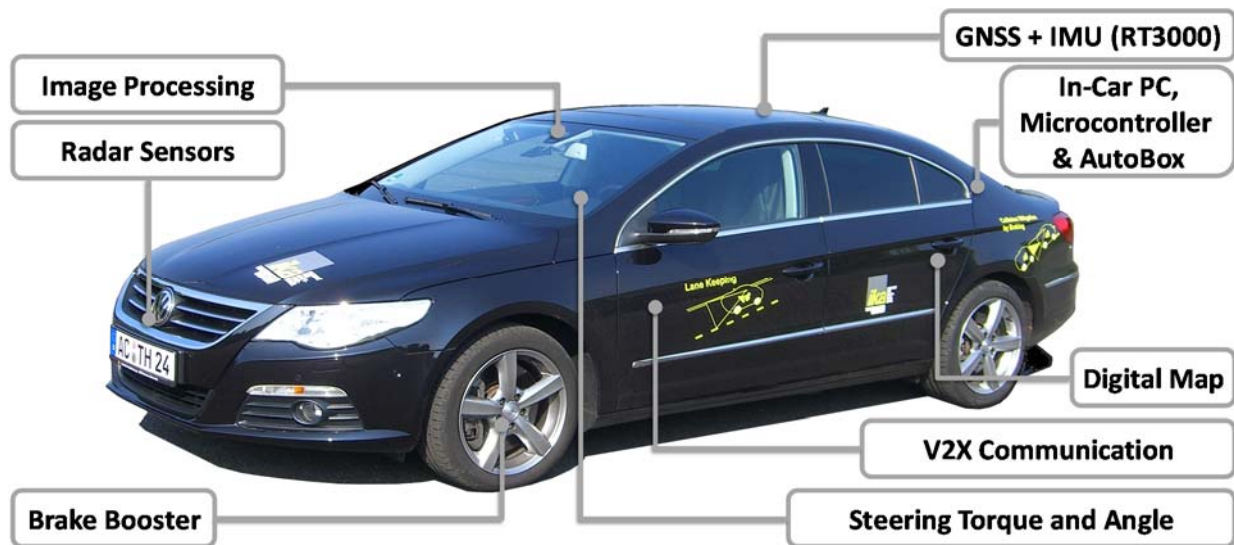


Figure 11: IKA's test vehicle (VW Passat CC).

### System characteristics

The Full ecoDriver System (FeDS, Figure 12) is a green driving support system that provides predictive feed-forward advice and feedback on driving performance as well as green driving scores, adaptive levels of difficulty and goal-setting options. For its calculation, it takes into account curves, slopes, road geometry, traffic signs and other vehicles.



Figure 12: Screenshots of FeDS: Standard HMI screen while driving (left), predictive driving advice as on-screen information with regard to a front vehicle (centre), additional driving advice for sharp curve and upcoming speed limit events (right).

### Limitations and deviations from planned setup

The original experimental setup stated that the study should be conducted using an A-B-A test design. However, this was in conflict with the trial protocols from WP32 (project-wide instructions). The



instructions asked the participant to drive normally, i.e. as in daily life, during the first drive which forbids analysing an increase in efficient driving strategies between the first and third drive.

Additionally, the pilot tests and direct inquiry of the test persons revealed that there were no detectable learning effects in the third drive. Thus, the third drive session was replaced with another system drive so that the experimental design was changed to A-B-B. Apart from avoiding non-significant results due to inappropriate instructions for the hypothesis in question, this change also brought the advantage of producing more system exposure data and more use cases to analyse. Furthermore, the new design enables comparisons and analyses for learning effects in terms of system usage ( $B_1$  vs.  $B_2$ ).

## 1.7 CTAG

### Vehicle preparation and operation

At the test site of CTAG at Vigo in Spain, two vehicles with different powertrains and a fleet of user vehicles participated in the studies carried out. Table 6 summarizes the vehicles and studies where the vehicles were involved (more information in D14.1 and D32.3):

Table 6: Overview of the vehicles and studies at CTAG.

	Type of Engine	Gearbox	Studies involved
<b>Nissan Leaf</b>	Full electric	Automatic	Controlled
<b>Renault Scenic</b>	Diesel	Manual	Controlled
<b>User fleet</b>	Diesel and petrol	Manual	Naturalistic

#### Nissan Leaf

The main characteristics of this FEV (Full Electric Vehicle) are the following:

- Motor type: AC synchronous
- Maximum power: 109 hp (80 kW) / 2730-9800 rpm
- Maximum torque: 280 Nm / 0-2730 rpm
- Maximum speed: 10,390 rpm
- Battery type: Lithium ion laminated
- Voltage: 360 v
- Capacity: 24 kWh
- Gearbox: Automatic, unique relationship
- Drive: Front
- Maximum speed (km / h: 145 km / h
- Acceleration 0-100 km / h: 11.9 seconds
- Power consumption: 173 Wh / km

#### Renault Scenic

The main characteristics of this ICE (Internal Combustion Engine) vehicle are the following:

- Power: 130 HP
- Type of gearbox: Manual
- Gearbox (number of gears): 6
- Maximum speed (km/h): 192
- Acceleration 0-100 km/h (s): 9.6
- Acceleration 0-1000 m (s) 31.2
- Urban consumption (l/100 km): 7.3
- Extra-urban consumption (l/100 km): 5.2
- Average consumption (l / 100 km): 6.0
- CO2 emissions (g /km): 159

### Naturalistic fleet

A naturalistic study was also performed at the test site of Vigo with a variety of vehicles from private users. The study carried out with this fleet was using the nomadic ecoDriver application. The route driven by the participants was free, intended to be the normal driving routes of the users.

The following table summarizes the vehicles part of the study.

Table 7: Overview of the vehicles in the naturalistic fleet at CTAG.

Brand/Model	Type of engine	Gearbox
<b>Peugeot 407</b>	Diesel	Manual
<b>Golf VI</b>	Petrol	Automatic
<b>Golf V</b>	Diesel	Manual
<b>C4</b>	Diesel	Automatic
<b>Golf V</b>	Petrol	Manual
<b>C3 Picasso</b>	Diesel	Manual
<b>Golf</b>	Diesel	Manual
<b>Seat León</b>	Diesel	Manual
<b>VW Passat</b>	Diesel	Manual
<b>Peugeot 407</b>	Diesel	Manual

### Participants

Participants were recruited via email. 10 drivers were looked for naturalistic test. In this case, an email was sent CTAG participants database contacts: the invitation to participate in the study was launched in April 2015. During a period of time they have to use a mobile phone in order to have the information to perform an ecoDriver behaviour. Drivers should have to fill in different questionnaires when researchers asked for it. Finally, 10 participants were recruited: 9 men and 1 woman with an age range between 34 and 57 years old.

Regarding controlled test (with nomadic and FeDS systems) a recruitment among CTAG workers were done. Once more, an email with sent workers with the aim to explain the requirements that participants should have: to be between 20 and 65 years old, have a valid driving license and two years of experience as driver, do not be under the influence of any substance that could affect their behaviour as driver during the study and not are working or having knowledge about ecoDriver project. 30 participants were recruited for controlled study with FeDS (22 men and 8 women, age range between 25 and 46 years old) and 10 for nomadic (half of the sample are men and the other half women between 28 and 46 years old). In both cases, participants received an economic grant for participating.

A summary about participants profile is presented in Table 8.

Table 8: Participants at the CTAG test site.

Study		Nº Participants	Recruitment	Gender	Age range
FeDS	Controlled	30	Internal CTAG employees	Both	25 - 46
	Naturalistic	10	External participants	Both	34 - 57
Nomadic		10	Internal CTAG employees	Both	28 - 46

Different routes were run in the studies performed:

- ***Routes used in controlled driving with system FeDS: Urban, rural, interurban and motorway (described in D34.1).***
- ***Route for Nomadic system - controlled studies: Urban (described in D34.1).***
- ***Route used in Naturalistic:***  
Free driving route. Each participant drove through their usual routes.

### Test procedures

- Controlled studies, FeDS and Nomadic system:

For controlled test, participants also have an ABA experimental design. They performed routes without ecoDriver system (baselines at the beginning and the end of the test period) and with the ecoDriver system (between baselines periods). Each participant performed the test with the same vehicle for a specific route. One driver performed two tests: one with the EV and other with the Scenic. Therefore, each participant run 8 eight times. These test were not run in the same day. The routes were randomized between the two vehicles. It was also randomized balanced if drivers drove first with EV or Scenic car. After baseline and treatment periods participants filled questionnaires in. The procedure for the controlled test is the next: the vehicle is positioned at the starting point of a path. He explained the nature of the test. Before each tour participant covers a questionnaire (Pre - baseline, pre-exposition, middle exposition and post-exposition.. In addition to the Nomadic study questionnaires were used after each run. It should be take into consideration that nomadic controlled test was only performed with EV

During the tour, in a tablet, you are marking traffic incidents on the route there according the information provided by the observer protocol.

- Naturalistic study:

The experimental design for naturalistic test was an ABA (after a baseline, drivers drove with the system and later there was again a baseline).

- Baseline1. The participant have not information about ecoDriving advices.
- Experimental Line 1. The participant have information about ecoDriving advices.
- Experimental Line 2. The participant have information about ecoDriving advices.
- Baseline 2. The participant have not information about ecoDriving advices.

## 1.8 IFSTTAR

### Introduction

In order to test how simple ecological driving assistances (EDAS) can impact efficiently the driving style, a light version of the full ecoDriver system has been designed specifically for nomadic systems. An Android application has been implemented, in order to be able to operate in different conditions depending on the available information.

Indeed, Android System has the possibility to connect to a vehicle OBD2 connector in order to access to some vehicle variables (such as speed, engine speed and throttle position). These inputs make it possible to use accurate algorithms similar to the ones of the full ecoDriver system, although different for technical reasons (output signals are similar but not computed the same way).

If such a connector is not available, only sensors from the phone itself are available, and crude versions of the ecoDriver algorithms needs to be used.

### Experimental design

The IFSTTAR study focus consist in estimating the effects of both versions of the Android application designed for nomadic devices: the one with access to OBDII information, and the one without. The second focus is to explore how these nomadic versions perform compared to the full ecoDriver system developed within the project.

The study design take all these goals into account and result in a rather complex experimental setup. The main set of data is collected through several (5 or 6 per subject) trips with and without the tested systems along the same route, and with the same experimental car (Clio III). Along this route, 30 drivers have tested the Androïd System with OBDII access. Additionally, the 10 of these drivers are also using it on the long term (2-3 months) with their own car following a naturalistic driving design (OBDII connector and HTC One phone are provided to the subjects).

The table below recalls the main features of the experiment.

Table 9: Main features of the IFSTTAR study.

VMC	1	2
Country	FR	FR
Partner	IFSTTAR	IFSTTAR
Type of vehicle	Car	Car
No of vehicle	10	2
veh model	Renault Clio III	Renault Clio III
type of engine	ICE (diesel or petrol)	ICE (petrol)
type of gearbox	Manual	Manual
ecoDriver system	Nomadic Android	Nomadic Android
Type of study	Naturalistic + Controlled	Controlled
exp format	A1-B-A1 A1: completely free from any eco-driving advices B: ecoDriver phase	A1-B
exp duration	2-3-1	2-3
Special focus	Safety in urban areas	Safety in urban areas
ADAS	None (subjects asked not to use)	None (subjects asked not to use)
onboard energy efficiency	-	-
data logging	CAN-logger + Android App logging	CAN-logger, front and rear radars, video + full system logging
incentives	free phone + subscription reimbursed, €200	€ 200
No of drivers	10	20
Selection criteria	Non-professional drivers without any eco-driving experience, recruited from the general public	Non-professional drivers without any eco-driving experience, recruited from the general public
criteria note	owners of a Renault Clio 3	
Traffic density	Low to congestion	Low to congestion
Traffic density note		off peak only
Routes	All	All
Landscape	Flat, hilly	Flat, hilly
Climate	Western/Atlantic European	Western/Atlantic European

The piloting test conducted at IFSTTAR were focused on both technical and experimental aspects. In the subsequent phase, the following steps are considered:

- The first set of tests aimed to check the technical functioning of the data collection systems in real driving situations. They should enable to identify potential problems of sensor calibration or drift and thus to establish the periodicity of maintenance procedures during the experiment

(especially the naturalistic driving part). They should also permit to validate the data collection procedure from data acquisition, data transmission to data storage.

- The second level of preliminary field test dealt mainly with the issue of assessing the usability and usage of the systems under study and of identifying the main critical issues associated with their use in real driving situations.
- The third level consists of testing the feasibility of the overall evaluation process from the selection of the participants through the data collection.

## Preparation and conduction

### Planned test route

Test plan has been organized around the same track as the one scheduled for the final experiment. This track is 25 km long, and mixes large urban conditions with inter-urban and motorway conditions. The whole route takes between 45min and 1h depending on traffic conditions.

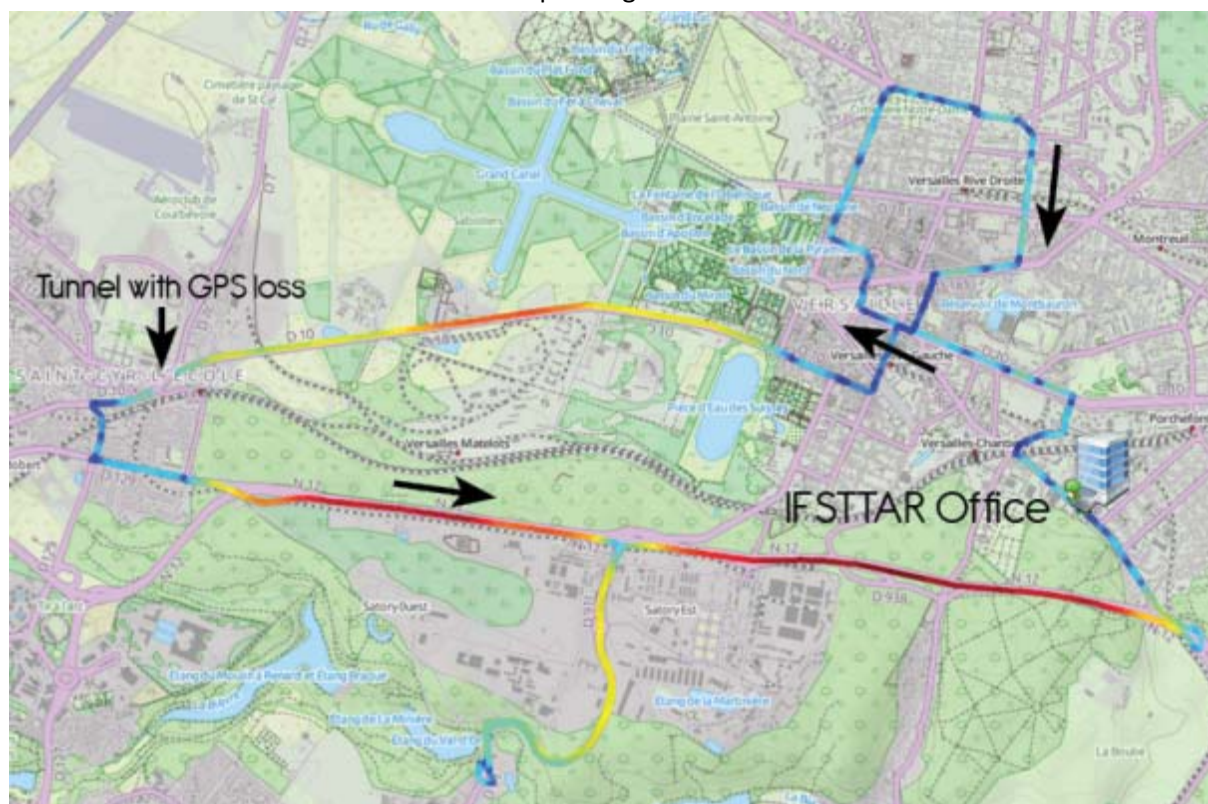


Figure 13: Experimental route with speed information.

During the technical preparation phase, a specific digital map of the route has been built to enrich Open Street Map (OSM) which is then used by the application, with very detailed information for the test route, and with usual OSM information for naturalistic drivers.

Several driving runs along this route allowed to test both the required time, the map accuracy, and the implications on the observer protocol (take care of specific infrastructure and potential dangers).

### Planned range of testing



It was planned that the ecoDriver pilot testing activity had to address the participant recruitment and briefing, and also the questionnaires issues (qualitative data collection). The testing plan at IFSTTAR therefore included technical aspects (sensors, logging, ecoDriver system), experimental (time for explanations and driving, margin between subjects, etc.), and human aspects (time for questionnaires and administrative documents, system explanations, etc.).

It was planned to drive at least ten times the final test route, with at least five different drivers, in order to obtain around 150 km of piloting data.

For the naturalistic driving part of the experiment, at least one week of data collection with the goal to collect 100km of data has been set up for a single testing driver.

### Data chain specification

The data chain used in the IFSTTAR experiments depends on the experimental groups (from naturalistic to controlled) and on the experimental phase (baseline or exposure). The nomadic group that is doing both naturalistic and controlled tests is logging data with a data logger connected on the vehicle CAN bus and to a GPS antenna and with a logging system in the android application during the exposure phase (second phase of trials after the baseline). The following figure presents the system and a log icon is added to each system producing a log file. To synthesize, the following log files are produced:

- Data logger Can File: .xml format with all signals listed in the corresponding .dbc file with a 10Hz acquisition frequency.
- Data logger GPS File: .txt file logging GPS signals.
- Android application: .csv and .xml are two different files format containing the equivalent list of signals (displayed events, computed signals (from SP2 RSG), GPS signals, OBD signals and map data information).

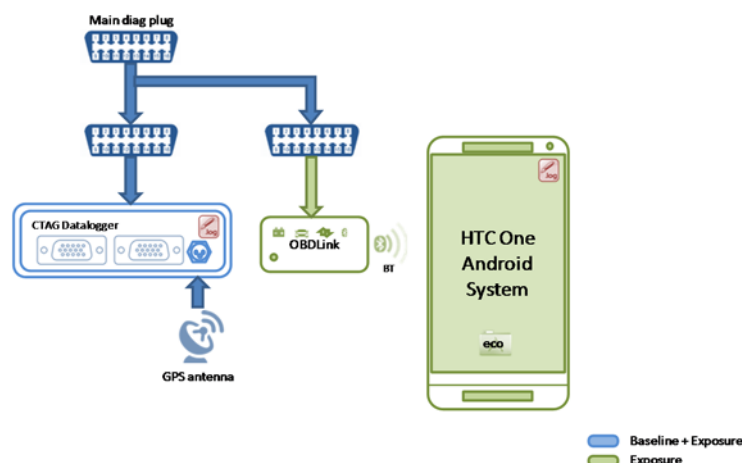


Figure 14: Experimental setup for Android application baseline in naturalistic study.

In the controlled tests (nomadic), a logging system is also included with the RTMaps software (Intempora) with CAN data access via a Vector Can Case interface. This enables the system to log additional sensors such as front and rear radar and Video images. Another log file is produced by the observer application where the observer notes all events that occurred during the trip (traffic light violation,...). The system also has a log feature for internal signals and events. The list of logs in the controlled study is the following:

- Data logger Can File: .xml format with all signals listed in the corresponding .dbc file with a 10Hz acquisition frequency.
- Data logger GPS File: .txt file logging GPS signals.
- Android application: .csv and .xml are two different files containing the equivalent list of signals (displayed events, computed signals (from SP2 RSG), GPS signals, OBD signals and map data information).
- Observer protocol log: .csv file logged with TapLog application (GPS position, timestamp, event). This file is directly converted to the ecoDriver Observer application standard (.xml file)
- RTMaps log: one .csv file per CAN address (to preserve data sampling, each sensor has its own frequency). One .csv file for front radar and one for rear radar (Auto Cruise AC20 in target mode) containing data information related to all detected preceding vehicles (absolute speed, relative speed, distance, azimuth,...). One .csv file for GPS signals according to NMEA standard. The front camera pictures are jpeg (named with the corresponding timestamp in ms) files gathered in a separate folder.

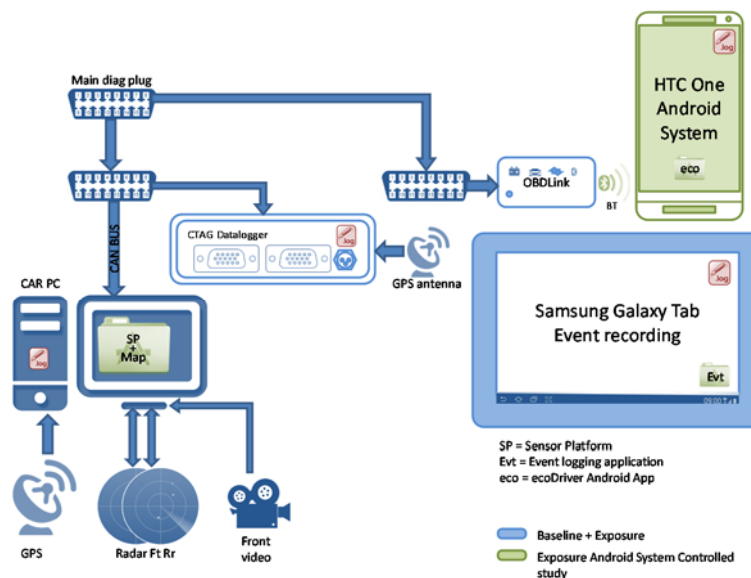


Figure 15: Experimental setup for Android application validation.

Data logger and Observer protocol application raw data are directly uploaded to the CTAG database and the signal processing and enrichment steps are directly done by CTAG. RTMaps files are processed internally at IFSTTAR using SAS software in order to perform signal interpolation that produce 1 Hz and 10 Hz data according to the common format. RTMaps files map data enrichment will be performed by IFSTTAR according to the CTAG requirements. Other log files are also converted to the common format as defined by CTAG and are then uploaded to the server. Only the camera pictures will be saved at IFSTTAR as it represents an important amount of data (several Go for each trip).

### System and data chain integration

The Android application can be used on any smartphone equipped with GPS and a data connection. The application works with a Bluetooth OBD2 dongle that needs to be paired to the smartphone before launching the application at first use.

### Application installation

An important step of the system integration is the application installation:

- Each participant had to create a Google Play Store account
- IFSTTAR added the participants to a Google group and sent them a link that all participants had to open from their phone.
- The application was then installed by clicking

### List of hardware integrated

All the following hardware has been integrated into one pilot vehicle:

- A smartphone with GPS, Bluetooth and data connection. The application has been developed on a HTC one and on a Samsung Galaxy S3.
- A specific phone holder to hold the phone.
- A lighter power supply. GPS and data connection could be very consuming and using a lighter power supply is necessary for long trips or several small trips in a row.
- A Bluetooth OBD2 dongle.

Finally the smartphone and hardware has been integrated into the test vehicle used for pilot testing



Figure 16: Left: Used Hardware; Right: Phone installed in the vehicle.

## 1.9 LEEDS

### Introduction

A version of the TomTom Telematics aftermarket ecoDriver system was designed specifically for the Leeds trials, which runs on the existing TomTom platform. The system will be installed in a fleet of 5 Volvo B5L hybrid buses and will be installed alongside an existing in-vehicle eco-driving assistance system, produced by Green Road. This additional system provides some rudimentary real-time feedback on aggressive driving and speeding behaviours in addition to post-trip scores and rankings. The in-trip feedback is provided by a series of three colour lights positioned above the driver's head.

The ecoDriver system designed for this trial will provide auditory feedback based on a fuel consumption comparison between the current driver and the average driver. An auditory alert will sound if the current driver's fuel consumption is worse than the average driver. This advice will be presented for a section of the bus route that the driver is highly familiar with.

A more precise description of the system tested is presented at chapter 3.

### Experimental design

This study looks at the impact of eco-driving feedback on fuel consumption in a hybrid vehicle fleet. Specifically, the feedback relates to driving uphill. The experiment duration will be 6 weeks; 2 weeks of baseline data collection followed by 2 weeks with the ecoDriver system switched on, followed by a final 2 weeks without the system. Drivers will be professional drivers within the fleet and will not be specifically recruited for the experiment. The table below lists features of the experimental design (Table 10):

Table 10: Features of the UK trial experimental design.

Country	UK
Partner	LEEDS
Type of vehicle	Bus
No. of vehicles	5
Vehicle model	Volvo V5L
Type of engine	Hybrid diesel and electric
Type of gearbox	Automatic
ecoDriver system	TomTom platform
Type of study	Naturalistic
Experiment format	A-B-A A: Rudimentary driver support device in operation B: ecoDriver experimental phase
Experiment duration	2-2-2
Special focus	Fuel consumption on gradients
ADAS	Existing Green Road system (subjects asked not to use)
Onboard energy efficiency	-
Data logging	TomTom LINK 510 + ecoPlus module (FMS gateway data feed)
Incentives	None
No. of drivers	30-50
Selection criteria	Professional driver without specific eco-driving system experience or training
Traffic density	Low to high
Routes	Urban
Landscape	Hilly
Climate	Western/Atlantic European

### Preparation and conduction

#### Planned test route



Following piloting, a test route was defined which satisfied a number of data collection criteria. The test route was selected to include a steep incline that was driven with high frequency by the hybrid bus fleet. The final route was a 2.0km long stretch of urban, dual-carriageway road (Figure 17). The total incline for the road section was 80m (average gradient = 4.0%). The route included four bus stops, with stopping frequency determined by time of day and passenger demand. This aspect of the design was not controlled nor was it factored into the fuel consumption calculations and subsequent advice produced by the ecoDriver system. Time to drive the route varied between 2 and 6 minutes. Individual driver experiences of this route varied depending on shift patterns. The planned test route can be driven up to 1050 times during a standard operating week. This is covered by the entire hybrid bus fleet, so it is hoped that the ecoDriver system buses can travel the route up to 150 times per week (300km).

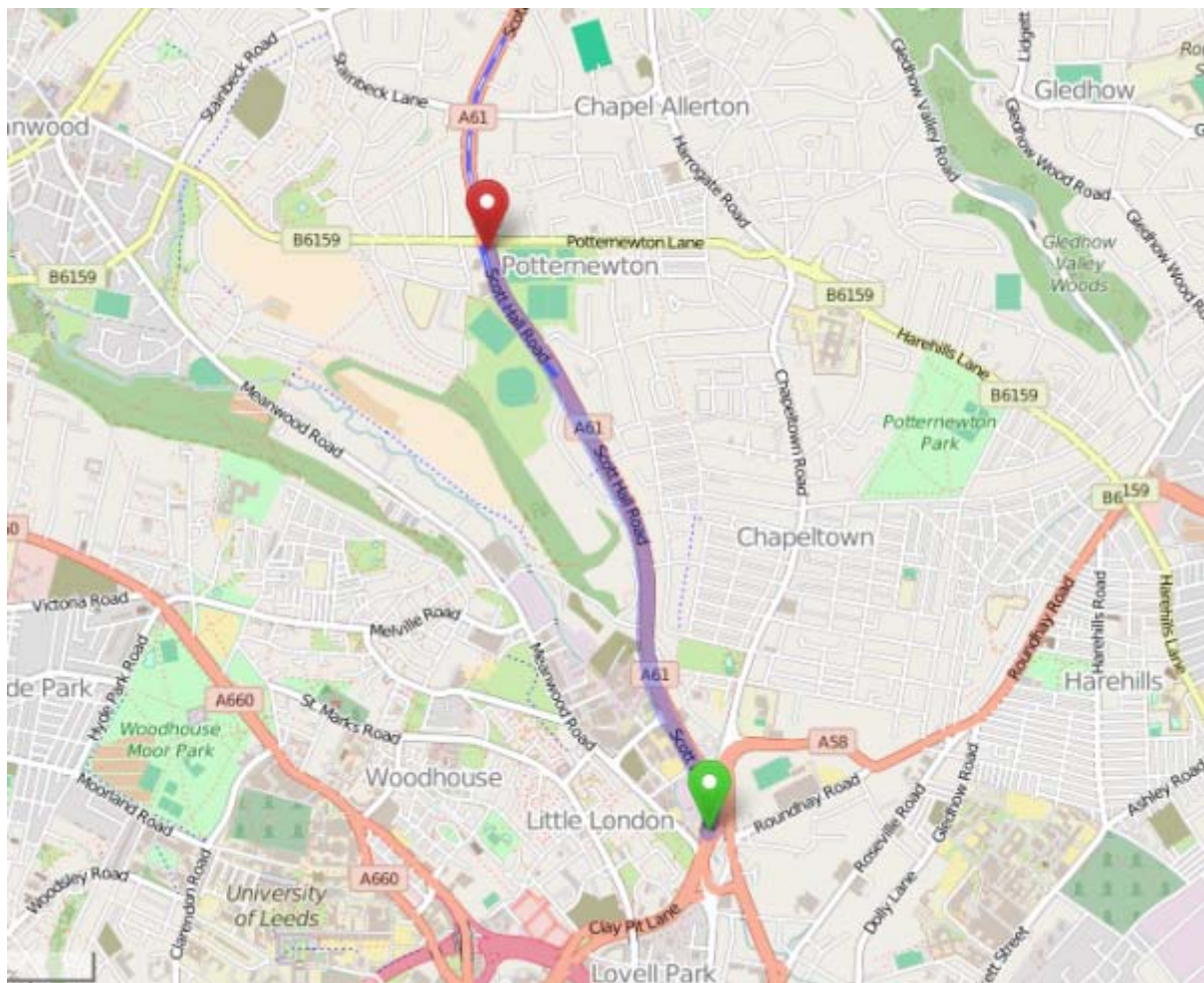


Figure 17: Experimental route Leeds [Source: OpenStreetMap].

### Procedure

Before the trial, all bus drivers will be briefed on the operation of the system and requested to make use of the advice provided by the system during the experimental phase. They will be requested to drive as normal during the baseline phase. Further guidance on how to adapt their behaviour in line with the system advice will be limited. Intervention from the experimental team will be restricted to troubleshooting during the trial, and is intended to allow the bus drivers to continue with their day-to-day work without additional workload being imposed by the ecoDriver experiment. There will be no incentives offered to the drivers, although they will be strongly encouraged to incorporate the ecoDriver system



advice into their driving, when it is available. Following completion of the trial, the driver roster will be available from the bus operator to enhance the quality of the subsequent data analysis.

#### Data collection

The following data were collected from the vehicle itself (Table 11). In addition, driver feedback regarding their experience with the system was collected via questionnaires after the testing phase.

Table 11: Leeds UK data collection.

INFORMATION		VMC DATA COLLECTION						
MEASURES IDENTIFICATION		DATA CHARACTERISTICS		DATA SOURCE				COMMENTS
ID	NAME	FREQ	RANGE	CAN	MAP	SENSOR	OTHER	
ME_01	Instantaneous consumption in kW (for electric vehicles)							No electric vehicles in our scope/fleet
	Fuel consumption (petrol/diesel)						FMS	unit: μ litres / frequency: 1Hz - TBC
ME_03	Distance driven						GPS	OK (possible data lag)
ME_04	Distance Headway (distance to the lead vehicle)							not available
ME_05	Engine status						FMS	
ME_06	Gear							NA
ME_07	Glance direcction							not available
ME_08	Outside temperature							not available
ME_09	rpms (revolutions)						FMS	OK
ME_10	Speed						GPS or FMS	OK (possible data lag)
ME_11	Speed limit				✓			OK
ME_12	Speed of the lead car							not available
ME_13	Accelerator pedal position							not available
ME_14	Brake pedal status (ON/OFF)							not available
ME_15	GPS position						GPS	OK
ME_16	Timestamp						GPS	1Hz frequency possible
ME_17	System active (Cruise Control, Speed Limiter,..)							NA

INFORMATION		VMC DATA COLLECTION						
MEASURES IDENTIFICATION		DATA CHARACTERISTICS		DATA SOURCE				COMMENTS
		FREQ	RANGE	CAN	MAP	SENSOR	OTHER	
ME_18	Road type (map info)				✓			OK
ME_19	Slope (map info)							not available
ME_20	Road condition (wet, dry, ice, fog...) (from Rain sensor and temperature (observer in controlled tests))							not available
ME_21	Traffic density(Front video (observer in controlled tests) or from a combination between car speed and speed limit and headway)							not available
ME_22	Front video							not available

## 2 Annex B: Situational variables definitions

Variable name in CTAG database	Short description
Road_type	Categorization of road types
Speed_limit	Categorization of speed limits
Slope_class	Categorization of slope
Curve_class	Categorization of curvature radius

### 2.1 Road\_type

<b>Definition</b>
<ul style="list-style-type: none"> <li>Urban comes from the map <ul style="list-style-type: none"> <li>« inCity »</li> <li>not binary, more complex. Urban flag available in all urban horizon data sets)</li> </ul> </li> <li>Motorway also, <ul style="list-style-type: none"> <li>« Highway » and « motorway »</li> <li>In the HERE maps, these flags always appear together when driving on motorways</li> </ul> </li> <li>The rest is inter-urban (rural)</li> </ul>
<b>Coding</b>
<ul style="list-style-type: none"> <li>999=NA</li> <li>1= "motorway"</li> <li>2= "urban"</li> <li>3= "rural"</li> <li>4= "2+1" (Specific to Sweden, if 2+1 is not part of the map data, VTI can provide road type as an additional measure in their vehicle data logs)</li> </ul>
<b>Responsible partners</b>
ALL

### 2.2 Speed\_limit

<b>Definition</b>
Map variable name: "SpeedLimit" The information value is the legal speed limit for this part of the road in km/h. Values 997, 998, and 999 mean no speed limit.
<b>Coding</b>
Database will contain the raw value (speed limit from the map), but analyses and result presentations will be limited to the following categories: <ul style="list-style-type: none"> <li>30-50-60-70-80-90-100-110-120-130</li> <li>0= no speed limit (Germany)</li> <li>999= missing value</li> </ul>
<b>Responsible partners</b>
IFSTTAR

## 2.3 Slope\_class

Definition
Coded directly from the map. Variable name "slope" (%)
Coding
<ul style="list-style-type: none"> <li>1=Downhill &lt;-3 (fall)</li> <li>2=Level -3 to 3</li> <li>35=Uphill &gt;3 (rise)</li> </ul>
References from relevant literature
<ul style="list-style-type: none"> <li>bus data Mangan, S.; Wang, J.; Wu, Q.</li> <li>Systems, Man and Cybernetics, 2003. IEEE International</li> <li>Conference on Volume 3, Issue , 5-8 Oct. 2003 Page(s): 2336 - 2341 vol.3</li> <li>Road Slope Estimation with Standard Truck Sensors Ken Johansson</li> </ul>
Responsible partners
Daimler, Leeds, IKA

## 2.4 Curve\_class

Definition
Map variable name: "radius" (m) Compute "curvature" ( $m^{-1}$ ) Compute average degree of curvature (ADC) [rad/km]
Coding
<ul style="list-style-type: none"> <li>1= Straight (<math>0 &lt; ADC &lt; 0.5</math>)</li> <li>2=Harmonic (<math>0.5 &lt; ADC &lt; 1</math>)</li> <li>3=Curvy (<math>ADC &gt; 1.25</math>)</li> </ul>
Responsible partners
Daimler, Leeds, IKA

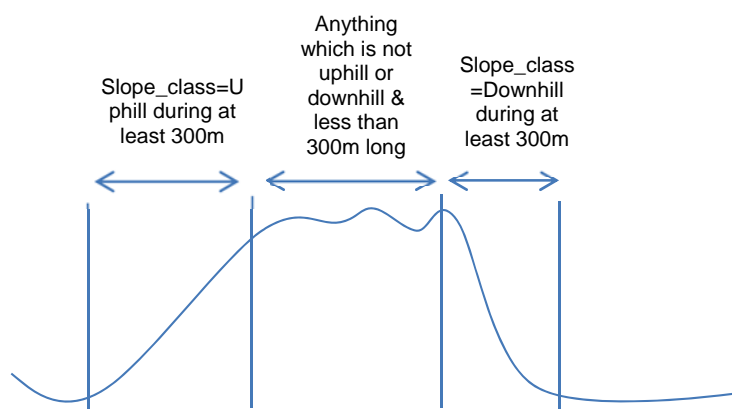
## 2.5 Crest

### Definition

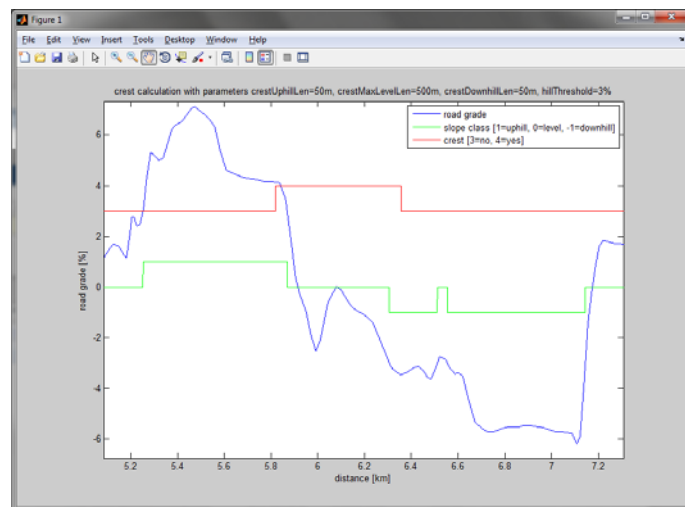
Derived from variable **Slope\_class**.

It is needed to identify the following sequences: Uphill-xxx-xxx-xxx-downhill

The full sequence is considered to be a crest



Crest example with almost 500m flat part, Daimler system was active here, giving coasting advice:



### Coding

- 0=no crest
- 1=crest

### Responsible partners

Daimler, Leeds, IKA



## 3 Annex C: Segment definitions

### 3.1 Choice of parameter values for segment definitions

Segments have been defined in the data collected from the trials in order to statistically analyze the operation of the ecoDriver systems and its influence on the driving behaviour in certain situations. The system operation depends on many factors like the vehicle, terrain and the speed chosen by the driver. Not all of these factors can be taken into account for the segment definitions. The parameters chosen for the segment definitions have been chosen beforehand without much experience with the system operation in the real world. Therefore, analyses have been done to verify the validity of the chosen parameters and to change some of them. The results of these analyses are shown in this chapter.

#### 3.1.1 Length of sharp curve entry and exit

The ecoDriver system becomes active when the driver approaches a sharp curve, giving coasting advice. Likewise, the system suggests avoiding sharp acceleration when exiting the sharp curve. Therefore, average speed and acceleration is evaluated for a certain length of road before and after a sharp curve. The length for these segments was chosen to be 200m.

To validate the chosen length of 200m and to show the effect of the ecoDriver system on the speed profile for a part of the controlled Daimler study, the average local vehicle speed was calculated for increments of 5m along the road separately for baseline trips, trips with ecoDriver GUI and trips with ecoDriver GUI and a haptic accelerator pedal that vibrates when coasting advice is active. This is shown in Figure 18 together with the system activity (coasting advice) and a map fragment showing the location. Coasting advice can be either inactive (0) or active (1) for any trip at any location. Coasting advice is given if the vehicle speed is high and the target speed for an upcoming curve can be reached by starting to coast. If the vehicle speed is lower at the same location, coasting advice might still be inactive until the vehicle comes closer to the curve. In the graph, the average coasting advice activity is shown as a number between 20 and 30 so that the same y-axis can be used with the vehicle speeds. A value of 20 means that coasting advice was never active in any of the trips with GUI or GUI + haptic. A value of 30 means that coasting advice was always active at that location.

The first sharp curve in the graph is at a location of approximately 7.45 km where the minimum speed is driven. Coasting advice starts becoming active at about 7.3 km, i.e. 150m before. It can also be seen that the average speed with GUI (red line) is somewhat lower in the section 7.3 to 7.45 km than the baseline case (black line) and that the haptic pedal (green line) further reduces the average speed. A similar effect can be seen for the sharp curve starting at 7.75 km where coasting advice and a reduced speed can be seen 200m before, i.e. starting at 7.55 km.

This shows that the 200m section length is a reasonable value.

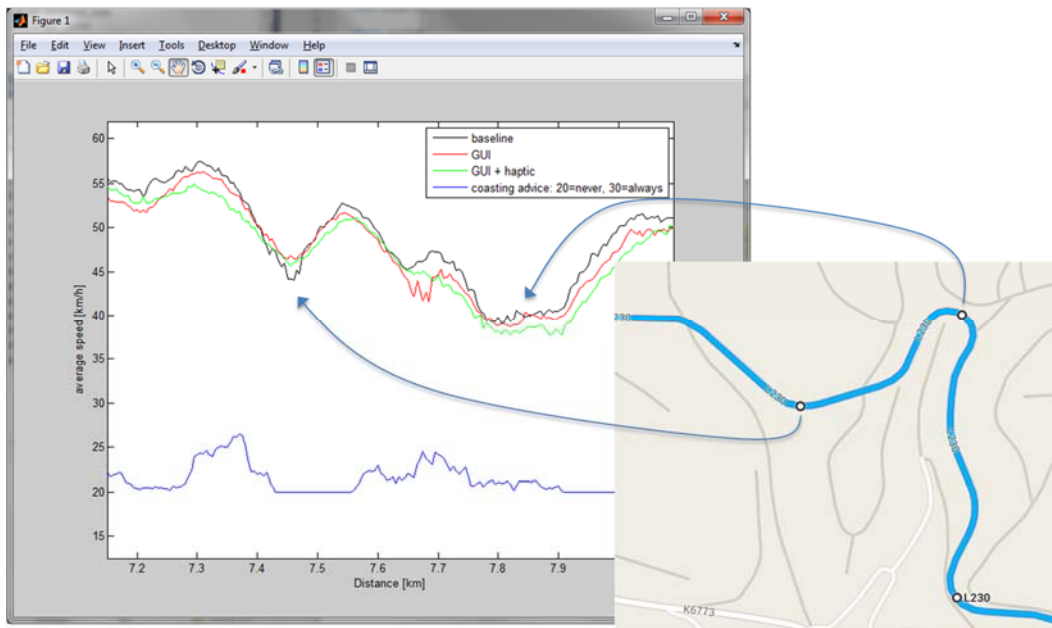


Figure 18: Daimler sharp curve entry example

### 3.1.2 Overlapping sharp curve entry and exit segments

After calculating the sharp curve entry and exit segments, it could be seen in the database that the segments frequently overlap. As the sharp curve condition is checked for each data point, there are cases where this condition is true only for a few meters, becomes false again as the curvature is slightly smaller and becomes true again a few meters later. It would result in having the same data points in the statistics for sharp curve entry multiple times. This is to be avoided.

When several overlapping sharp curve entries are found, all but the first of these segments are deleted from the database. Only the first sharp curve entry is uninfluenced by another curve in the vicinity and gives the best opportunity to study the effect of the system.

Likewise, only the last sharp curve exit segment is kept in the database out of a sequence of overlapping sharp curve exits. Again, this is the one that is not influenced by another curve.

In summary, this is how overlapping sharp curve entries and exits are handled:

- Only use the first curve entry when overlapping
- Only use the last curve exit when overlapping

### 3.1.3 Crest

In the original definition of a crest segment, a crest consists of an uphill section of at least 300m followed by a level section of at most 300m and a downhill section of at least 300m.

With this setting, however, only a few crests were found in the data although (in the case of the Daimler system), the system gave crest-related coasting advice a lot more frequently. It was found that a setting of a reduced 50m of minimum uphill and downhill section resulted in better results that are more in-line with the system operation. The maximum length of 300m for the level section was left as is.

To summarize, the new definition of a crest segment is:

- At least 50m uphill (slope > +3%)
- At most 300m level (-3% ≤ slope ≤ +3%)
- At least 50m downhill (slope < -3%)

## 3.2 Definitions used in ecoDriver data analysis

Segment name in common database	Short description
<b>Freedriving</b>	Identification of sections while driving unconstrained
<b>Freedriving_op</b>	Sections where free driving is identified using the observer protocol.
<b>Cruising</b>	Vehicle is cruising
<b>Stationary</b>	Vehicle is not moving
<b>Acceleration after being stationary</b>	
<b>Accel_phase</b>	Vehicle is accelerating after a stop
<b>Manoeuvre_direction</b>	
<b>Junction_signalisation</b>	
<b>Signalised_junction</b>	
<b>Non_signalised_junction</b>	
<b>Intersection_priority</b>	
<b>Intersection_segment</b>	Vehicle is in the vicinity of an intersection
<b>Sharp curve</b>	
<b>sharp curve entry</b>	
<b>sharp curve exit</b>	
<b>Zebra_segment</b>	Vehicle is in the vicinity of a zebra
<b>Speedbump_segment</b>	Vehicle is in the vicinity of a speedbump
<b>Trafficlight_segment</b>	
<b>Speedlimit_change</b>	The area around the position where the speed limit changes along the driven route.

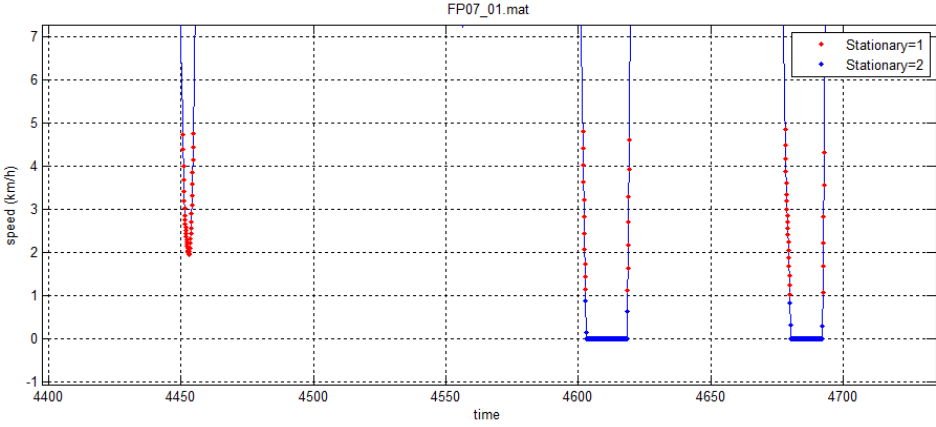
### 3.2.1 Freedriving

Definition
<p>Identification of sections while driving unconstrained.</p> <p>Free driving when:</p> <ul style="list-style-type: none"> <li>• (Time Headway &gt; x sec) or (Relative ahead vehicle speed is higher than y km/h (i.e., gap is widening)) or (Time headway = infinity or missing)</li> <li>• x default value : 6 secs</li> <li>• y default value : 10 km/h</li> </ul>
Coding
<ul style="list-style-type: none"> <li>• 0=not free driving (some constraint not identified precisely, and therefore not suitable for analysis)</li> <li>• 1= free driving</li> </ul>
Responsible partners
Daimler, TNO, BMW

### 3.2.2 Freediving\_op

Definition
Sections where free driving is identified <u>using the observer protocol</u> .
Coding
<ul style="list-style-type: none"> <li>0=not free driving (some constraint not identified precisely, and therefore not suitable for analysis)</li> <li>1= free driving</li> </ul>
Responsible partners
ALL

### 3.2.3 Stationary

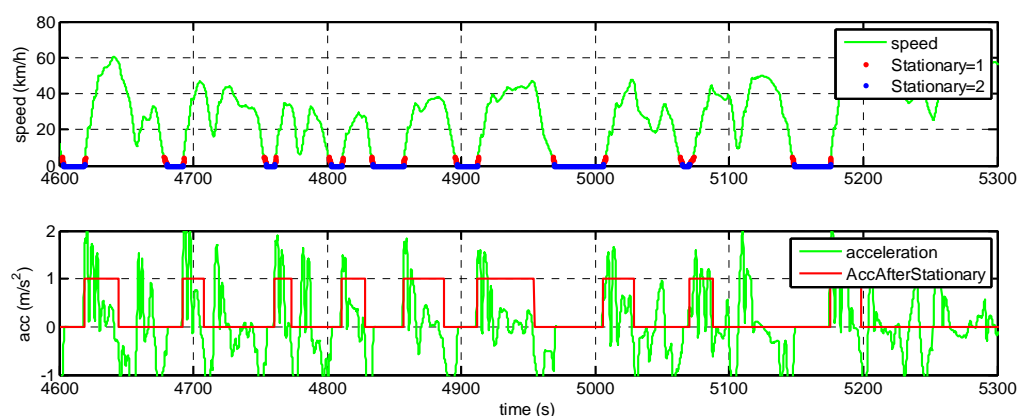
Definition
<p>Identifies situations where the vehicle is stopped.</p> <p>Two levels of stationary are distinguished. They are identified in a two-step approach. First, find all consecutive segment where Speed &lt; x1 km/h &amp; stopped more than y seconds.</p> <ul style="list-style-type: none"> <li>X1 default parameter value : 5 km/h</li> <li>y default parameter value: 3 secs.</li> </ul> <p>Step 1: all samples that fulfil this criterion are assigned with Stationary level 1.</p> <p>Step 2: Stationary level 2 is assigned when</p> <ul style="list-style-type: none"> <li>Speed &lt; x2 km/h</li> <li>x2 default = 1 km/h</li> </ul> <p>Note: logical application of this segment variable will be 'Stationary==2' or 'Stationary&gt;=1'.</p>

Coding
<ul style="list-style-type: none"> <li>0=moving</li> <li>1=stationary (loose)</li> <li>2= stationary (strict)</li> </ul>
Responsible partners
Daimler, TNO, BMW

### 3.2.4 Acceleration after being stationary

#### Definition

'acceleration\_after\_stationary' is a flag that is derived from Is Stationary and from the acceleration measure (smoothed with the Savitzky-Golay filter). See the next figure for an illustration.

- Initially, acceleration\_after\_stationary is 0 by default.
- A transition of 0 to 1 of acceleration\_after\_stationary occurs when Stationary changes from equal to 2 ('stationary, strict') to unequal to 2.
- After that, a transition of 1 back to 0 occurs when:
  - (acceleration < -0.6 m/s<sup>2</sup>) OR (Stationary==2)



#### Coding

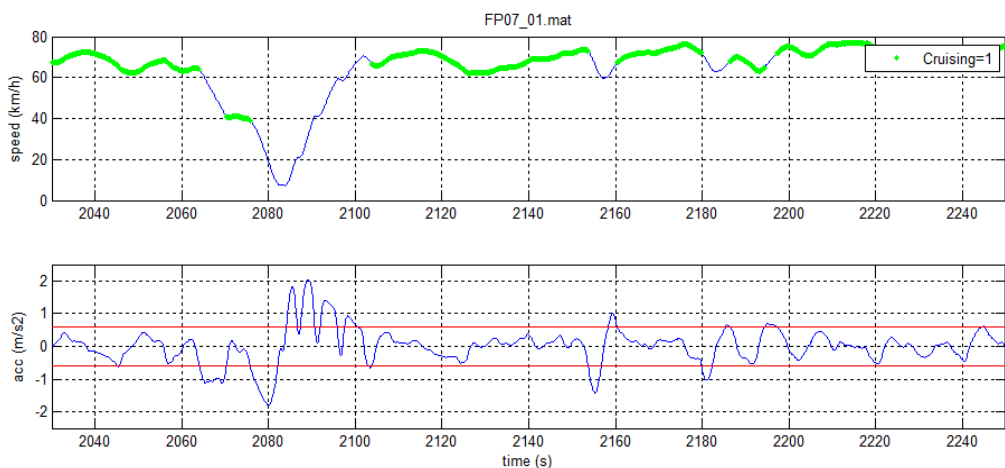
- 0=not 'acceleration\_after\_stationary'
- 1= 'acceleration\_after\_stationary'

#### Responsible partners

TNO



### 3.3 Cruising

Definition
<p>Identifies sections where the driver is in a cruise mode.</p> <p>Cruising situation when:</p> <ul style="list-style-type: none"> <li>• (Stationary == 0) AND ( Abs(acceleration) &lt; a m/s<sup>2</sup>) during a period of at least y seconds</li> <li>• a default value : 0.6 m/s<sup>2</sup></li> <li>• y default value : 5 secs</li> </ul>

Coding
<ul style="list-style-type: none"> <li>• 0=no cruising</li> <li>• 1=cruising</li> </ul>
Responsible partners
Daimler, TNO, BMW

#### 3.3.1 Intersection\_segment

Definition
<p>Define a geographical area where an intersection is present and influence driving behaviour.</p> <p>Defined as:</p> <ul style="list-style-type: none"> <li>• X m before and after an intersection position (GPS).</li> <li>• X default value = 500 m.</li> </ul>
Coding
<ul style="list-style-type: none"> <li>• 0 no intersection</li> <li>• 1 before the intersection (300 m)</li> <li>• 2 Inside intersection (start &amp; end)</li> <li>• 3 after the intersection (350m)</li> </ul>
Responsible partners
Daimler, Leeds, IKA

### 3.3.2 Sharp\_curve

Definition
<p>A sharp curve is a section where the maximum safe speed of the vehicle, <math>V_{safe}</math>, is smaller than the legal speed limit, <math>V_{legal}</math>. When there is no speed limit (German Autobahn), use 130 km/h as the value of <math>V_{legal}</math>.</p> <p><math>V_{safe}</math> is calculated with the following formula taken from the VE3 algorithm:</p> <p> <math>\mu = 1.1</math>; % [-] Friction coefficient  <math>g = 9.81</math>; % [m/s<sup>2</sup>] Gravity  <math>SF = 0.7</math>; % [-] Safety factor  <math>V_{safe} = SF * \sqrt{\mu * g * CurveRadius}</math>; </p>
Coding
<ul style="list-style-type: none"> <li>0=no sharp curve</li> <li>1=sharp curve</li> </ul>
Responsible partners
Daimler, Leeds, IKA

### 3.3.3 Sharp\_curve\_entry

Definition
<p>The sharp curve section plus the section 200 m before.</p> <p>This is where the curve ahead and possibly the ecoDriver system should influence the deceleration behaviour of the driver.</p>
Coding
<ul style="list-style-type: none"> <li>0=no sharp curve entry</li> <li>1=sharp curve entry</li> </ul>
Responsible partners
Daimler, Leeds, IKA

### 3.3.4 Sharp\_curve\_exit

Definition
<p>The sharp curve section plus the section 200 m after it.</p> <p>This is where the driver is expected to accelerate and the acceleration behaviour can be influenced by the ecoDriver system.</p>
Coding
<ul style="list-style-type: none"> <li>0=no sharp curve exit</li> <li>1=sharp curve exit</li> </ul>
Responsible partners
Daimler, Leeds, IKA

## 3.3.5 Zebra\_segment

Definition
<p>Define a geographical area where a zebra is present and influence driving behaviour.</p> <ul style="list-style-type: none"> <li>Defined as X m before and after a zebra crossing position (SV <b>zebra</b>).</li> <li>X default value=150m</li> </ul>
Coding
<ul style="list-style-type: none"> <li>0 no zebra</li> <li>1 before zebra (50 meters)</li> <li>2 Zebra</li> <li>3 after zebra (50 m)</li> </ul>
Responsible partners
Daimler, Leeds, IKA

## 3.3.6 Speedbump\_segment

Definition
<p>Define a geographical area where a speed bump is present and influence driving behaviour.</p> <ul style="list-style-type: none"> <li>Defined as 150m before and after a speed bump position (SV <b>speedbump</b>).</li> <li>X default value=150m</li> </ul>
Coding
<ul style="list-style-type: none"> <li>0 no speedbump</li> <li>1 before speedbump</li> <li>2 Speedbump</li> <li>3 after speedbump</li> </ul>
Responsible partners
Daimler, Leeds, IKA

## 3.3.7 Trafficlight\_segment

Definition
<p>Define a geographical area where a traffic light is present and influence driving behaviour.</p> <ul style="list-style-type: none"> <li>Defined as Xm before and after a traffic light position (SV <b>Trafficlight</b>).</li> <li>X default value=150m</li> </ul>
Coding
<p>Final coding in database:</p> <ul style="list-style-type: none"> <li>0 no traffic light</li> <li>1 before traffic light</li> <li>2 traffic light</li> <li>3 after traffic light</li> </ul>
Responsible partners
ALL

### 3.3.8 Speedlimit\_change

<p>The area around the position where the speed limit changes along the driven route.</p> <ul style="list-style-type: none"><li>• Defined as Xm before and after a speed limit change.</li><li>• X default value=150m</li></ul>
<b>Coding</b>
<p>Final coding in database:</p> <ul style="list-style-type: none"><li>• 0 no speed limit change</li><li>• 1 speed limit decreasing (changing from a higher to a lower value)</li><li>• 2 speed limit increasing (changing from a lower to a higher value)</li></ul>
<b>Responsible partners</b>
Daimler, Leeds, IKA

## 4 Annex D: Events definitions

Event name in database	Short description
Overspeeding	Vehicle is over speeding
Redlight_violation	Red traffic light violation
Overtaking	Vehicle is overtaking

### 4.1 Overspeeding

<b>Definition</b>
<ul style="list-style-type: none"> <li>Speed limit is exceeded by at least X1 km/h (<math>\max(\text{speed-limit}) &gt; X1 \text{ km/h}</math>) &amp; (Speed limit is exceeded during at least X2 seconds)</li> <li>X1 default value : 4 km/h</li> <li>X2 default value : 10 secs</li> </ul>
<b>Coding</b>
<ul style="list-style-type: none"> <li>0=speed in line with the actual limitation</li> <li>1= overspeeding</li> </ul>
<b>Responsible partners</b>
ALL

### 4.2 Redlight\_violation

<b>Definition</b>
<u>Defined by Observer protocol</u>
<b>Coding</b>
<ul style="list-style-type: none"> <li>0=nothing related to traffic light</li> <li>1= redlight violation</li> </ul>
<b>Responsible partners</b>
ALL

### 4.3 Overtaking

<b>Definition</b>
<u>Defined by Observer protocol</u>
Do not consider motorway overtaking
<b>Coding</b>
<ul style="list-style-type: none"> <li>0=no overtaking</li> <li>1=overtaking</li> </ul>
<b>Responsible partners</b>
ALL



## 5 Annex E: Detailed results per hypothesis (Energy)

### 5.1 Hypothesis 1: Impact of systems on fuel consumption and CO<sub>2</sub> emission

#### Hypothesis analysis summary table

Hypothesis formulations:

Using ecoDriver systems will reduce the average fuel consumption (l/100km)

Using ecoDriver system will reduce the average CO<sub>2</sub> emissions

1. Using an ecoDriver system, the average fuel consumption and CO<sub>2</sub> emissions will be reduced. [Type A]
2. Using an embedded ecoDriver system (Emb.), the average fuel consumption and CO<sub>2</sub> emissions will be reduced. [Type B]
3. Using the full ecoDriver system (FeDS), the average fuel consumption and CO<sub>2</sub> emissions will be reduced. [Type C]
4. Using the ecoDriver application (App), the average fuel consumption and CO<sub>2</sub> emissions will be reduced. [Type D]
5. Using a haptic ecoDriver system, the average fuel consumption and CO<sub>2</sub> emissions will be reduced. [Type E]

#### Performance indicator (PI):

Percentage of fuel consumption reduction/increasing with respect to the average fuel consumption of the same driver in the same road type during baseline. Acquired consumption was used where available, and modelled consumption was used for the sites where acquired consumption was not available.

#### Data reduction method:

500 m sections

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced. Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment (Type A dataset) For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline</li> <li>• Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id
<b>Baseline Emb. vs Embedded (Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_embedded</li> <li>• Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

## Hypothesis analysis summary table

<b>Baseline FeDS vs FeDS (Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id
<b>Baseline App vs App (Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id
<b>Non-haptic vs Haptic (Type E dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 5.1.1 Controlled studies

#### 5.1.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterwhaite approximation for the degrees of freedom.

Table 12: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	63132.2	63132.2	1	31670.4	36.7	<0.001
road_type	68652.2	34326.1	2	31171.6	20.0	<0.001
Main_effect:road_type	19632.3	9816.1	2	34204.1	5.7	0.003

Table 13: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.89	-0.81	2.59	0.306
Treatment	2.58	0.88	4.28	0.003
Rural	1.07	-0.72	2.86	0.240
Motorway	5.05	2.39	7.72	<0.001
Treatment:Rural	3.18	1.05	5.31	0.003

<b>Treatment:Motorway</b>	-0.37	-3.41	2.67	0.813
<b>Random part</b>	<b>N</b>			
<b>Driver_id</b>	114			
<b>Number of observations</b>	34271			

Reference of the model is baseline during urban driving condition. The estimated effect is the percentage reduction in fuel consumption when current condition is compared to the reference.

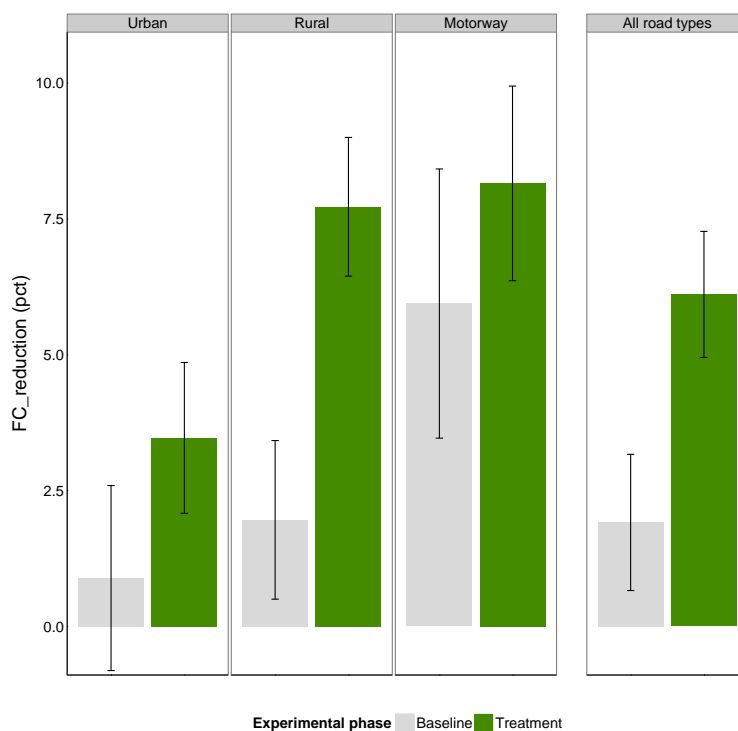


Figure 19: model based average values of percentage of fuel consumption reduction for fixed effects.

Table 14 Percentage of fuel consumption reduction for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
<b>Urban</b>	0.89	3.47	-2.58	0.032
<b>Rural</b>	1.96	7.72	-5.76	<0.001
<b>Motorway</b>	5.94	8.15	-2.21	0.510
<b>All road types</b>	1.91	6.11	-4.20	<0.001

**Preliminary conclusions:**

Both treatment and road type and also their interaction have a significant impact on the considered PI (percentage of fuel saved); it means that treatment has a significant impact on the considered PI, with the impact varying significantly with different road types.

The treatment (i.e. ecoDriver) increases significantly the percentage of fuel saved compared to baseline and percentage of fuel saved is around 2.6% in urban, 5.8% in rural and 2% in motorway roads, in average on all chunk is 4%. The difference between baseline and treatment is significant globally and both on urban and rural roads. In motorway the impact is not significant even if the average saving is similar to the urban condition and this is due mainly to the smaller sample (16% of total sample) and higher dispersion of data in motorway condition.

The ecoDriver systems positive impact is increased when driving on rural roads compared to urban roads and this difference is around 3.2% of additional saving.

## 5.1.1.2 Type B: Baseline embedded vs embedded

Table 15: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	64404.3	64404.3	1	29159.1	36.1	<0.001
road_type	68308.3	34154.2	2	28403.4	19.2	<0.001
Main_effect:road_type	16321.1	8160.5	2	29825.9	4.6	0.010

Table 16: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.34	-0.83	3.51	0.227
Embedded	2.98	1.02	4.95	0.003
Rural	1.49	-0.67	3.66	0.177
Motorway	5.55	2.71	8.39	<0.001
Embedded:Rural	3.05	0.57	5.53	0.016
Embedded:Motorway	-0.75	-3.98	2.48	0.650
Random part	N			
Driver_id	74			
Number of observations	29839			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

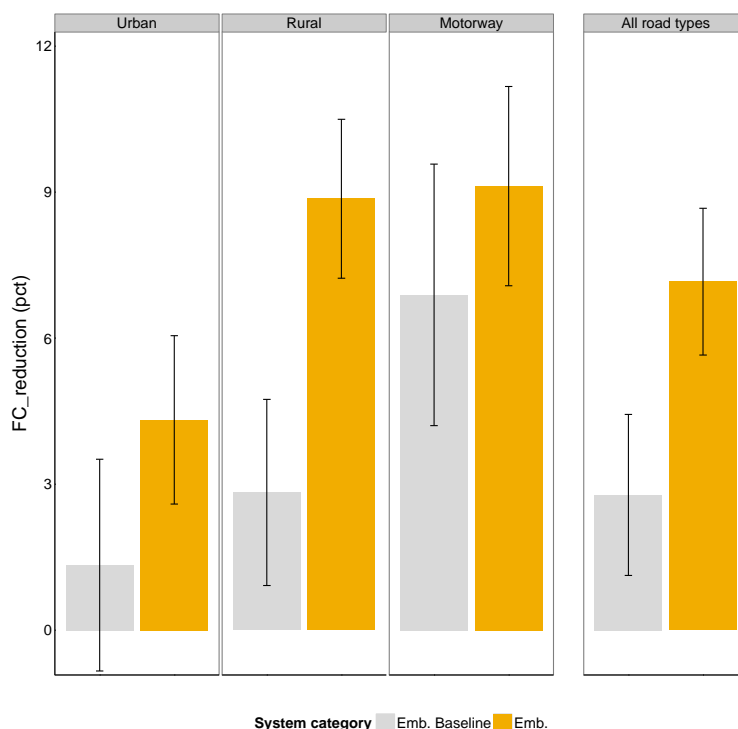


Figure 20: model based average values of percentage of fuel consumption reduction for fixed effects.

Table 17 Percentage of fuel consumption reduction for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates			Tukey multiple comparisons significance test
	Baseline	Embedded	Difference (B-E)	
Urban	1.34	4.32	-2.98	0.032
Rural	2.83	8.86	-6.03	<0.001
Motorway	6.89	9.12	-2.24	0.520
All road types	2.78	7.16	-4.38	<0.001

#### Preliminary conclusions:

Both treatment and road type and also their interaction have a significant impact on the considered PI (percentage of fuel saved); it means that treatment has a significant impact on the considered PI, with the impact varying significantly with different road types.

The treatment condition increases significantly the percentage of fuel saved compared to baseline and percentage of fuel saved is around 3.0% in urban, 6.0% in rural and 2.2% in motorway roads, globally 4.4%. The difference between baseline and treatment is significant globally and both on urban and rural roads. In motorway the impact is not significant even if the average saving is higher than in urban condition and this is due mainly to the smaller sample and higher dispersion of data in motorway condition. The embedded ecoDriver systems positive impact is increased when driving on rural roads compared to urban roads and this difference is around 3.1% of additional saving.



## 5.1.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 18: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	2376.1	2376.1	1	13174.4	2.1	0.144
road_type	26469.6	13234.8	2	12917.2	11.9	<0.001
Main_effect:road_type	6983.8	3491.9	2	13935.3	3.1	0.043

Table 19: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.73	-2.01	3.47	0.602
FeDS	-1.28	-3.84	1.29	0.329
Rural	-0.20	-2.76	2.37	0.881
Motorway	2.86	0.02	5.70	0.049
FeDS:Rural	3.93	0.86	7.01	0.012
FeDS:Motorway	2.80	-0.55	6.16	0.102
Random part	N			
Driver_id	30			
Number of observations	13946			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

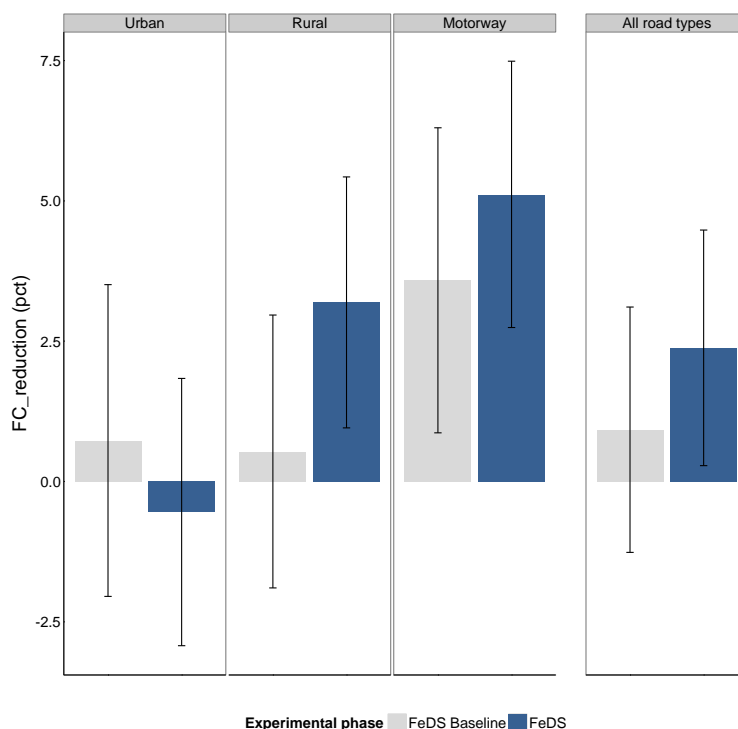


Figure 21: model based average values of percentage of fuel consumption reduction for fixed effects.

Table 20 Percentage of fuel consumption reduction for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	0.73	-0.54	1.28	0.923
Rural	0.54	3.19	-2.66	0.035
Motorway	3.59	5.11	-1.53	0.746
All road types	0.92	2.38	-1.46	0.022

#### Preliminary conclusions:

The impact of the treatment is not significant, whereas the additional impact of road type is significant. The FeDS system have a significant impact on road type with a saving of 2.7%; and globally a significant impact of 1,5%. In rural roads and in motorway the impact is not significant but it must be considered also that the sample is lower than in other considered comparisons.

## 5.1.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 21: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	5602.2	5602.2	1	4432.3	4.3	0.038
road_type	913.3	913.3	1	4432.3	0.7	0.402
Main_effect:road_type	658.3	658.3	1	4432.3	0.5	0.476

Table 22: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	-0.13	-2.42	2.15	0.908
App	1.54	-1.95	5.04	0.387
Rural	0.14	-2.74	3.03	0.922
App:Rural	1.61	-2.82	6.04	0.476
Random part	N			
Driver_id	40			
Number of observations	4432			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

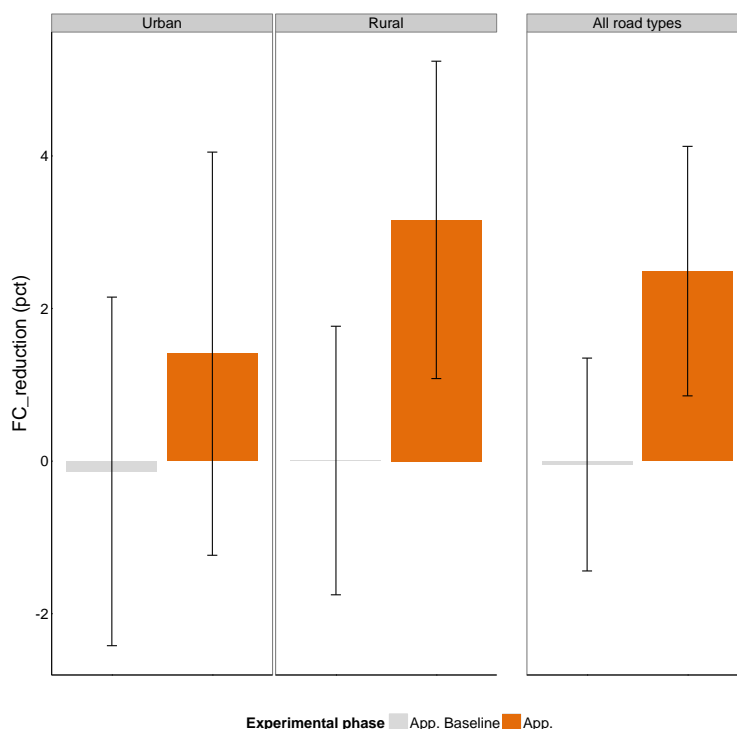


Figure 22: model based average values of percentage of fuel consumption reduction for fixed effects.

Table 23 Percentage of fuel consumption reduction for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates			Tukey multiple comparisons significance test
	Baseline	App	Difference (B-A)	
Urban	-0.13	1.41	-1.54	0.821
Rural	0.01	3.16	-3.15	0.104
Motorway	NA	NA	NA	NA
All road types	-0.04	2.49	-2.54	0.021

#### Preliminary conclusions:

The treatment is generally considered significant by the ANOVA tables and globally the impact of this system is significant with an average fuel saving of 2.5%. The impact is also at limit of 90% of significance in rural roads with 3.1% of fuel saving.

It must be also taken into account that the sample for this system is very small (only one site).

## 5.1.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 24: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	9086.7	9086.7	1	4613.7	2.9	0.086
road_type	56820.5	56820.5	1	4992.3	18.4	<0.001
Main_effect:road_type	22.5	22.5	1	5408.2	0.0	0.932

Table 25: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	2.80	-2.06	7.67	0.259
Haptic	3.12	-2.20	8.43	0.250
Rural	7.52	1.95	13.09	0.008
Haptic:Rural	-0.29	-6.89	6.32	0.932
Random part	N			
Driver_id	36			
Number of observations	5434			

Table 26: Percentage of fuel consumption reduction for the different systems and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	2.80	5.92	-3.12	0.653
Rural	10.32	13.15	-2.83	0.519
Motorway	NA	NA	NA	NA
All road types	7.80	10.53	-2.73	0.104

**Preliminary conclusions:**

The impact of haptic pedal is not significant in this analysis, where it is highlighted only the differences between urban and rural in non-haptic condition. Globally the impact of the system is estimated 2.7% and it is at limit of 90% of statistical significance.

This result is probably due also to the small sample (only 1 car and 1 truck have the haptic pedal) and to the high variability in consumption data in chunks. In fact, if the total trip consumption or sum of consumption of each trip for road type is considered in the analysis, the additional percentage of fuel saving is similar to the percentage obtained for chunk analysis (3.2%) and it is statistically significant ( $\alpha=0.001$ ).



### 5.1.2 Naturalistic studies

#### 5.1.2.1 TypeA : Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 27: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	6735.2	6735.2	1	19646.8	4.3	0.039
road_type	195178.4	97589.2	2	19578.2	62.0	<0.001
Main_effect:road_type	6763.0	3381.5	2	19781.0	2.1	0.117

Table 28: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	-10.85	-15.57	-6.14	<0.001
Treatment	-1.57	-3.67	0.52	0.142
Rural	-0.46	-2.54	1.62	0.666
Motorway	6.03	4.07	7.99	<0.001
Treatment:Rural	-0.92	-3.85	2.02	0.541
Treatment:Motorway	1.87	-0.82	4.57	0.173
Random part	N			
Driver_id	20			
Number of observations	19788			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

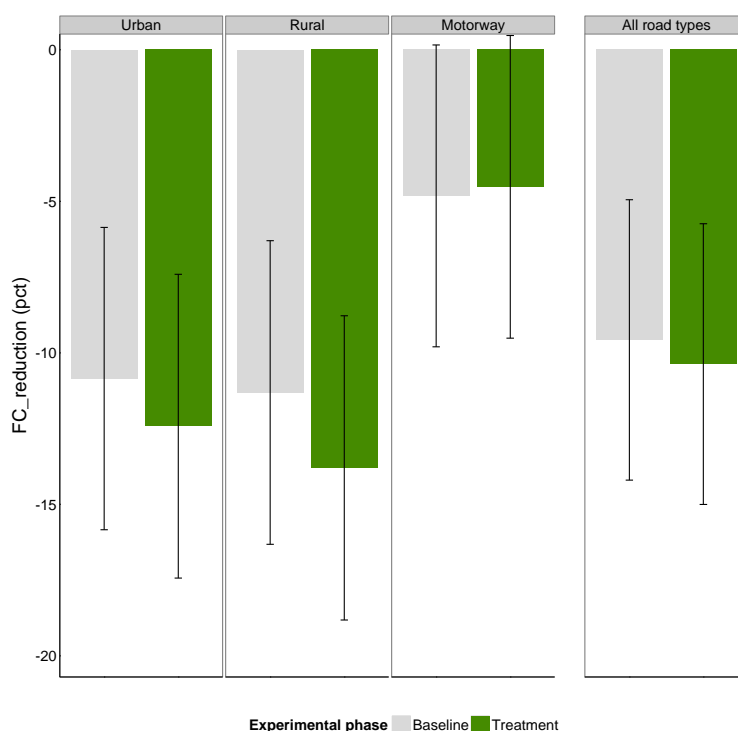


Figure 23: model based average values of percentage of fuel consumption reduction for fixed effects.

Table 29 Percentage of fuel consumption reduction for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates			Tukey multiple comparisons significance test
	Baseline	Treatment	Difference (B-T)	
Urban	-10.85	-12.42	1.57	0.682
Rural	-11.31	-13.80	2.49	0.211
Motorway	-4.82	-4.52	-0.30	0.999
All road types	-9.57	-10.37	0.80	0.178

#### Preliminary conclusions:

Even if Anova table highlights a globally significant impact for the main effect, in single comparisons significant results can't be highlighted.

Probably it is due also to high variability of data.

### 5.1.3 Results summary

Table 30: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-2.58	-2.98	1.28 (N.S.)	-1.54 (N.S.)	-3.12 (N.S.)	1.57 (N.S.)
Rural	-5.76	-6.03	-2.66	-3.15 (N.S.)	-2.83 (N.S.)	2.49 (N.S.)
Motorway	-2.21 (N.S.)	-2.24 (N.S.)	-1.53 (N.S.)	-	-	-0.3 (N.S.)
All road types	-4.2	-4.38	-1.46	-2.54	-2.73 (N.S.)	0.8 (N.S.)

Note that for Haptic pedal the baseline is the visual system on same vehicles and not absence of system.

Next table reports summary of results considering total trip data analysis, that it means that all data collected during the on-field tests are analysed without any segmenting or chunking. Then, in the trip data analysis no differentiation on road types (e.g. urban, rural...) is feasible.

Results obtained on chunks analysis are comparable with trip analysis. In trip analysis, FeDS impact is significant with 90% of confidence.

Effect sizes (differences from relevant baseline)				
Treatment (all systems)	Embedded	FeDS	App	Haptic
-4.44	-4.93	-1.18 (N.S.)	-3.49	-3.25

### 5.1.4 Conclusions and implications

The analysis was done using acquired fuel consumption where it was available, or modeled consumption for the sites where the real fuel consumption was not available. The Performance Indicator used is the percentage reduction (or increase) in fuel consumption with respect to the average fuel consumption of the same driver in the same road type during baseline.

The use of the ecoDriver systems reduces significantly fuel consumption and CO<sub>2</sub> emission in all considered types of systems using controlled data, the average impact is 4-4.5% (4.2% considering average of chunks, 4.4% considering trips).

The percentage of reduction in urban road is in average 2.6%, in rural 5.8% and in motorway 2.2%. The difference between baseline and treatment is significant on urban and rural road.

The effect is generally a bit stronger with embedded systems.

The ecoDriver systems positive impact is not significantly increased by haptic pedal, even if at limit of significance at 90%; but the sample is small and the impact of dispersion on fuel consumption due to the analysis on chunk is high. Indeed, surely on these small segments the impact of not considered

parameters like slope is important and moreover an analysis done on trips highlight a similar, but in this case also statistically significant, additional impact (3.2%).

The impact of systems is not significant in naturalistic driving tests. Anyway the average value of impact is not so different from impact of App in controlled test for urban and rural condition, but the not statistical significance could be due to the high dispersion of data and smaller impact of systems on motorway.

## 5.2 Hypothesis 2: Impact of systems on energy consumption

### Hypothesis analysis summary table

Hypothesis formulations:

*Using ecoDriver system will reduce the average energy consumption*

1. Using an ecoDriver system, the average energy consumption will be reduced. [Type A]
2. Using an embedded ecoDriver system, the average energy consumption will be reduced. [Type B]
3. Using the full ecoDriver system (FeDS), the average energy consumption will be reduced. [Type C]
4. Using the ecoDriver application (App), the average energy consumption will be reduced. [Type D]
5. Using a haptic ecoDriver system, the average energy consumption will be reduced. [Type E]

#### Performance indicator (PI):

Percentage of energy consumption reduction/increasing with respect to the average energy consumption of the same driver in the same road type during baseline.

The energy consumption is acquired only for a electric car with FeDS system.

#### Data reduction method:

500 m sections

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline FeDS vs FeDS (Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_FeDS</li> <li>• FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 5.2.1 Controlled studies

#### 5.2.1.1 Type A: Baseline vs Treatment

#### 5.2.1.2 Type B: Baseline embedded vs embedded

#### 5.2.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis for FeDS system are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 31: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	8.7	8.7	1	1066.8	0.0	0.976
road_type	4518.3	2259.2	2	1066.8	0.2	0.786
Main_effect:road_type	13709.5	6854.8	2	1066.8	0.7	0.482

Table 32: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	11.63	-3.62	26.88	0.135
FeDS	-9.24	-28.17	9.69	0.339
Rural	-12.77	-42.76	17.23	0.404
Motorway	-9.12	-30.45	12.21	0.402
FeDS:Rural	12.40	-24.98	49.78	0.516
FeDS:Motorway	15.97	-10.42	42.35	0.236
Random part	N			
Driver_id	28			
Number of observations	1066			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the percentage reduction in energy consumption when current condition is compared to the reference.



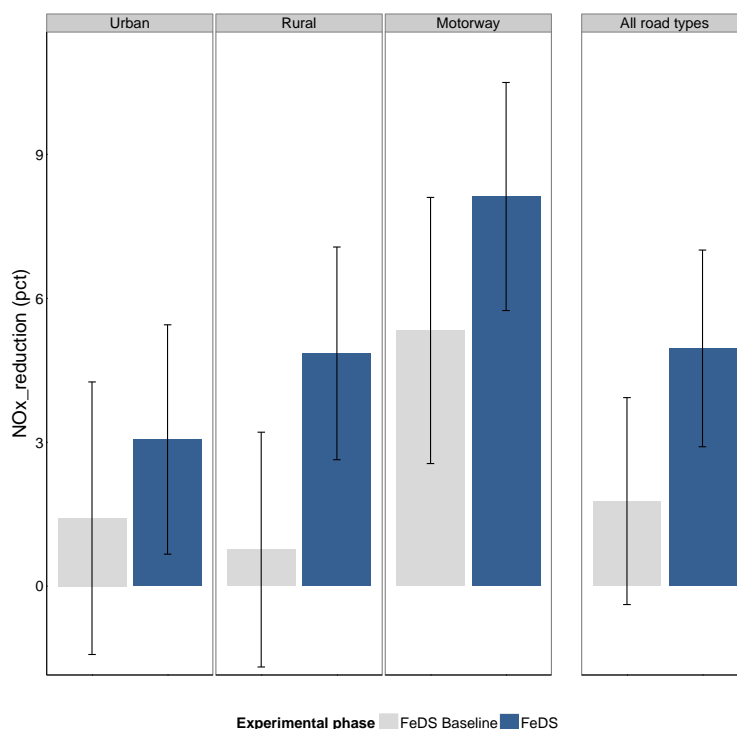


Figure 24: model based average values of percentage of energy reduction for fixed effects.

Table 33 Percentage of energy reduction for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	11.63	2.39	9.24	0.927
Rural	-1.14	2.02	-3.16	1.000
Motorway	2.51	9.24	-6.72	0.979
All road types	5.79	5.41	0.38	0.952

#### Preliminary conclusions:

The impact of system on electric car is not significant, but it is important to highlight the small available sample. Moreover, also some specific characteristic of site (slope) can have had an impact on the result. Anyway the impact is significant considering analysis on trips.

#### 5.2.1.4 Type D: Baseline App vs App

#### 5.2.1.5 Type E: Non-haptic vs Haptic

### 5.2.2 Naturalistic studies

### 5.2.3 Results summary

Table 34: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban			9.24 (N.S.)			
Rural			-3.16 (N.S.)			
Motorway			-6.72 (N.S.)			
All road types			0.38 (N.S.)			

For homogeneity with previous research question, trip analysis was done too, but it has to be taken into account that in this case the data sample is small. Next table reports summary of results considering total trip data analysis, that it means that all data collected during the on-field tests are analysed without any segmenting or chunking. Then, in the trip data analysis no differentiation on road types (e.g. urban, rural...) is feasible.

Effect sizes (differences from relevant baseline)				
Treatment (all systems)	Embedded	FeDS	App	Haptic
		-6.42		

### 5.2.4 Conclusions and implications

The analysis was done for only one site and one electric vehicle. The Performance Indicator used is the percentage reduction (or increase) in energy use with respect to the average energy consumption of the same driver in the same road type during baseline.

The sample was very small so results don't highlight significance in differences between baseline and treatment on chunks, whereas a significant impact is highlighted by analysis on trips.

### 5.3 Hypothesis 3: Impact of systems on NOx emission

#### Hypothesis analysis summary table

Hypotheses formulations:

Using ecoDriver systems will reduce the average Greenhouse effect gas (GEG) emissions

1. Using an ecoDriver system, the average NOx emissions will be reduced. [Type A]
2. Using an embedded ecoDriver system, the average NOx emissions will be reduced. [Type B]
3. Using the full ecoDriver system (FeDS), the average NOx emissions will be reduced. [Type C]
4. Using the ecoDriver application (App), the average NOx emissions will be reduced. [Type D]
5. Using a haptic ecoDriver system, the average NOx emissions will be reduced. [Type E]

#### Performance indicator (PI):

Percentage of NOx reduction/increasing with respect to the average NOx emission of the same driver in the same road type during baseline. The NOx emissions are estimated by emission model.

#### Data reduction method:

500m sections

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced. Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment (Type A dataset)</b> For both controlled and naturalistic data	Main effect	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id
<b>Baseline Emb. vs Embedded (Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id
<b>Baseline FeDS vs FeDS (Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id
<b>Baseline App vs App (Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

## Hypothesis analysis summary table

Non-haptic vs Haptic (Type E dataset)	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 5.3.1 Controlled studies

#### 5.3.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 35: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	68199.4	68199.4	1	33317.5	52.4	<0.001
road_type	72212.5	36106.3	2	33277.7	27.7	<0.001
Main_effect:road_type	9808.3	4904.2	2	34259.8	3.8	0.023

Table 36: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.47	-1.14	2.08	0.564
Treatment	2.61	1.13	4.09	<0.001
Rural	0.72	-0.84	2.28	0.365
Motorway	5.06	2.74	7.39	<0.001
Treatment:Rural	2.50	0.65	4.35	0.008
Treatment:Motorway	0.68	-1.97	3.34	0.613
Random part	N			
Driver_id	114			
Number of observations	34292			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on percentage of NOx reduction when current condition is compared to the reference.

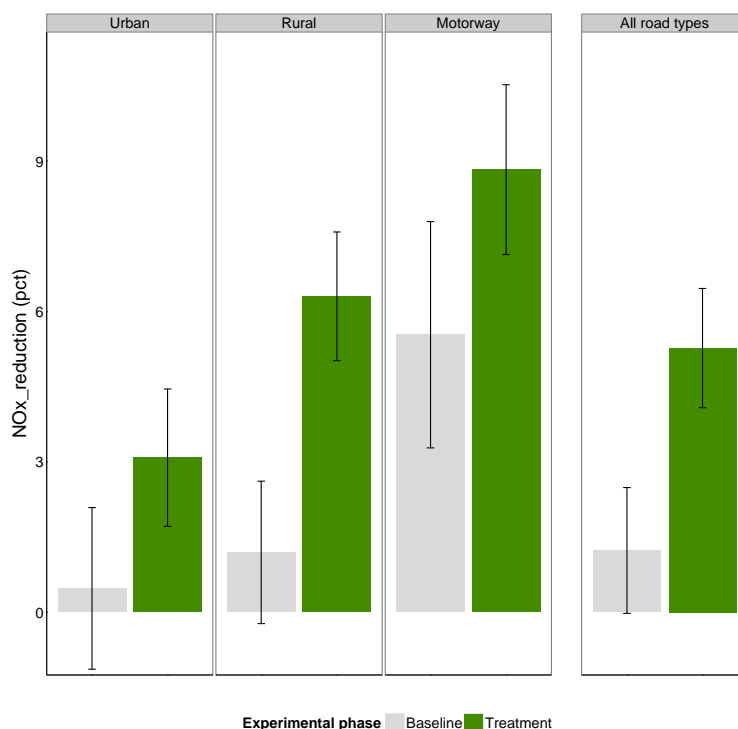


Figure 25: model based average values of percentage of NOx emission reduction for fixed effects.

Table 37 Percentage of Nox emission reduction for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	0.47	3.08	-2.61	0.007
Rural	1.19	6.31	-5.11	<0.001
Motorway	5.54	8.83	-3.29	0.039
All road types	1.23	5.27	-4.04	<0.001

#### Preliminary conclusions:

Both treatment and road type and also their interaction have a significant impact on the considered PI (percentage of NOx emission saved); it means that treatment has a significant impact on the considered PI, with the impact varying significantly with different road types.

The treatment condition increases significantly the percentage of emission reduction compared to baseline, and percentage of NOx reduction is in average 4%, around 2.6% in urban, 5.1% in rural and 3.3% in motorway roads. The difference between baseline and treatment is significant in all the road types.

The ecoDriver systems positive impact is increased when driving on rural roads compared to urban and this difference is around 2.5% of additional reduction.

## 5.3.1.2 Type B: Baseline embedded vs embedded

Table 38: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	76022.9	76022.9	1	29707.0	58.8	<0.001
road_type	71123.0	35561.5	2	29459.7	27.5	<0.001
Main_effect:road_type	7998.2	3999.1	2	29836.9	3.1	0.045

Table 39: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.65	-1.42	2.72	0.540
Embedded	3.27	1.59	4.94	<0.001
Rural	0.91	-0.93	2.75	0.333
Motorway	5.56	3.13	7.99	<0.001
Embedded:Rural	2.38	0.27	4.49	0.027
Embedded:Motorway	0.08	-2.68	2.83	0.956
Random part	N			
Driver_id	74			
Number of observations	29864			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.



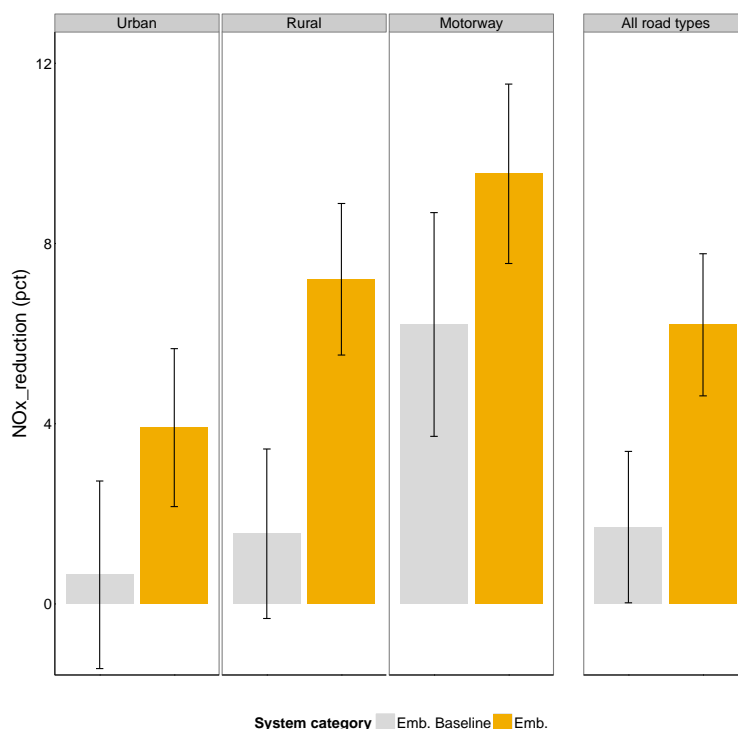


Figure 26: model based average values of percentage of NOx emission reduction for fixed effects.

Table 40 Percentage of NOx emission reduction for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	0.65	3.91	-3.27	0.002
Rural	1.56	7.21	-5.65	<0.001
Motorway	6.20	9.55	-3.34	0.034
All road types	1.71	6.20	-4.49	<0.001

#### Preliminary conclusions:

Both treatment and road type and also their interaction have a significant impact on the considered PI (percentage of NOx emission saved); it means that treatment has a significant impact on the considered PI, with the impact varying significantly with different road types.

The treatment condition increases significantly the percentage of NOx reduction compared to baseline and percentage of NOx reduction is in average around 4.5%, 3.3% in urban, 5.7% in rural and 3.3% in motorway roads. The difference between baseline and treatment is significant in all road types.

The ecoDriver systems positive impact is increased when driving on rural roads compared to urban and this difference is around 2.4% of additional reduction.

### 5.3.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 41: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	20389.9	20389.9	1	13054.8	16.1	<0.001
road_type	40488.1	20244.1	2	12803.1	16.0	<0.001
Main_effect:road_type	2881.8	1440.9	2	13905.0	1.1	0.321

Table 42: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.42	-1.40	4.23	0.326
FeDS	1.64	-1.09	4.38	0.239
Rural	-0.65	-3.39	2.08	0.640
Motorway	3.91	0.88	6.95	0.011
FeDS:Rural	2.45	-0.84	5.73	0.144
FeDS:Motorway	1.15	-2.44	4.74	0.529
Random part	N			
Driver_id	30			
Number of observations	13911			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

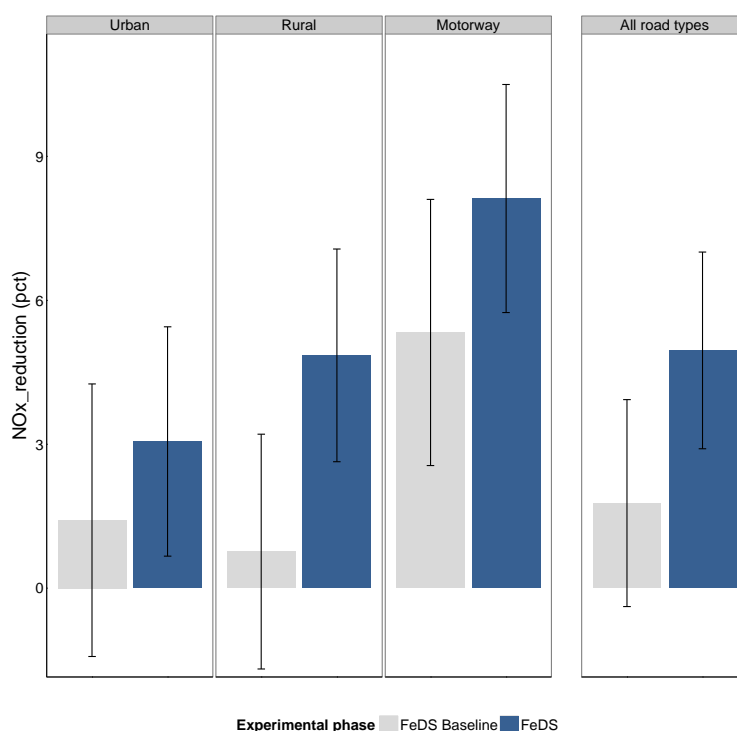


Figure 27: model based average values of percentage of NOx reduction for fixed effects.

Table 43 Percentage of NOx reduction for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	1.42	3.06	-1.64	0.842
Rural	0.76	4.85	-4.09	<0.001
Motorway	5.33	8.12	-2.79	0.182
All road types	1.77	4.96	-3.18	<0.001

#### Preliminary conclusions:

Both treatment and road type have a significant impact on the considered PI (percentage of NOx reduction).

The treatment (i.e. ecoDriver) increases significantly the percentage NOx reduction compared to baseline and percentage of fuel saved is globally around 3.2%, 1.6% in urban, 4.1% in rural and 2.8% in motorway roads. The difference between baseline and treatment is significant globally and on rural roads.

### 5.3.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 44: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	1093.5	1093.5	1	4428.4	0.8	0.369
road_type	2949.3	2949.3	1	4428.4	2.2	0.140
Main_effect:road_type	1758.2	1758.2	1	4428.4	1.3	0.255

Table 45: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	-0.07	-2.41	2.26	0.952
App	-0.28	-3.85	3.29	0.879
Rural	0.39	-2.56	3.34	0.796
App:Rural	2.63	-1.90	7.16	0.255
Random part	N			
Driver_id	40			
Number of observations	4428			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

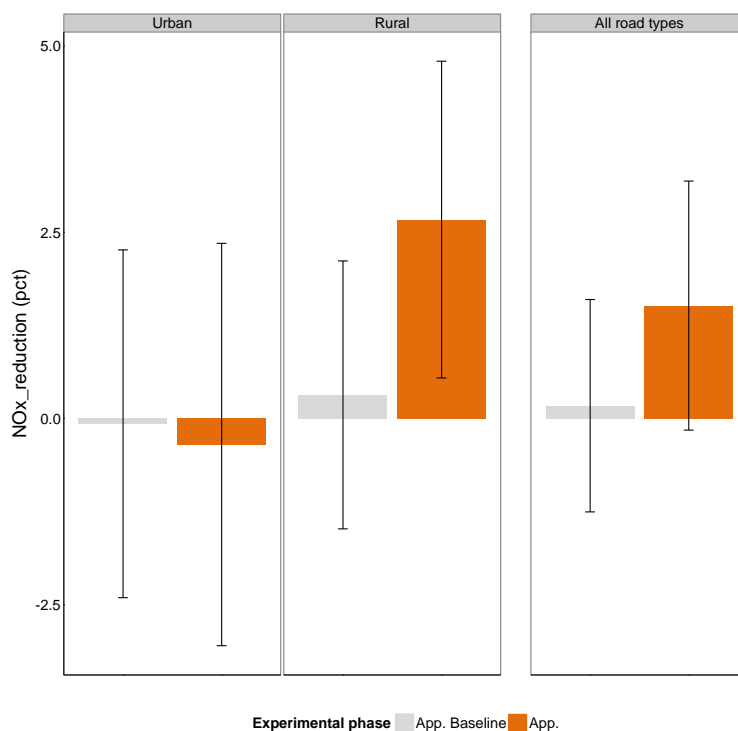


Figure 28: model based average values of percentage of NOx reduction for fixed effects.

Table 46 Percentage of NOx reduction for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates			Tukey multiple comparisons significance test
	Baseline	App	Difference (B-A)	
Urban	-0.07	-0.35	0.28	0.999
Rural	0.32	2.67	-2.35	0.344
Motorway	NA	NA	NA	NA
All road types	0.17	1.52	-1.34	0.230

**Preliminary conclusions:**

None significant impact was observed on this PI for this comparison.

This result can be due to the small sample (only one site data are available).

## 5.3.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 47: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	878.9	878.9	1	5430.2	0.9	0.348
road_type	7994.2	7994.2	1	5458.0	8.0	0.005
Main_effect:road_type	763.7	763.7	1	5447.6	0.8	0.382

Table 48: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.07	-2.23	4.37	0.525
Haptic	1.77	-1.27	4.80	0.253
Rural	3.63	0.45	6.80	0.025
Haptic:Rural	-1.67	-5.41	2.07	0.382
Random part	N			
Driver_id	36			
Number of observations	5477			

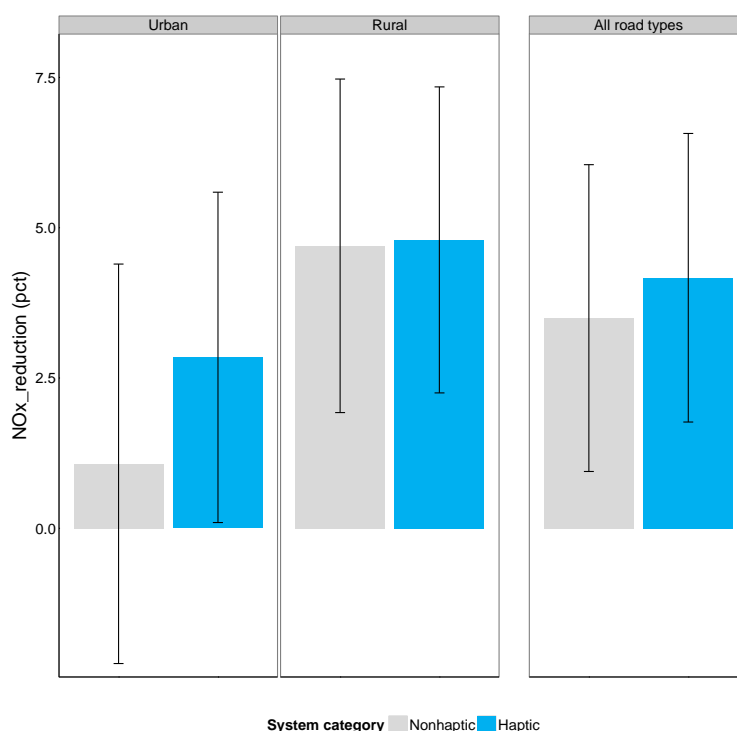


Figure 29: model based average values of percentage of NOx reduction for fixed effects.

Table 49 Percentage of NOx reduction for the different systems and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	1.07	2.84	-1.77	0.657
Rural	4.70	4.80	-0.10	1.000
Motorway	NA	NA	NA	NA
All road types	3.50	4.17	-0.67	0.485

#### Preliminary conclusions:

The impact of haptic pedal is not significant in this analysis.

This result can be due to the small sample (only one car and one truck have the haptic pedal) and to high variability in emission simulated data.



### 5.3.2 Naturalistic studies

#### 5.3.2.1 TypeA : Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 50: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	1050.7	1050.7	1	19407.6	0.7	0.417
road_type	132974.1	66487.1	2	19225.0	41.8	<0.001
Main_effect:road_type	22633.6	11316.8	2	19767.9	7.1	<0.001

Table 51: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	-4.00	-7.96	-0.04	0.060
Treatment	-1.06	-3.17	1.04	0.322
Rural	6.61	4.52	8.70	<0.001
Motorway	3.13	1.16	5.09	0.002
Treatment:Rural	0.17	-2.78	3.12	0.910
Treatment:Motorway	4.51	1.80	7.22	0.001
Random part	N			
Driver_id	20			
Number of observations	19788			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

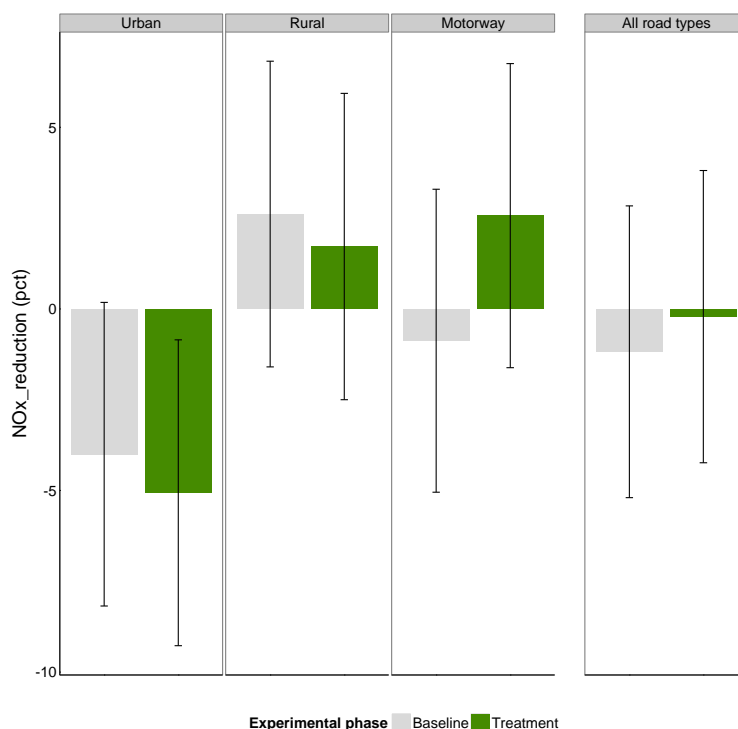


Figure 30: model based average values of percentage of NOx reduction.

Table 52: Percentage of NOx reduction for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	-4.00	-5.06	1.07	0.920
Rural	2.61	1.72	0.90	0.966
Motorway	-0.87	2.57	-3.44	0.001
All road types	-1.18	-0.21	-0.97	0.105

#### Preliminary conclusions:

The treatment condition increases significantly the percentage of emission reduction compared to baseline in motorway roads with an average saving of 3.4%.

The impact of system is globally at limit of significance with an average saving of 1%.

### 5.3.3 Results summary

Table 53: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-2.61	-3.27	-1.64 (N.S.)	0.28 (N.S.)	-1.77 (N.S.)	1.07 (N.S.)
Rural	-5.11	-5.65	-4.09	-2.35 (N.S.)	-0.1 (N.S.)	0.9 (N.S.)
Motorway	-3.29	-3.34	-2.79 (N.S.)	-	-	-3.44
All road types	-4.04	-4.49	-3.18	-1.34 (N.S.)	-0.67 (N.S.)	-0.97 (N.S.)

Note that for Haptic pedal the baseline is the visual system on same vehicles and not absence of system.

Next table reports summary of results considering total trip data analysis, that it means that all data collected during the on-field tests are analysed without any segmenting or chunking. Then, in the trip data analysis no differentiation on road types (e.g. urban, rural...) is feasible.

Results obtained on chunks analysis are comparable with trip analysis.

Effect sizes (differences from relevant baseline)				
Treatment (all systems)	Embedded	FeDS	App	Haptic
-4.07	-5.38	-3.56	-1.05 (N.S.)	-1.32 (N.S.)

### 5.3.4 Conclusions and implications

The analysis was done considering NOx emission estimated by the model. The Performance Indicator used is percentage of NOx reduction/increasing with respect to the average NOx emission of the same driver in the same road type during baseline.

The usage of the ecoDriver systems reduces NOx emission in all road types. The average NOx reduction due to the systems is 4%. The percentage of reduction in urban road is in average 2.6%, in rural 5.1% and in motorway 3.3%.

The effect is generally slightly stronger with embedded systems.

For FeDS the effect is globally significant (both considering average of chunks and trip analysis) and in rural roads.

For App none significant impact emerged, but it is important to highlight that the sample is smaller and the system was tested in only one site.

The ecoDriver systems positive impact is not significantly increased by haptic pedal but also in this case the sample is small.

In naturalistic driving the impact is significant in motorway, but it is important to highlight the high dispersion of data that can have had an impact on results.

## 6 Annex F: Detailed results per hypothesis (Driver attention)

### 6.1 Hypothesis 6: Drivers are more distracted when using an ecoDriver system

#### Hypothesis analysis summary table

Hypotheses formulations:

6. Compared to baseline, drivers are more distracted when using an ecoDriver system (which provides in-trip feedback)

#### Performance indicator (PI):

mean single glance duration to FeDS  
 95th percentile glance duration to FeDS  
 percentage of time glancing at FeDS  
 number of glance clusters to FeDS per km  
 mean number of glances in cluster  
 percentage of "single glance clusters"  
 percentage of time looking through windscreen within cluster  
 number of AttenD warnings per km

#### Data reduction method:

Segments outlined by a consecutive sequence of data segmented based on road type and speed limit. The segments have unequal length/duration.

#### Statistical models

Different models depending on the analysis. See the text below for more details.

#### Statistical analysis information

<b>FeDS across different treatment phases</b>	Main effect	Phase (B1, B2, T1, T2, T3, T4, T5, B3, B4)
	Additional fixed effect	Road_type
	Random effects	

#### 6.1.1 Learning effects

It is likely that the visual interaction with the FeDS changes over time, as the users get familiar with the system's display and the messages that can appear. In terms of prevalence it is more interesting to investigate the visual behaviour of an experienced user, instead of only looking at the effects during the first encounter with the system. The percentage of glances to various targets per drive and road type is presented in Figure 31. The FeDS was not installed in the baseline drives. A small percentage of glances was directed at the position of the FeDS screen in baseline drives, anyway, which is why values above zero can occur.

A multivariate GLM with the factors road type and drive and the dependent variables “all mirrors”, “speedometer” and “glances away from windscreen” showed that both factors significantly influenced all dependent variables, but there was no significant interaction effect. A post-hoc analysis showed that mirror glances had a higher time share of all glances during the first drive (B1, 4.4 %) than any other (1.5-2.7 %). Mirror glance percentage differed significantly between all road types, with the highest share on motorways (4.9 %), followed by two+one roads (2.9 %), urban roads (1.8 %) and rural roads (1.2 %).

Glances to the speedometer had the lowest share during the second drive (B2, 5.2 %) and the highest share during the last drive (B4, 8.4 %), with a higher share of speedometer glances on the faster roads (highway: 8.9 %, two+one: 8.2 %) than on the slower roads (urban: 6.5 %, rural: 5.7 %).

Generally, drivers had a higher share of glances away from the windscreen during treatment drives (15.8 % - 20.7 %) than baseline drives (11.6 % - 13.7 %). During the treatment drives the share of glances away from the windscreen decreased over time. The highest share of glances away from the windscreen was found on the motorway (19.7 %), which was significantly more than for urban (16.6 %) and two+one (16.4 %), which, in turn, had a significantly higher share than the rural road sections (12.3 %).

During the treatment drives the FeDS was implemented. A similar analysis for the treatment drives only showed that both road type and drive influenced the share of glances to the FeDS. Significantly higher shares were found for the first two treatment drives (T1: 9.4 %, T2: 7.6 %) than for the following treatment drives (T3: 5.2 %, T4: 6.1 %, T5: 5.3 %). A higher glance share to the FeDS was found for urban roads (8.3 %) than any other road type (highway: 6.3 %, two+one: 6.0 %, rural: 5.8 %).

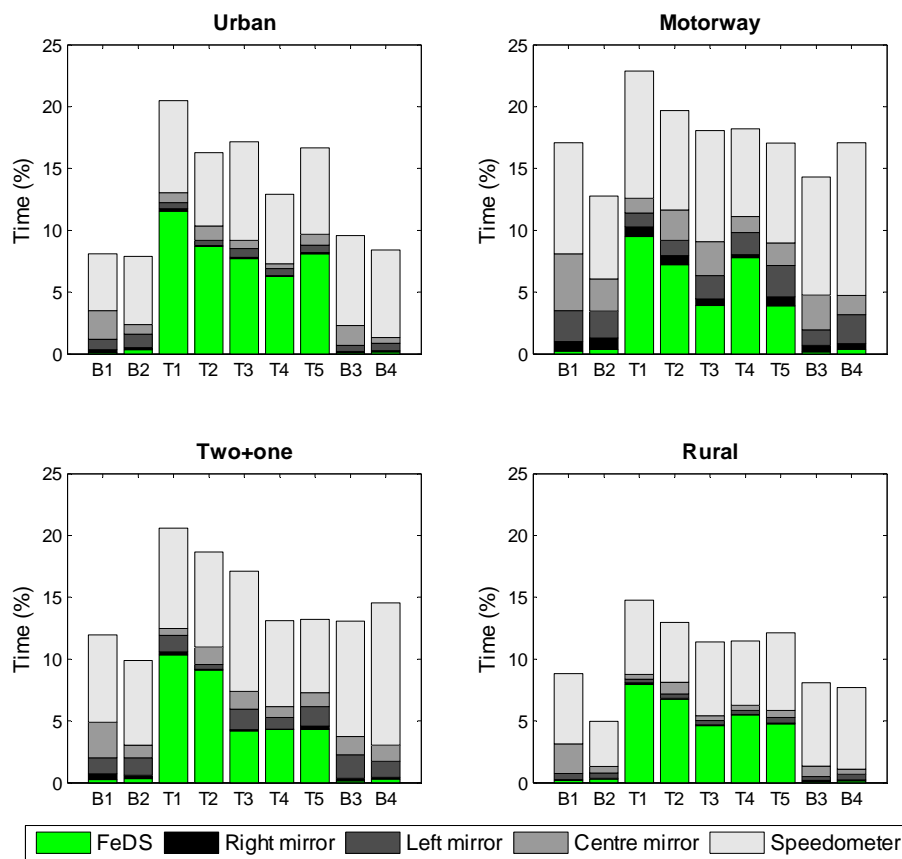


Figure 31: Percentage of glances to different targets per trip per road type.

In addition to the time share spent looking at different targets, the number of glance clusters to the same targets was analysed. This was done, because previous research indicates that the number of glances to safety critical targets may be more indicative of actually having noticed and dealt with the target, than the percentage of time spent looking at the target (Ahlstrom, Kircher, Thorslund, & Adell, 2015).

Significantly more glances were directed at the mirrors during the first drive (3.0 clusters/km) than all other drives (1.4-2.1 clusters/km). The glance cluster frequency was highest on urban roads (2.8 clusters/km), followed by the motorway (2.2 clusters/km), with the lowest frequencies found for both two+one roads (1.7 clusters/km) and rural roads (1.4 clusters/km). The glance frequency to the speedometer was lowest during the second drive (3.8 clusters/km) and the first drive (4.4 clusters/km), with all the treatment drives and also the two last baseline drives showing higher frequencies of 5.1 to 5.8 clusters/km. The speedometer was glanced at much more frequently per distance (7.1 clusters/km) on urban roads than on any of the other three road types (rural: 4.6 clusters/km, motorway: 4.1 clusters/km, two+one: 3.8 clusters/km).

The frequency of glance clusters to the FeDS was highest during the first (T1, 5.3 clusters/km) and second (T2, 4.5 clusters/km) treatment drive, and somewhat lower (T3: 3.6 clusters/km, T4: 4.2 clusters/km, T5: 3.6 clusters/km) during the following treatment drives. The highest frequency per

distance was found for urban roads (6.4 clusters/km), followed by rural roads (4.2 clusters/km) and then followed by motorways (2.6 clusters/km and two+one-roads (2.2 clusters/km) together (Figure 32).

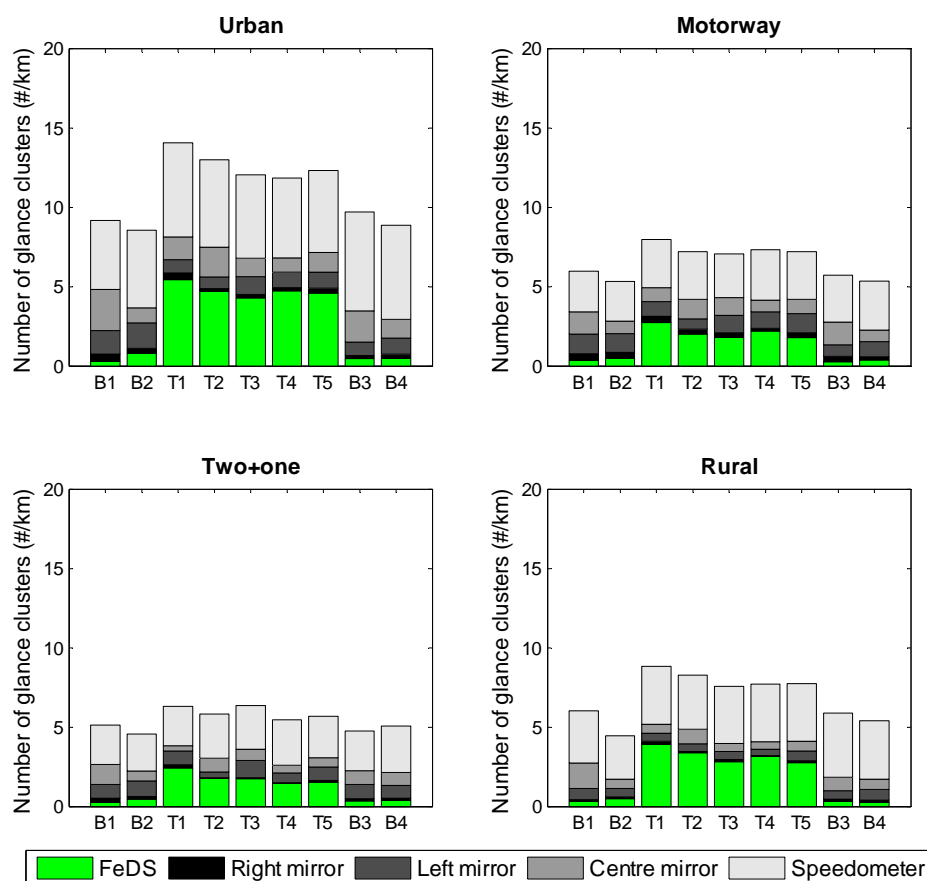


Figure 32: Number of glance clusters to different targets per trip per road type.

It could be observed that the visual interaction with the FeDS decreased both in time, frequency and intensity already over the first few treatment trials. This indicates that the system is easy to learn and understand, which is advantageous. It has to be noted, however, that the decreased glance proportion to the FeDS is accompanied by an increased glance proportion to the speedometer. An integration of the two displays may, thus, have a positive effect, decreasing the glance proportion away from the forward roadway.

### 6.1.2 Glance duration, number of glances and percentage of glances to FeDS

The FeDS has a visual user interface, therefore it has to be expected that the participants will glance at the display. A number of basic glance performance indicators related to display glances are presented in Table 54. They are shown for the first treatment drive (T1) and for the fourth treatment drive (T4). T-tests were used to examine whether glance behaviour changed between the first encounter with the FeDS and the fourth drive with the system. Overall, glances towards the FeDS were shorter and fewer, and clusters were used less frequently with increased familiarity with the system.



Table 54. Performance indicators for glance behaviour in relation to the FeDS for the first treatment drive (T4) and the fourth treatment drive (T7), t-values and significance levels (\*  $p < .05$ ; \*\*  $p < .01$ ; \*\*\*  $p < .001$ ) for a t-test.

glance performance indicator	T1	T4	t(160)
mean single glance duration to FeDS	0.62 s	0.52 s	4.7***
95 <sup>th</sup> percentile glance duration to FeDS	1.15 s	0.93 s	4.3***
percentage of time glancing at FeDS	9.4 %	6.1 %	3.9***
number of glance clusters to FeDS per km	3.9	3.2	2.2*
mean number of glances in cluster	3.6	4.1	-0.7
percentage of "single glance clusters"	34.7 %	46.9 %	-3.2**
percentage of time looking through windscreen within cluster	63.1 %	67.4 %	-2.6**
number of AttenD warnings per km	.034	0.019 <sup>1</sup>	0.84

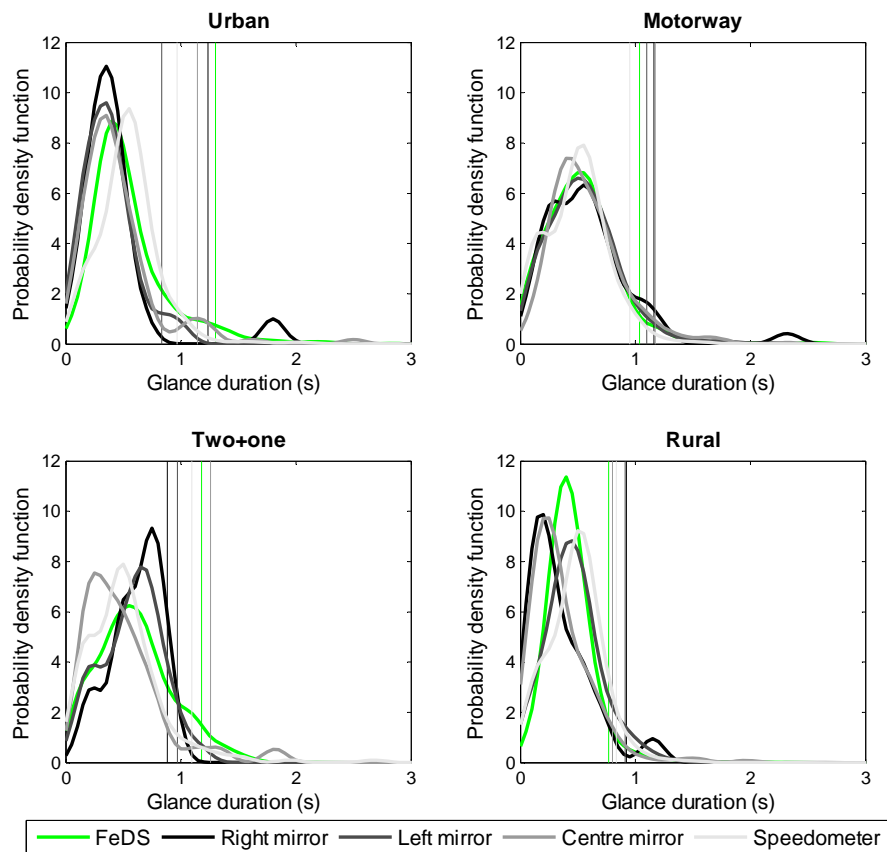


Figure 33: Probability density functions of glance durations per glance target per road type. The vertical lines indicate the 95<sup>th</sup> percentile of glance duration for each target.

<sup>1</sup> After removal of one outlier at 3.0 AttenD-warnings per km in an urban area.

### 6.1.2.1 Single long glances away from forward roadway (windscreen)

Single glances away from the forward roadway of durations of two seconds or more have been associated with an increased crash risk (Dingus, et al., 2006). Therefore, the number of long (> 2 s) single glances away from the windscreen was compared for each included drive per road type with the help of an univariate analysis of variance. The overall mean was 0.038 glances/km, which means that a glance of 2 s or more in duration occurred approximately every 26<sup>th</sup> kilometre. There was no significant difference for drive ( $F(3, 302) = 1.7$ ;  $p > .05$ ), but road type had an effect on single long glance frequency ( $F(3, 302) = 4.5$ ;  $p < .05$ ). Post-hoc tests with Sidak correction showed that single long glances were significantly more frequent on urban road (0.066 single long glances/km) and highway sections (0.062 single long glances/km) than on rural sections (0.012 single long glances/km).

### 6.1.2.2 Percentage of glances away from windscreen

Not looking at the forward roadway enough has been identified as a safety related issue, especially in connection with rear-end crashes. The percentage of glances directed elsewhere than through the windscreen was assessed per drive and road type with a univariate analysis of variance ( $F(15, 302) = 9.2$ ;  $p < .05$ ). Both road type ( $F(3, 302) = 32.4$ ;  $p < .05$ ) and drive ( $F(3, 302) = 5.4$ ;  $p < .05$ ) significantly influenced the percentage of glances away from the windscreen, with significant differences between all road types except urban and “2+1”-road, and significant differences between the treatment drive (T4) and both the baseline before (B2) and the baseline immediately after the treatment block (B3), and also between the baseline before (B2) and the last baseline (B4).

For road type, the highest percentage of glances away from the windscreen occurred when driving on the motorway (18.1 %), followed by 2+1-roads (15.2 %) and urban roads (14.0 %). The lowest percentage was found on rural sections (10.5 %). During the treatment phase (T4) the participants looked away from the windscreen the most (15.8 %), followed by the last baseline (B4; 13.6 %), B3 (12.6 %) and B2 (11.6 %).

As looking away from the windscreen intensively is less suitable when closely following another vehicle, this was analysed additionally. It was differentiated between occasions in which the driver was following another vehicle with a time headway of less than 2 s and occasions in which the driver was “free”, with a time headway of more than 6 s. A GLM analysis with the factors road type, drive and “free vehicle or not” was conducted. No difference in the percentage of glances away from the windscreen could be found for the free-vehicle factor, with 12.8 % of the glances directed elsewhere when following with a time headway of 2 s or less, and 14.3 % of the glances directed elsewhere when driving with a time headway of 6 s or more.

### 6.1.2.3 Discussion

The comparison of glance behaviour between the first and the fourth treatment drive shows that drivers reduce their visual interaction with the device already after a limited time of exposure to the system.

The single glance duration distribution is comparable to what was found for other targets both in this study and in previous studies (for a review see Katja Kircher, 2007), and the percentage of display glances in clusters is comparable to what was found during an interaction with a navigation system (Chiang, Brooks, & Weir, 2004). A visual occlusion study conducted on the same highway as the current study showed that drivers occluded their vision in a self-paced fashion for about 11 % of the time, which

is a higher percentage than what was found for FeDS glances on the highway (Katja Kircher & Ahlstrom, 2015). No occlusion data are available for other road types, and it has not been established whether the drivers distributed their time between the different lanes similarly as in the occlusion study, but the results can be taken as a first indication that drivers seem to keep to the visual spare capacity limits available in the situation.

The overall time spent glancing at other targets than the windscreen is larger with the FeDS present than when it is absent, and possibly somewhat larger in the baseline drives after having experienced the FeDS than before. The highway data indicate that this percentage increase is likely within the available visual spare capacity, but this would have to be investigated further for other road types as well.

## 6.2 Hypothesis 7: Feedback from the ecoDriver system cause inappropriate/dangerous visual behaviour

### Hypothesis analysis summary table

Hypotheses formulations:

7. In-car feedback from the ecoDriver system cause inappropriate/dangerous visual behaviour, in terms of glances towards the device.

#### Performance indicator (PI):

number of clusters per km (absolute number of clusters, including single glance clusters)

mean cluster duration (s)

number of glances in cluster

percentage looking forward in cluster (% , with # glance > 1)

AttenD

Percentage looking at FeDS

#### Data reduction method:

- Segments outlined by a consecutive sequence of data segmented based on road type and speed limit. The segments have unequal length/duration.
- Segments surrounding popup event (before: six seconds leading up to the popup, during: six seconds while the popup information is shown, after: six seconds after the popup information disappears.

#### Statistical models

Different models depending on the analysis. See the text below for more details.

#### Statistical analysis information

<b>Baseline vs FeDS across different baseline and treatment phases</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_FeDS (B2, B3, B4)</li> <li>• FeDS (T1, T4)</li> </ul>
	Additional fixed effect	Road_type Glance target
	Random effects	

### 6.2.1 Visual engagement in the FeDS

The following analyses are intended to indicate whether there is a risk that the FeDS in the tested form is likely to lead to unsafe visual behaviour. Indications for dangerous glance behaviour might be a decreased glance activity to mirrors and the speedometer due to focus being directed at the FeDS instead. Also, if the FeDS consumes much more attention than mirrors and the speedometer typically do, this could be an indication for a poorly designed interface. For statistical analyses four of the nine drives will be used as specified in Table 3.

Table 55. Drives in the visual behaviour study, and motivations for why they are included in or excluded from the analyses.

name	type of drive	motivation for inclusion in/exclusion from analysis
B1	Baseline 1 (excluded)	First time encounter with the car and first test day, therefore possibly less natural behaviour than during the second baseline.
B2	Baseline 2 (included)	Pre-treatment baseline, more familiar with car and experimental setup.
O1	Off-line instruction 1 (excluded)	Not driving, therefore no eye tracking recorded.
T1	Treatment 1 (included in descriptives, excluded from inferential statistics)	First encounter with full ecoDriver system, therefore included for comparison in some analyses, but main research interest lies in more “standard” behaviour when familiar with the system.
T2	Treatment 2 (excluded)	Treatment 2 and Treatment 3 were planned for training with the FeDS, therefore not included in the study.
T3	Treatment 3 (excluded)	
T4	Treatment 4 (included)	Included as the “experienced” treatment trial. Some experience was gained during previous drives, while the current drive still was not the last with the system.
T5	Treatment 5 (excluded)	The participants knew that this was the last trial with the system, which may have prompted them to be extra attentive to the system in order to remember everything for the following drives.
B3	Baseline 3 (included)	Comparison to Baseline 2 and also to Treatment 4 to assess learning effects.
B4	Baseline 4 (included)	Comparison to Baseline 2, Baseline 3 and Treatment 4, to assess learning (and decay) effects after 1 month.

The first step is to describe the visual engagement in the FeDS, in comparison to the visual engagement in other driving related targets, like the three mirrors, the instrument cluster and the speedometer. Results are presented separately for each road type since road type significantly influences glance behaviour.

The number of available clusters varies widely with road type and target. Therefore it was investigated whether the values of interest differed between the segments included in the analyses, and the whole route for which road type classification was available. It turned out that the differences were minor, which led to the inclusion of all clusters on identified road types, in order to maximise the number of cases per drive.

In Table 56 to Table 59 the absolute number of clusters per road type and drive is shown, both including and excluding 1-glance-clusters, in order to give an indication of the reliability of the measured values in the tables. It has to be noted, that the absolute values are influenced both by the distance and speed driven on each type of road, and by missing and low quality data occurrences, such that comparisons based on absolute values are not always meaningful.

## 6. Annex F: Detailed results per hypothesis (Driver attention)

Table 56. Glance cluster related performance indicators for the four analysed test drives B2, T4, B3 and B4 for the urban roads.

urban environment	number of clusters per km (absolute number of clusters, including single glance clusters)				mean cluster duration (s)				number of glances in cluster				percentage looking forward in cluster (% , with # glance > 1)			
	B2	T4	B3	B4	B2	T4	B3	B4	B2	T4	B3	B4	B2	T4	B3	B4
right mirror	36 5 0.33	26 1 0.20	27 4 0.18	28 3 0.24	1.0 4.1	0.4 2.5	0.8 2.9	0.5 1.8	1.4 3.8	1.3 9.0	1.4 3.5	1.3 4.0	67.5	28.9	28.1	20.8
left mirror	92 14 1.6	91 12 1.0	66 11 0.86	88 15 0.99	0.9 3.3	0.9 3.6	1.1 4.4	0.8 2.8	1.7 5.6	1.7 6.0	2.0 7.0	1.7 3.5	42.8	38.1	27.8	17.9
centre mirror	60 10 0.94	122 11 0.89	166 25 2.0	114 17 1.2	1.0 3.6	0.5 2.4	1.0 3.6	0.7 3.2	1.6 5.2	1.3 4.4	1.6 4.7	1.6 4.2	65.0	46.9	54.6	49.1
speedometer	262 68 4.9	465 147 5.0	446 161 6.2	499 162 5.8	1.8 5.1	2.0 5.3	3.0 7.2	2.1 5.3	2.2 5.7	2.7 6.3	3.2 7.0	2.5 5.5	52.3	47.0	55.4	51.0
instrument cluster	29 8	32 7	13 3	13 1	0.7 1.5	0.8 3.2	0.6 2.0	0.3 1.3	1.8 4.0	2.1 5.2	1.9 4.7	1.2 4.0	25.7	34.8	17.3	18.3
FeDS		525 211 1.7				3.5 8.0				4.4 9.5						



## 6. Annex F: Detailed results per hypothesis (Driver attention)

Table 57. Glance cluster related performance indicators for the four analysed test drives B2, T4, B3 and B4 for the motorway environment.

motorway environment	number of clusters per km (absolute number of clusters)				mean cluster duration (s)				number of glances in cluster				percentage looking forward in cluster (% , with # glance > 1)			
	B2	T4	B3	B4	B2	T4	B3	B4	B2	T4	B3	B4	B2	T4	B3	B4
right mirror	52 11 0.36	53 9 0.16	52 6 0.35	63 9 0.21	1.2 3.4	0.9 2.4	1.0 3.7	1.1 3.2	1.7 4.1	1.6 4.8	1.4 4.5	1.5 4.3	33.2	15.3	30.2	20.3
left mirror	229 40 1.2	259 43 1.0	176 39 0.72	311 78 0.95	1.2 4.6	1.3 5.1	1.3 4.2	1.7 5.2	1.9 5.9	1.9 6.4	2.1 5.7	2.5 6.8	34.7	41.5	29.7	33.2
centre mirror	157 34 0.79	228 52 0.73	293 84 1.4	214 52 0.73	1.4 4.4	1.5 4.9	2.0 5.8	1.3 3.7	1.9 5.3	2.1 5.6	2.6 6.6	2.0 5.3	40.2	41.2	50.0	47.4
speedometer	487 149 2.5	751 257 3.2	637 248 2.9	785 260 3.1	2.4 6.7	2.3 5.6	3.2 7.4	2.8 7.2	2.8 6.9	2.9 6.6	3.4 7.0	2.9 6.8	50.4	50.8	46.5	54.1
instrument cluster	36 7	78 12	41 6	20 3	1.1 4.4	0.7 3.6	0.6 2.9	0.3 2.3	2.0 6.0	2.0 7.2	1.6 5.0	1.6 4.7	35.3	33.8	43.7	24.9
FeDS		523 171 2.2				2.3 6.0				4.4 7.9				45.5		

## 6. Annex F: Detailed results per hypothesis (Driver attention)

Table 58. Glance cluster related performance indicators for the four analysed test drives B2, T4, B3 and B4 for the two+one road section.

two+one environment	absolute number of clusters number of clusters per km				mean cluster duration (s)				number of glances in cluster				percentage looking forward in cluster (% , with # glance > 1)			
	B2	T4	B3	B4	B2	T4	B3	B4	B2	T4	B3	B4	B2	T4	B3	B4
right mirror	2 - 0.16	2 - 0.028	5 - 0.13	5 - 0.13	0.4 - -	0.3 - -	0.5 - -	0.5 - -	1.0 - -	1.0 - -	1.0 - -	1.0 - -	- - -	- - -	- - -	- - -
left mirror	27 2 0.99	26 2 0.64	30 5 0.91	31 6 0.82	0.8 4.4 -	0.8 5.9 -	1.1 4.4 -	1.0 3.2 -	1.2 4.0 -	1.3 4.5 -	1.8 5.6 -	1.9 5.8 -	71.9	32.2	40.6	36.2
centre mirror	18 3 0.62	23 4 0.47	36 7 0.88	39 8 0.80	1.2 4.6 -	1.1 4.1 -	1.0 2.7 -	1.0 3.0 -	1.8 5.7 -	1.9 6.0 -	1.6 4.0 -	1.7 4.6 -	63.6	31.7	52.1	45.7
speedometer	74 22 2.3	131 39 2.9	86 35 2.5	12 61 2.9	2.2 5.9 -	2.0 5.5 -	3.2 7.1 -	3.6 7.7 -	2.7 6.6 -	2.5 6.0 -	3.6 7.5 -	3.6 7.2 -	57.0	54.6	54.8	49.7
instrument cluster	6 - -	13 5 -	3 - -	16 6 -	0.4 2.3 -	1.9 4.6 -	0.2 - -	3.4 6.3 -	1.0 - -	3.2 6.6 -	1.0 - -	4.9 8.8 -	- -	36.1	43.7	32.9
FeDS		75 25 1.5				2.0 4.8				2.6 5.9				42.1		

## 6. Annex F: Detailed results per hypothesis (Driver attention)

Table 59. Glance cluster related performance indicators for the four analysed test drives B2, T4, B3 and B4 for the rural roads.

rural environment	number of clusters per km (absolute number of clusters)				mean cluster duration (s)				number of glances in cluster				percentage looking forward in cluster (% , with # glance > 1)			
	B2	T4	B3	B4	B2	T4	B3	B4	B2	T4	B3	B4	B2	T4	B3	B4
right mirror	43 2 0.11	10 - 0.060	20 - 0.15	38 2 0.14	0.5 2.2	0.7 -	0.3 -	0.5 3.3	1.2 5.0	1.0 -	1.0 -	1.2 5.5	41.0	-	-	49.9
left mirror	129 18 0.54	123 14 0.37	146 11 0.54	149 14 0.65	0.6 1.7	0.6 1.9	0.6 3.4	0.6 2.5	1.3 3.4	1.3 3.8	1.3 5.4	1.2 3.5	24.1	38.8	20.6	34.9
centre mirror	161 21 0.59	152 39 0.47	229 43 0.84	146 18 0.59	0.7 2.9	0.9 2.5	0.9 3.2	0.7 3.0	1.4 4.0	1.8 4.1	1.8 5.3	1.4 4.2	48.0	43.5	57.3	54.7
speedometer	492 150 2.7	1253 378 3.6	1211 407 4.0	1107 354 3.6	1.5 4.2	2.0 5.5	2.5 6.3	2.4 6.2	1.9 4.7	2.6 6.4	2.6 5.8	2.5 5.5	52.8	51.4	56.6	56.6
instrument cluster	54 11	111 20	44 11	33 -	0.7 2.3	0.7 3.4	1.3 4.7	0.3 -	1.6 3.7	1.8 5.2	2.5 6.8	1.0 -	41.4	36.1	18.8	-
FeDS		1256 462 3.2				2.6 6.5				3.5 7.8				55.6		

Table 56 to Table 59 show that the frequency of glance clusters to the FeDS as well as to other targets varies with road type. In the analyses for Hypothesis 11 it was shown that road type significantly influences glance behaviour to the FeDS. Both drive ( $F(15, 812) = 2.3$ ;  $p < .05$ ; Wilks' Lambda correction) and road type ( $F(15, 812) = 12.4$ ;  $p < .05$ ; Wilks' Lambda correction) also influence the glance behaviour to other targets like the three mirrors and the speedometer. The number of glance clusters to the mirrors per kilometre is generally higher on urban roads and highways than on rural roads and the two+one-road, and the number of glance clusters to the speedometer per kilometre is higher in urban areas than in the three other environments. Mirror glance clusters were most frequent in B3, and speedometer glance clusters were higher in T4 than in B2, and remained at the T4-level or higher for B3 and B4.

Cluster duration and the number of glances per cluster for wing mirrors were not influenced by drive, with larger values for urban and highway driving. For the centre mirror, cluster duration and the number of glances per cluster were largest on the highway, and this was particularly pronounced for B3. Overall, mirror glance behaviour was not greatly affected by drive, whereas speedometer glance behaviour changed during the treatment in the direction of devoting more attention to the speedometer, and that effect persisted in the two following baseline drives. In general, speedometer glance clusters are more frequent and of longer duration than mirror glances.

The FeDS receives an amount of attention that is comparable to the attention devoted to the speedometer both in frequency and in the size of the clusters.

### 6.2.2 AttenD distraction detections

The distraction detection algorithm AttenD monitors the driver's attentional status continuously (K. Kircher & Ahlstrom, 2010; Katja Kircher & Ahlstrom, 2013). It considers both single long glances and time sharing in glance clusters when assessing the driver's status. An increased number of distraction occurrences as defined by AttenD would indicate a risk for insufficient traffic monitoring. In Figure 34 the number of AttenD distractions for all four baseline drives (left) and all five treatment drives (middle) is shown, alongside a graph that illustrates the number and location of FeDS popups, that is, discrete advice and feedback to the driver announced by a "beep". The number of AttenD distractions is normalised by the number of drives.

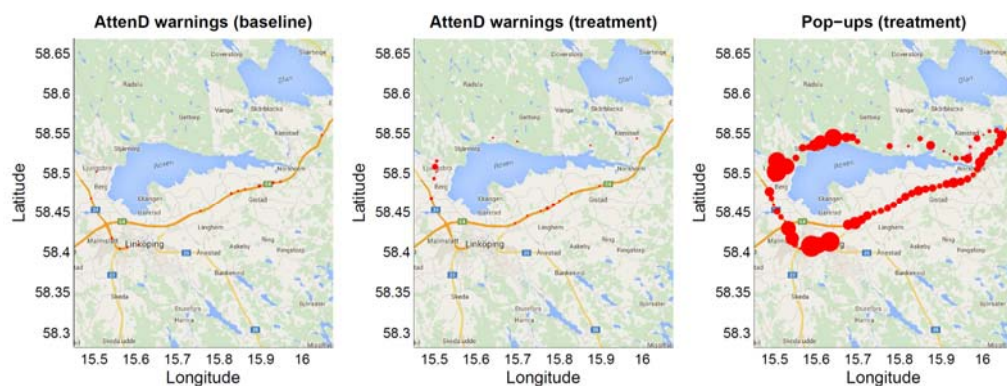


Figure 34: Maps of the route showing the locations and frequency of AttenD distractions during baseline driving and during treatment driving, normalised for the number of drives. In addition, a map with the occurrences of pop-up-information on the FeDS is shown. Larger circles indicate more frequent occurrences.

Descriptive analyses showed that the sum of AttenD distractions per kilometre was higher in the treatment drives than in the baseline drives on urban roads. A further analysis showed that three outlier values (on the same segment, stemming from three different drivers and during three different drives) had a strong influence on the values. These three outliers had more than three AttenD distractions per kilometre, while the overall mean was 0.026 per km (corresponding to one occurrence per 38 km driven). Excluding these three outliers still resulted in a higher AttenD distraction frequency on urban roads for treatment drives.

A general linear model with the factors road type and drive (including B2, T1, T4, B3 and B4), and excluding the three outliers, showed that there was a significant interaction between road type and drive in their influence on the number of AttenD warnings per kilometre ( $F(8, 340) = 2.3$ ;  $p < .05$ ). The number of AttenD warnings increased in the treatment drives on urban roads, but they decreased in the treatment drives on the motorway. For rural roads the number of AttenD warnings was low in general, and not influenced by drive.

### 6.2.3 Popups

In certain traffic situations the drivers are provided with advice, followed by feedback via popup information. Advice is announced with a beep sound, whereas the feedback does not have any auditory primer, but can be expected to follow an advice when the action is completed. The glance behaviour in close vicinity to the popups can give indications about how compelling they are – if drivers feel urged to look at the popups immediately, no matter what, there is a potential danger. Also, the intensity with which the popup is glanced at, is indicative of possible visual distraction. The 2+1-road segment was excluded from the analyses, as only five advices and five feedbacks were given on that segment.

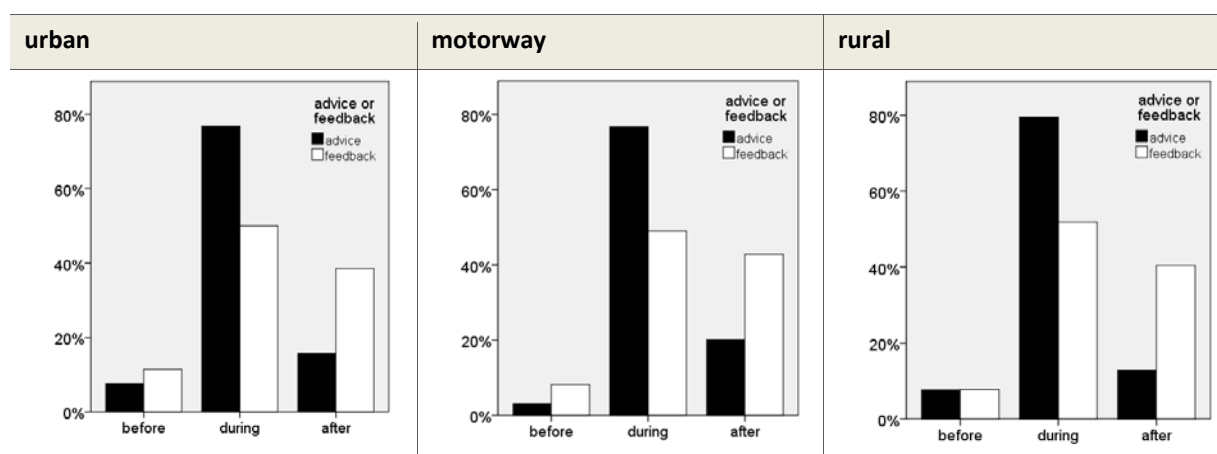


Figure 35: Indicates the percentage of advice and feedback popups where the driver already glanced at the FeDS screen when the popup was activated (before), where the driver glanced at the FeDS screen after the popup had been activated and was still active (during), and where the driver glanced at the FeDS screen first after the popup had disappeared.

On average, around 40 % of the feedback popups and 10-20 % of the advice popups were missed (see Figure 35). These figures are comparable across road types, with a slightly lower probability that advice is missed on rural roads.

For those cases in which the driver glanced at the FeDS screen after the popup was activated, but before it disappeared, the glance occurred significantly faster after the popup onset for advice (1.1 s) than for feedback (1.7 s;  $F(1, 287) = 20.5$ ;  $p < .05$ ), regardless of road type ( $F(2, 287) = 0.37$ ).

Further, an analysis of the percentage of glances to the FeDS in the six seconds before the popup occurred, in the six seconds during the popup, and in the six seconds after the popup disappeared (factor time) was made for drive T4. Separate repeated measures analyses were made for each road type, with “advice or feedback” as additional factor.

For the three analysed road types the interaction between the factor time interacted significantly with the factor advice or feedback ( $p < .05$  for all road types). In each case the percentage of glances directed at the FeDS showed a similar pattern for advice popups respectively feedback popups. Before the advice is given, about 3-5 % of all glances were directed at the FeDS. The advice is then announced with a sound, and during the six seconds while the advice is active the drivers direct 11-13 % of the glances at the FeDS, which corresponds to an accumulated 1-1.3 s. When the advice has disappeared, the percentage decreases again slightly, but remains above the level measured before the advice was given, at around 8-10 %.

The picture looks different for the feedback popups, which are not prompted by a sound. The percentage of glances directed at the FeDS is very similar before the feedback is provided and while it is present, and it decreases only slightly afterwards. The percentage of glances directed to the FeDS before, during and after the feedback popup is higher than in the time slot before the advice popup (Figure 36).

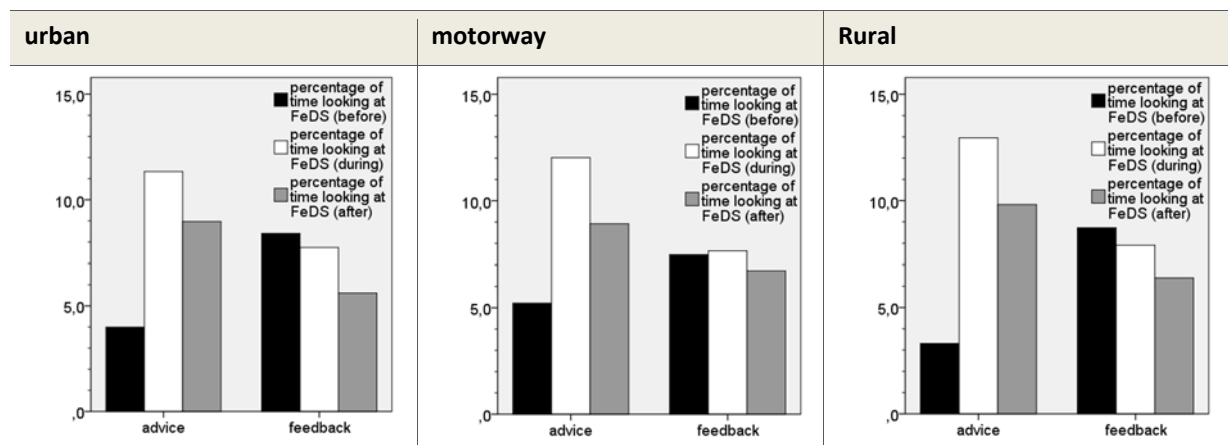


Figure 36: Percentage of glances directed at the FeDS, separated for advice and feedback, in the six seconds before the popup appeared, in the six seconds while the popup was shown, and in the six seconds after the popup had disappeared.

In Figure 37 the distribution of glances to the FeDS over time before, during and after advice and feedback popups is shown. There is a peak in glances to the FeDS within the first two seconds after the sound signal is given for the advice popup. This occurs on all road types. After this initial peak, the likelihood to glance at the FeDS still is slightly increased compared to before the sound, even when the

advice disappears after six seconds. For the feedback popup, there is only a slight peak around the initiation of the popup. This is most pronounced on the motorway. Another small peak appears just after the popup has disappeared.

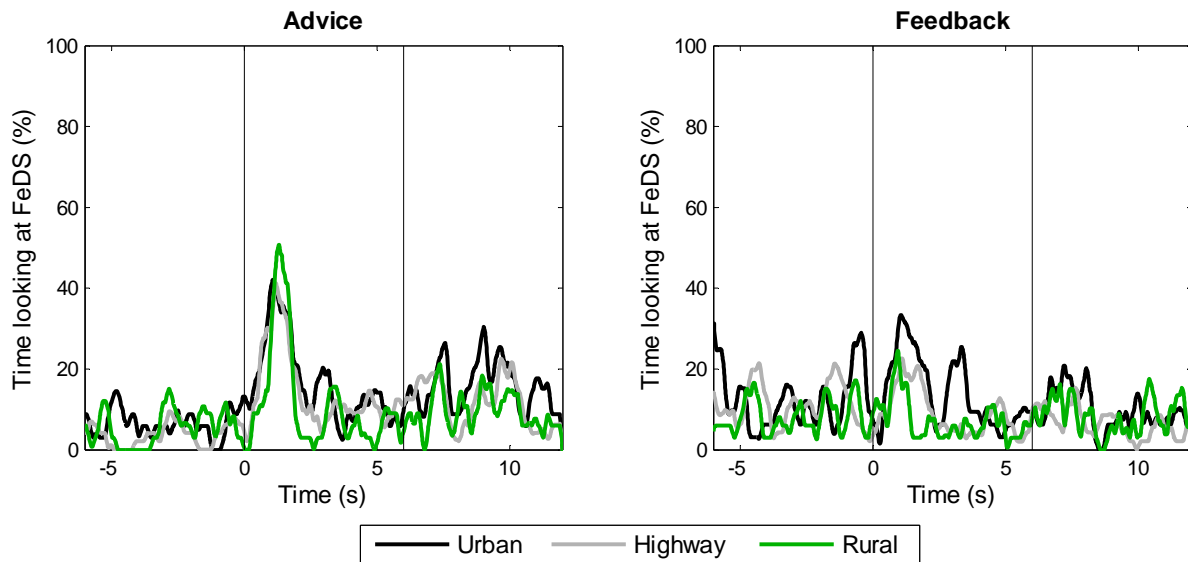


Figure 37: Percentage of time looking at FeDS per road type as a function of time. The vertical lines corresponds to the advice/feedback popup ( $t = 0$  seconds) and when the popup disappears ( $t = 6$  seconds). The two+one road was excluded since it did not contain enough data points.

#### 6.2.4 Discussion

Even though the FeDS obviously and clearly receives visual attention, it is important to notice that drivers do not neglect to glance at the mirrors or speedometer when the FeDS is mounted, or after. The glance intensity to the FeDS is comparable to what is found for the speedometer, such that it cannot be said to be extraordinarily high.

However, on urban roads inattention events as classified by AttenD increase with the FeDS present, as compared to baseline driving, and there is a correlation with the occurrence of popups. It has been noted before, that the AttenD algorithm performance is weakest on urban roads, which demand much more variable glance behaviour than other road types do, in combination with low speeds. This means that one does not travel very far when looking away from the forward roadway for a longer period of time. Therefore, an increased number of AttenD warnings on urban roads may possibly rather indicate a weakness in the AttenD algorithm than showing that the FeDS should be considered overly distracting.

The average glance share devoted to the FeDS lies at about seven per cent in general, but this number is much higher in the vicinity of popups, which may indicate that the popups are rather compelling. On the other hand, not all popups were attended to. Here, the difference between advice and feedback is illustrative. About 10 – 20 % of the advice popups were not looked at, even though they were preceded by the auditory alarm. It can therefore be assumed that most of them were ignored on purpose. It can only be speculated why they were ignored – the driver might have been able to guess without looking,



and react to be sound alone, as he or she already was familiar with the system in T4. It may also be the case that the traffic situation was so complicated that the driver did not want to look away from the forward roadway out of workload reasons. Drivers could expect the feedback to follow the advice, as it always did. This may be an explanation for the increased glance percentage to the FeDS even before the feedback was given. As this value was not higher while the feedback was presented, it is likely that the expectation alone provoked the glance frequency, and that the visual popup alone was not compelling enough to pull more glances. This is also corroborated by the fact that the auditory signal was followed quickly by a drastic increase in glance frequency, which was not the case for the visual popup alone.

The FeDS is an information system that provides both continuous and situation specific advice, which have been shown to have different effects on glance behaviour (Katja Kircher, Fors, & Ahlstrom, 2014). It attracts a similar amount of glances as the speedometer does, and it leads to a slight, but significant increase in glances to targets other than the windscreen. It has to be noted, that this increase is smaller than the percentage of glances directed at the FeDS, which means that the drivers glance less at other non-windscreen targets. As analyses showed that the mirrors and speedometer are not among those targets, it can be speculated that the drivers mainly use their spare capacity to interact visually with the FeDS.

Information that is always missed is as bad as information that is too compelling, and the goal must be to let the driver know of available information in a way that draws enough attention to itself, without being hard to ignore. Having to “lie in waiting” for the feedback is likely not the best solution. A possible alternative would be to let the driver initiate the feedback when it feels acceptable to the driver, such that unnecessary screen monitoring can be avoided. Another solution would be to always allow the driver to access the information that was presented last. Also, an optional sound signal, as for the advice, could be added.

### 6.3 Hypothesis 8: Drivers look more at the speedometer/rev counter when using an ecoDriver system

#### Hypothesis analysis summary table

Hypotheses formulations:

8. The driver will look more at the speedometer/rev counter when using the ecoDriver system

#### Performance indicator (PI):

mean number of speedometer clusters per km  
mean duration of speedometer glances

#### Data reduction method:

Segments outlined by a consecutive sequence of data segmented based on road type and speed limit. The segments have unequal length/duration.

#### Statistical models

Generalized linear mixed model

#### Statistical analysis information

FeDS across different treatment phases	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type Drive (B1, B2, T1, T2, T3, T4, T5, B3, B4)
	Random effects	

#### 6.3.1 Glance behaviour towards the speedometer

One major control parameter for eco-driving is speed, and much of the advice given by the FeDS is centred around speed adjustment. Therefore it is likely that the driver's visual interaction with the speedometer will be influenced by the presence of the FeDS.

The mean number of speedometer clusters is with 5-7 clusters per km higher in urban areas than on other roads (ca. 3-4 clusters/km;  $F(3, 267) = 41.0$ ;  $p < .05$ ). There was a tendency for the glance clusters to become more frequent when the FeDS was introduced, and then they remained frequent throughout the remaining treatment drives and also in the following two baseline drives ( $F(3, 267) = 2.2$ ;  $p < .10$ ).

The mean duration of speedometer glances was slightly shorter in T4 (0.50 s) than in any of the baseline drives (0.56-0.62 s), with a significant difference between T4 and B4 ( $F(3, 257) = 3.5$ ;  $p < .05$ ), and single glances are about .05-.1 s longer on the motorway than the rural road with the other road types in between ( $F(3, 257) = 3.5$ ;  $p < .05$ ). The slightly shorter single glance duration during treatment is counterbalanced by the increased glance cluster frequency, such that the percentage of time spent glancing at the speedometer is approximately equal during B2 and T4, but significantly higher during B3 and B4 ( $F(3, 257) = 7.6$ ;  $p < .05$ ), and this effect is more pronounced on the faster road types highway and two+one road.

### 6.3.2 Discussion

The speedometer receives frequent attention already in baseline (B2) driving – at least in the investigated driving environment both the glance frequency and the percentage of time spent glancing at the speedometer was higher than for all mirrors together. The introduction of the FeDS led to a slight increase in glance frequency to the speedometer, however, the single glance duration even decreased slightly. Only when the FeDS was removed again, the percentage of speedometer glances increased substantially, and mainly on high-speed roads. This can have several possible explanations.

When the FeDS was present, the driver had access to the driving speed both at the speedometer and at the FeDS. If the driver had learned to rely on accurate and frequently updated speed readings, it is not surprising that the amount of glances to the speedometer increased when the FeDS was removed.

While the FeDS was still present, the drivers shared their glances away from traffic between different targets, as they monitored both the FeDS and the speedometer amongst other targets. When the FeDS was removed, it could not be glanced at any more, therefore more potential off-road glance capacity was freed up to be used for monitoring the speedometer.

Also, it is possible that the participants felt that they could not rely on the information given by the FeDS any more, once the FeDS was removed. Therefore they used the acquired knowledge and spent more time in B3 and B4 confirming that they actually went at the desired speed.

Speedometer monitoring was more pronounced on faster roads, which can be due to a more strongly felt necessity to monitor one's speed, lest it become too high, but also that those roads generally constitute a less complex visual environment, such that more spare visual capacity is available to the driver, which is then used for speed monitoring.

The fact that the increased speed monitoring is still observable in B3 and even one month later in B4 indicates that drivers do not simply return to normal, as soon as the support system is removed. Rather, a longer-term glance behavioural change could be observed, which can be taken as an indication that drivers actively monitor their behaviour.

Given that the speedometer appears to be an important asset in the pursuit of an eco-friendly driving style, it is advisable to integrate the eco-support system with the speedometer. This is likely to reduce the percentage of glances away from traffic, and the driver does not have to integrate information from two different displays, which might entail an unnecessary increase in workload.

## 7 Annex G: Detailed results per hypothesis (Driver behaviour)

### 7.1 Hypothesis 9: Using an ecoDriver system the average velocity when cruising will be lower

#### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system the average velocity when cruising will be lower*

9. Using an ecoDriver system, the average speed when cruising will be reduced. [Type A]
10. Using an embedded ecoDriver system, the average speed when cruising will be reduced. [Type B]
11. Using the full ecoDriver system (FeDS), the average speed when cruising will be reduced. [Type C]
12. Using the ecoDriver application (App), the average speed when cruising will be reduced. [Type D]
13. Using a haptic ecoDriver system, the average speed when cruising will be reduced. [Type E]

#### Performance indicator (PI):

Average speed when cruising (avg\_speed\_cruising, km/h )

#### Data reduction method:

500m sections

Cruising\_time\_ratio over 50%, i.e., only 500m sections where at least 50% of the time the driver was cruising

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment (Type A dataset)</b> For both controlled and naturalistic data	Main effect	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded (Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>

## Hypothesis analysis summary table

<b>(Type C dataset)</b>	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline App vs App (Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Non-haptic vs Haptic (Type E dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 7.1.1 Controlled studies

#### 7.1.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom. The results show a statistically significant effect of the system [ $p < 0.001$ ]. On rural roads and motorways, drivers reduce their cruising speed with 2.7 and 3.5 km/h, respectively, when driving with the system. On urban roads, however, their average cruising speed increased with 1.4 km/h. When considering the system on all road types the average speed when cruising is 1.6 km/h lower when driving with ecoDriver compared to baseline.

Table 60: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	13813.9	13813.9	1	33032.6	83.0	<0.001
road_type	6348966.5	3174483.3	2	33086.1	19076.1	<0.001
Main_effect:road_type	26525.6	13262.8	2	32999.8	79.7	<0.001

Table 61: Model summary for type A comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	49.05	44.72	53.39	<0.001
Treatment	1.37	0.79	1.95	<0.001
Rural	18.63	18.03	19.24	<0.001

<b>Motorway</b>	54.31	53.48	55.13	<0.001
<b>Treatment:Rural</b>	-4.10	-4.81	-3.40	<0.001
<b>Treatment:Motorway</b>	-4.90	-5.83	-3.98	<0.001
<b>Random part</b>	<b>N</b>			
<b>Driver_id</b>	143			
<b>Vmc_id</b>	7			
<b>Number of observations</b>	33136			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

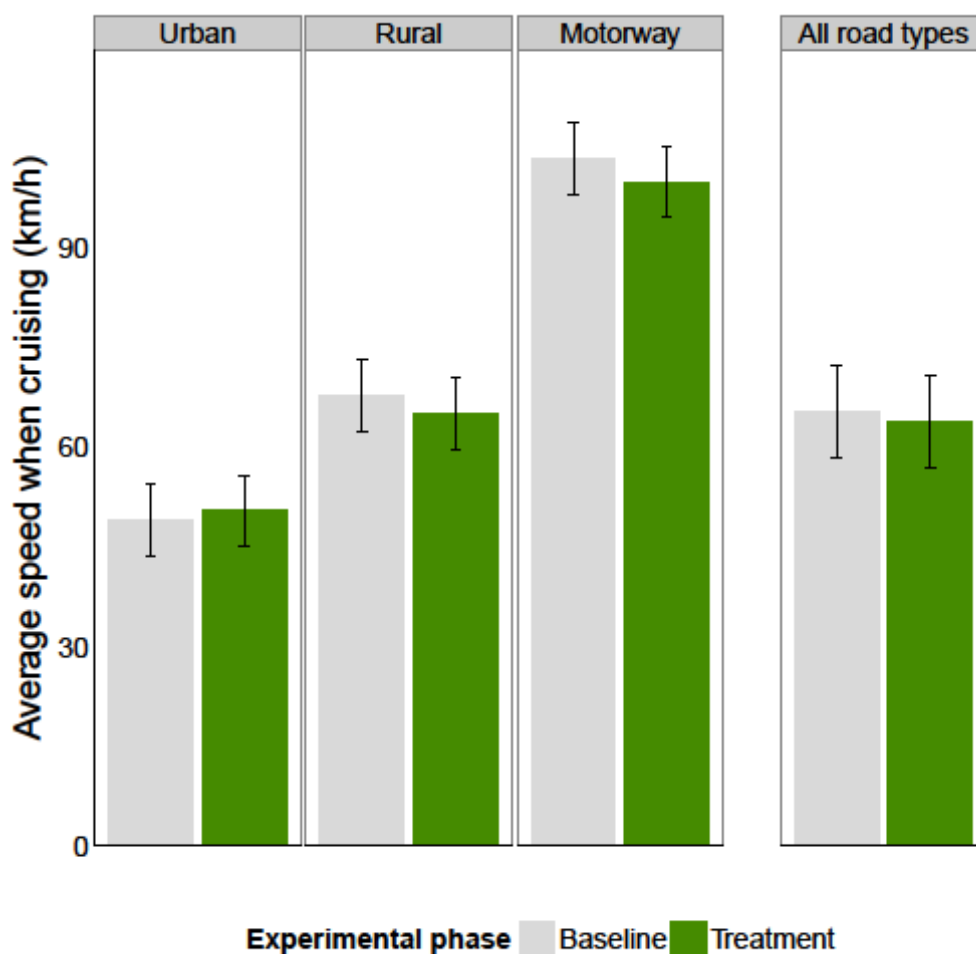


Figure 38: model based average values of average speed when cruising for fixed effects.

Table 62: Average speed when cruising for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates			Tukey multiple comparisons significance test
	Baseline	Treatment	Difference (B-T)	
Urban	49.05	50.43	-1.37	<0.001
Rural	67.69	64.96	2.73	<0.001
Motorway	103.36	99.83	3.53	<0.001
All road types	65.48	63.91	1.56	<0.001

#### Preliminary conclusions:

When driving with an ecoDriver system cruising speed is significantly reduced on motorways and rural roads, whereas it is increased on urban roads.

#### 7.1.1.2 Type B: Baseline embedded vs embedded

Table 63: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	22073.8	22073.8	1	29449.6	148.7	<0.001
road_type	5593876.5	2796938.2	2	29416.1	18843.3	<0.001
Main_effect:road_type	4273.3	2136.6	2	29413.8	14.4	<0.001

Table 64: Model summary for type B comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	54.59	49.60	59.58	<0.001
Embedded	-1.80	-2.39	-1.20	<0.001
Rural	11.88	11.23	12.53	<0.001
Motorway	49.44	48.63	50.25	<0.001
Embedded:Rural	0.58	-0.16	1.32	0.124
Embedded:Motorway	-1.65	-2.55	-0.75	<0.001
Random part	N			
Driver_id	103			
Vmc_id	6			
Number of observations	29498			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

A significant effect of the embedded system on cruising speed is found [ $p < 0.001$ ]: on all road types, the average cruising speed is reduced when driving with an embedded ecoDriver system.

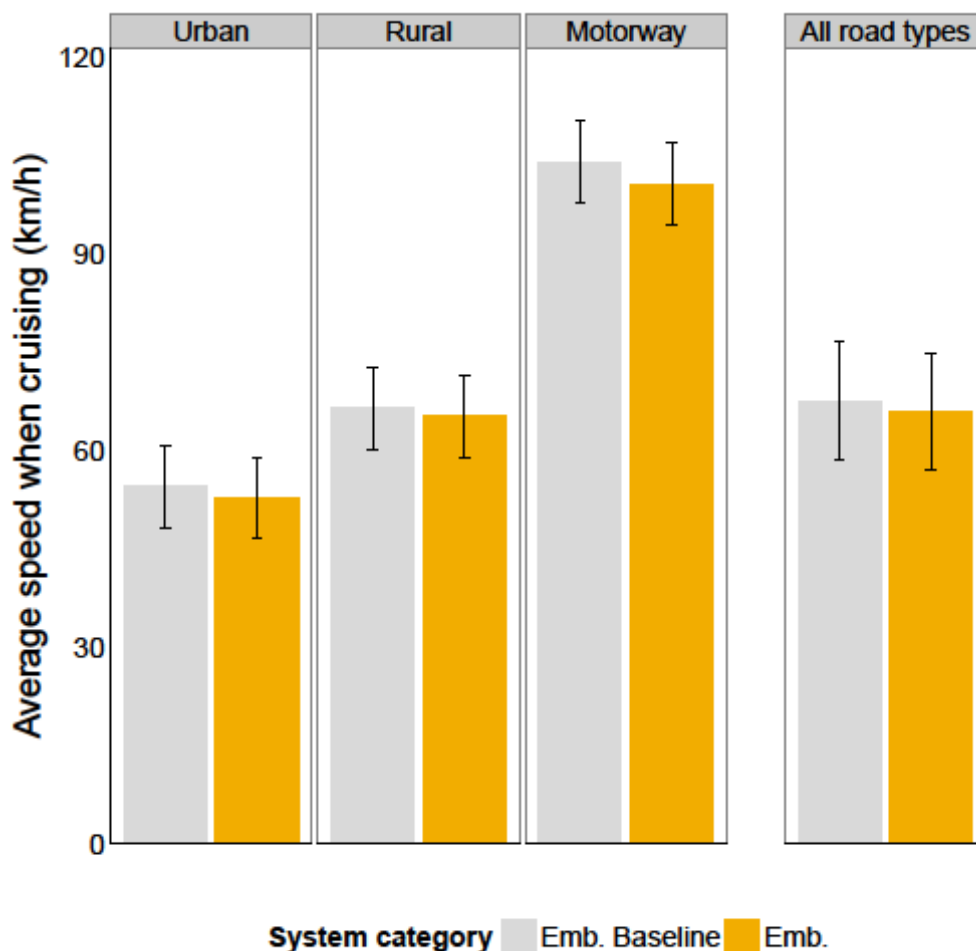


Figure 39: model based average values of average speed when cruising for fixed effects.

Table 65: Average speed when cruising for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	54.59	52.79	1.80	<0.001
Rural	66.47	65.26	1.21	<0.001
Motorway	104.02	100.58	3.45	<0.001
All road types	67.62	65.92	1.71	<0.001

#### Preliminary conclusions:

On all road types, the average cruising speed is reduced when driving with an embedded ecoDriver system.



### 7.1.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 66: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
<b>Main_effect</b>	17660.5	17660.5	1	15608.1	100.1	<0.001
<b>road_type</b>	4402656.9	2201328.4	2	15562.5	12473.0	<0.001
<b>Main_effect:road_type</b>	4027.7	2013.9	2	15586.1	11.4	<0.001

Table 67: Model summary for type C comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	53.92	51.05	56.78	<0.001
FeDS	-2.57	-3.51	-1.62	<0.001
Rural	13.27	12.27	14.26	<0.001
Motorway	50.87	49.79	51.94	<0.001
FeDS:Rural	1.42	0.26	2.58	0.017
FeDS:Motorway	-1.09	-2.32	0.13	0.080
<b>Random part</b>	<b>N</b>			
Driver_id	59			
Vmc_id	3			
<b>Number of observations</b>	15636			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

A significant effect of the FeDS on cruising speed is found [ $p < 0.001$ ]: on all road types, the average cruising speed is reduced when driving with the FeDS system.

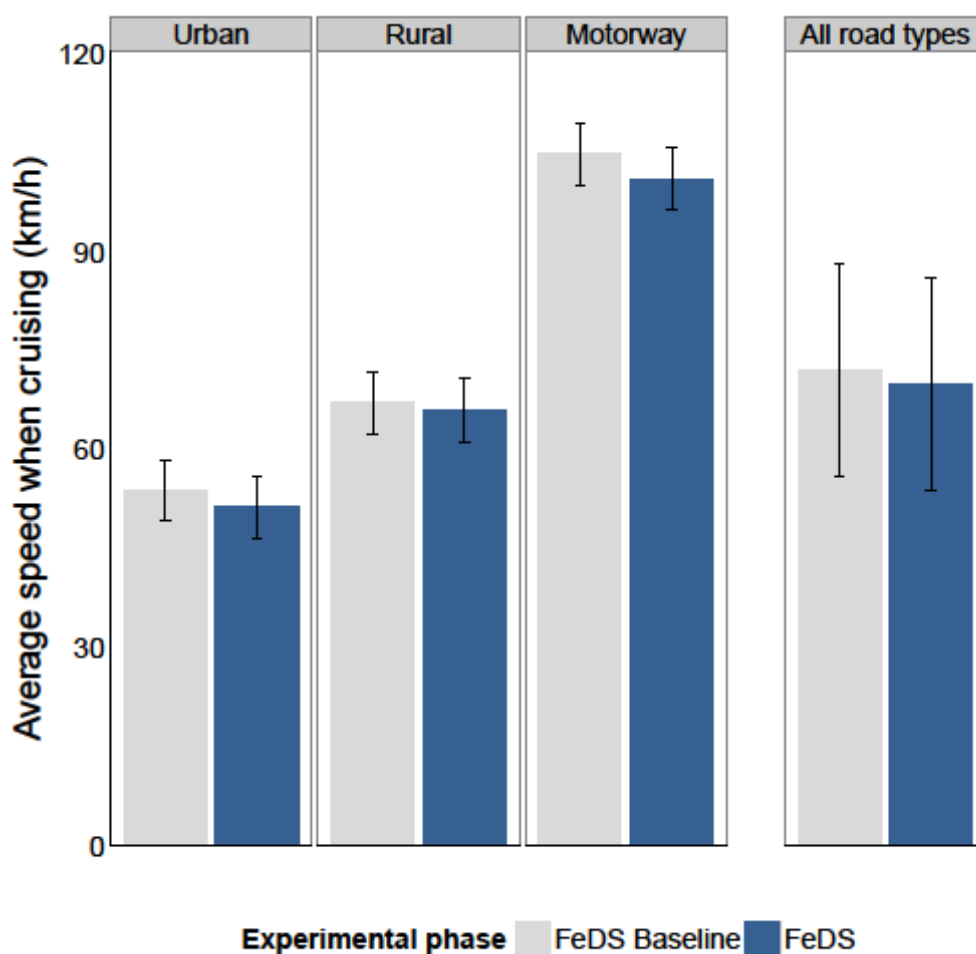


Figure 40: model based average values of average speed when cruising for fixed effects.

Table 68: Average speed when cruising for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	53.92	51.35	2.57	<0.001
Rural	67.18	66.03	1.15	0.014
Motorway	104.78	101.12	3.66	<0.001
All road types	72.13	70.01	2.13	<0.001

**Preliminary conclusions:**

On all road types, the average cruising speed is reduced when driving with the FeDS.

## 7.1.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 69: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	38.5	38.5	1	3608.1	0.2	0.656
road_type	1048164.8	1048164.8	1	3615.8	5393.8	<0.001
Main_effect:road_type	1675.1	1675.1	1	3612.7	8.6	0.003

Table 70: Model summary for type D comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	20.43	3.88	36.98	0.136
App	1.81	0.00	3.62	0.050
Rural	40.83	39.46	42.19	<0.001
App:Rural	-3.13	-5.23	-1.04	0.003
Random part	N			
Driver_id	40			
Vmc_id	2			
Number of observations	3638			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

There was a significant effect of the App [ $p=0.05$ ], showing an increase of 1.8 km/h in cruising speed when driving with the App. However, results showed that on rural roads speed was decreased by 1.3 km/h, whereas the effect on urban roads was not significant.

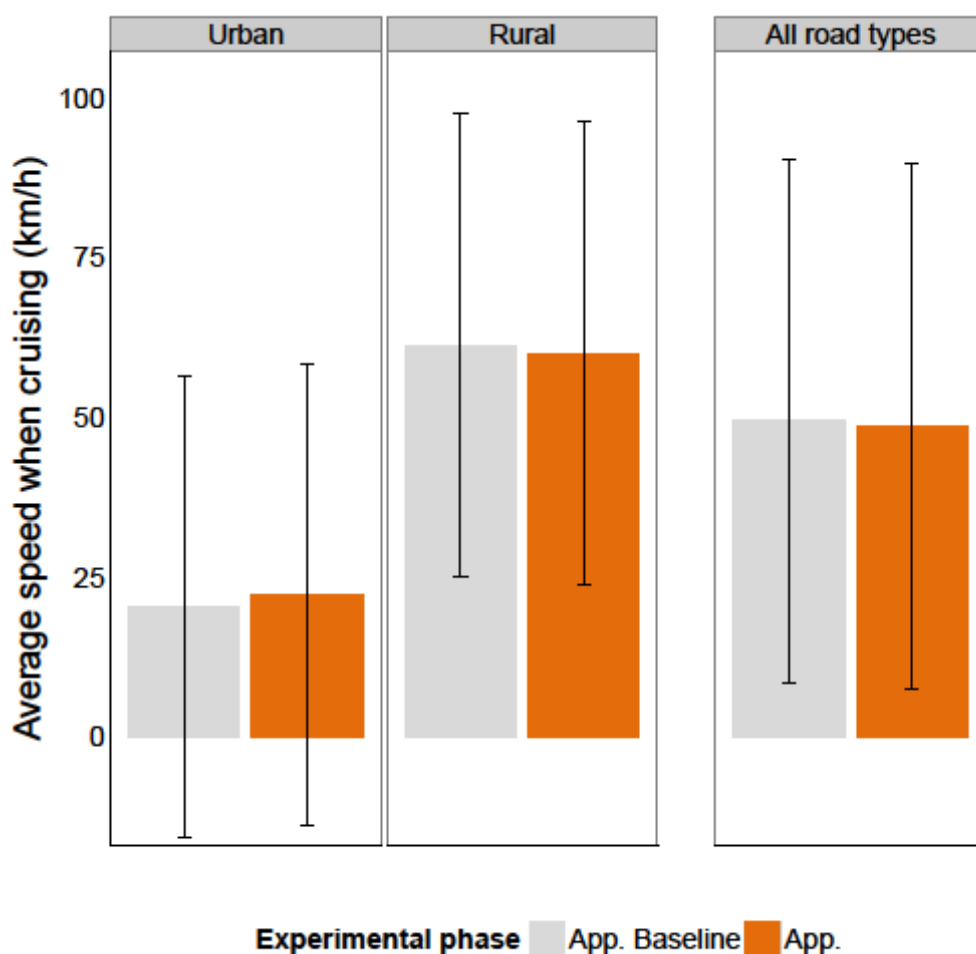


Figure 41: model based average values of average speed when cruising for fixed effects.

Table 71: Average speed when cruising for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	20.43	22.24	-1.81	0.199
Rural	61.26	59.93	1.33	0.076
All road types	49.39	48.61	0.78	0.307

**Preliminary conclusions:**

There was no significant effect of the ecoDriver App on the average speed when cruising on either road type.

### 7.1.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 72: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	347.0	347.0	1	4824.4	3.5	0.060
road_type	79746.7	79746.7	1	4866.8	811.8	<0.001
Main_effect:road_type	1327.2	1327.2	1	4835.1	13.5	<0.001

Table 73: Model summary for type E comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	49.83	48.73	50.92	<0.001
Haptic	-1.81	-2.87	-0.76	<0.001
Rural	8.17	7.12	9.23	<0.001
Haptic:Rural	2.37	1.10	3.63	<0.001
Random part	N			
Driver_id	36			
Number of observations	4867			

Results showed a significant main effect of Haptic [ $p < 0.001$ ]: with the haptic system, the average cruising speed was 1.8 km/h lower than with the non-haptic system. This effect was only found on urban roads; on rural roads the effect was not significant.

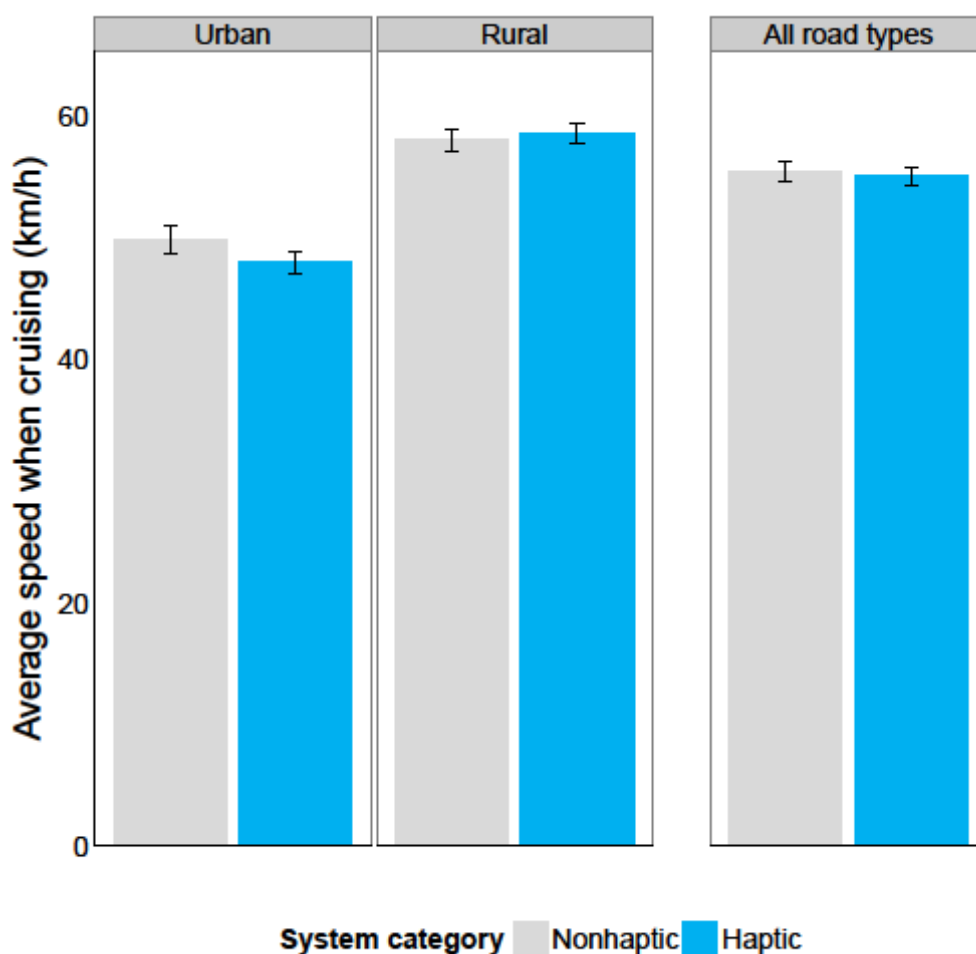


Figure 42: model based average values of average speed when cruising for fixed effects.

Table 74: Average speed when cruising for the different systems and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	49.83	48.01	1.81	0.004
Rural	58.00	58.55	-0.55	0.457
All road types	55.46	55.04	0.41	0.234

**Preliminary conclusions:**

On urban roads, the average cruising speed was about 1.8 km/h lower when driving with the haptic interface (compared to non-haptic).

### 7.1.2 Naturalistic studies

#### 7.1.2.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 75: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	16294.6	16294.6	1	59499.5	47.5	<0.001
road_type	25187670.2	12593835.1	2	59490.7	36707.3	<0.001
Main_effect:road_type	8489.5	4244.8	2	59486.5	12.4	<0.001

Table 76: Model summary for type A comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	59.40	52.81	65.99	0.003
Treatment	-1.95	-2.55	-1.35	<0.001
Rural	18.29	17.73	18.85	<0.001
Motorway	53.77	53.25	54.29	<0.001
Treatment:Rural	1.94	1.13	2.74	<0.001
Treatment:Motorway	0.54	-0.21	1.29	0.156
Random part	N			
Driver_id	20			
Vmc_id	2			
Number of observations	59501			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

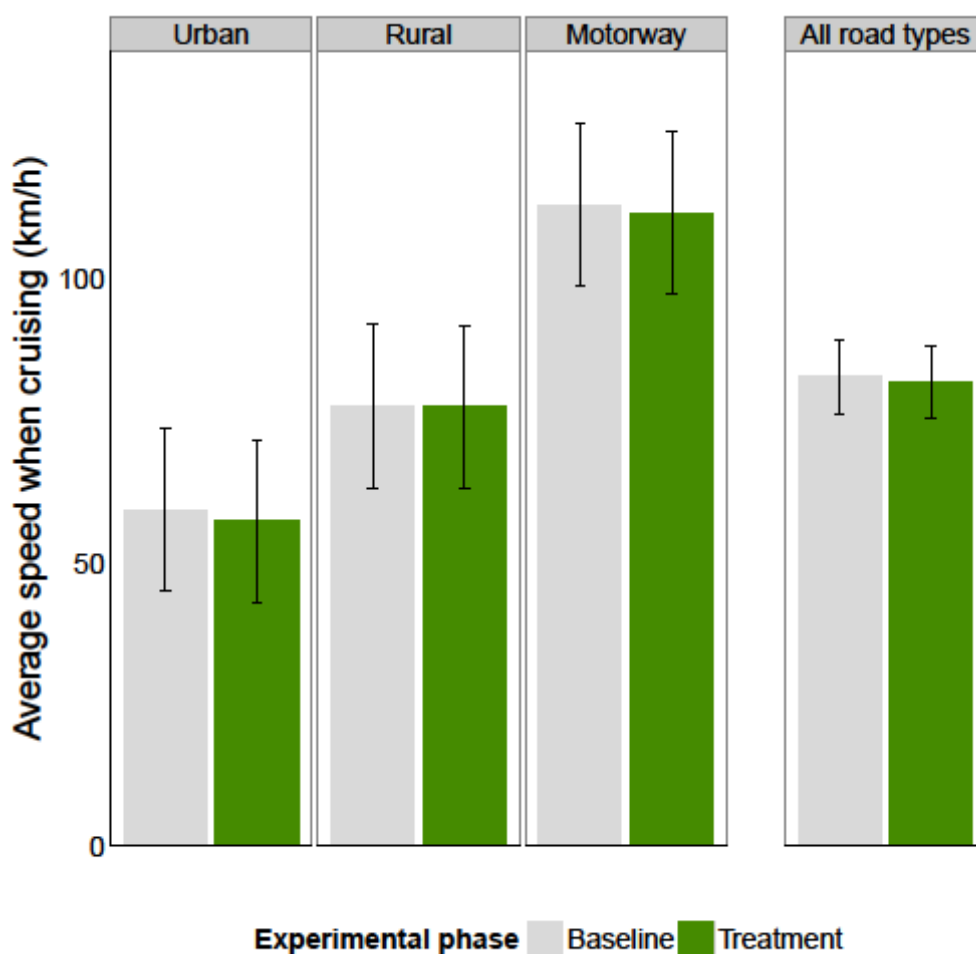


Figure 43: model based average values of average speed when cruising for fixed effects.

Table 77: Average speed when cruising for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	59.40	57.45	1.95	<0.001
Rural	77.69	77.67	0.02	1.000
Motorway	113.17	111.76	1.41	<0.001
All road types	82.91	81.89	1.03	<0.001

#### Preliminary conclusions:

On urban roads and motorways, the average cruising speed was reduced when driving with an ecoDriver system during naturalistic drives. For rural roads during the naturalistic drives there was no significant effect on average cruising speed of ecoDriver compared to baseline.



### 7.1.3 Results summary

Table 78: Comparisons of the average cruising speed effect size (km/h difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-1.37	1.8	2.57	-1.81 (N.S.)	1.81	1.95
Rural	2.73	1.21	1.15 (N.S.)	1.33 (N.S.)	-0.55 (N.S.)	0.02 (N.S.)
Motorway	3.53	3.45	3.66	-	-	1.41
All road types	1.56	1.71	2.13	-	0.41 (N.S.)	1.03

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-2.79	3.3	4.76	-8.86 (N.S.)	3.63	3.28
Rural	4.04	1.82	1.71 (N.S.)	2.17 (N.S.)	-0.95 (N.S.)	0.03 (N.S.)
Motorway	3.42	3.32	3.5	-	-	1.25
All road types	2.39	2.53	2.95	-	0.74 (N.S.)	1.24

### 7.1.4 Conclusions and implications

The usage of the ecoDriver systems reduced average cruising speed in almost all categories. One notable exception, which occurred when taking all systems into account during controlled drives, is a higher expected average speed when cruising on urban roads for the ecoDriver systems. However, considering Embedded or the FeDS systems separately, average cruising speed is reduced on all road types, including urban, by about 2-4 km/h. For motorways this effect is most pronounced with an approximate 3.5 km/h reduction in average cruising speed compared to baseline. The App (android application) ecoDriver system did not show significant reduction in average cruising speed compared to baseline. In fact the data showed a (non-significant) increase of speed on urban roads. Do note that the App subset of the data had relatively few data points (3638 segments, compared to 33136 for all systems). The haptic ecoDriver system reduced cruising speed in urban settings by 1.81 km/h compared to the non-haptic version of the ecoDriver system. For naturalistic drives, the ecoDriver system reduced average cruising speed by around 1 km/h across all road types. Overall, the lower average cruising speeds will translate into safer roads if the ecoDriver system is widely implemented.

## 7.2 Hypothesis 10: Using an ecoDriver system the average free velocity will be reduced

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system the average free velocity will be reduced*

1. Using an ecoDriver system, the average free velocity will be reduced. [Type A]
2. Using an embedded ecoDriver system, the average free velocity will be reduced. [Type B]
3. Using the full ecoDriver system, (FeDS) the average free velocity will be reduced. [Type C]
4. Using the ecoDriver application, (App), the average free velocity will be reduced. [Type D]
5. Using a haptic ecoDriver, system the average free velocity will be reduced. [Type E]

#### Performance indicator (PI):

Average speed during free driving (avg\_speed\_freedriving)

#### Data reduction method:

500m sections

Freedriving\_time\_ratio over 50%%, i.e., only 500m sections where at least 50% of the time was free driving

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> <b>(Type A dataset)</b> <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> <b>(Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b> <b>(Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline App vs App</b> <b>(Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id

## Hypothesis analysis summary table

Non-haptic vs Haptic (Type E dataset)	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 7.2.1 Controlled studies

#### 7.2.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 79: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	2357.1	2357.1	1	6506.0	13.0	<0.001
road_type	1345313.1	672656.6	2	6378.0	3700.5	<0.001
Main_effect:road_type	883.1	441.6	2	6455.0	2.4	0.088

Table 80: Model summary for type A comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	46.54	40.74	52.34	<0.001
Treatment	-1.43	-2.71	-0.16	0.027
Rural	29.20	27.93	30.48	<0.001
Motorway	48.98	46.93	51.03	<0.001
Treatment:Rural	-1.26	-2.89	0.38	0.132
Treatment:Motorway	0.89	-1.23	3.02	0.410
Random part	N			
Driver_id	124			
Vmc_id	6			
Number of observations	6516			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

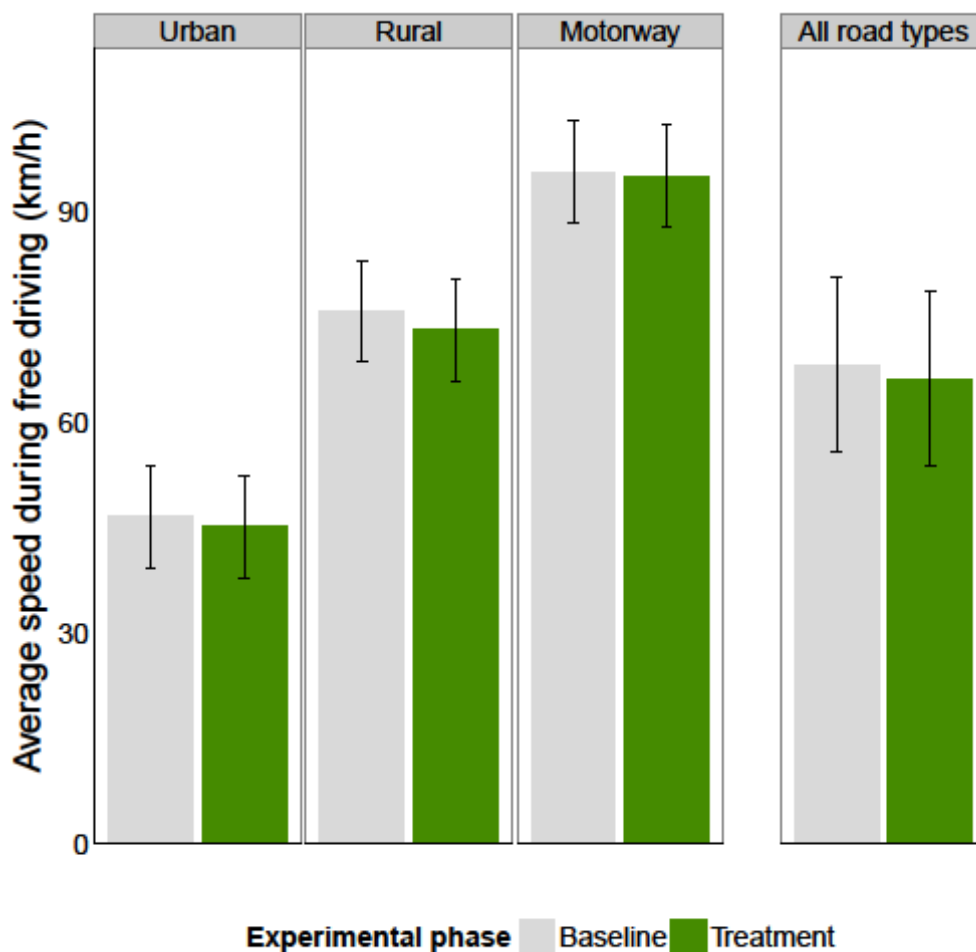


Figure 44: model based average values of average speed during free driving for fixed effects.

Table 81: Average speed during free driving for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	46.54	45.10	1.43	0.222
Rural	75.74	73.05	2.69	<0.001
Motorway	95.52	94.98	0.54	0.990
All road types	68.11	66.08	2.02	0.001

**Preliminary conclusions:**

On rural roads, the EcoDriver system significantly reduces average speed during free driving.

## 7.2.1.2 Type B: Baseline embedded vs embedded

Table 82: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	3550.6	3550.6	1	4550.3	25.3	<0.001
road_type	700430.5	350215.2	2	4463.6	2490.7	<0.001
Main_effect:road_type	5806.1	2903.0	2	4539.1	20.6	<0.001

Table 83: Model summary for type B comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	56.25	50.25	62.25	<0.001
Embedded	-5.97	-7.33	-4.61	<0.001
Rural	14.65	13.03	16.28	<0.001
Motorway	41.10	39.19	43.02	<0.001
Embedded:Rural	5.71	3.72	7.70	<0.001
Embedded:Motorway	5.32	3.31	7.33	<0.001
Random part	N			
Driver_id	10			
Vmc_id	5			
Number of observations	4557			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

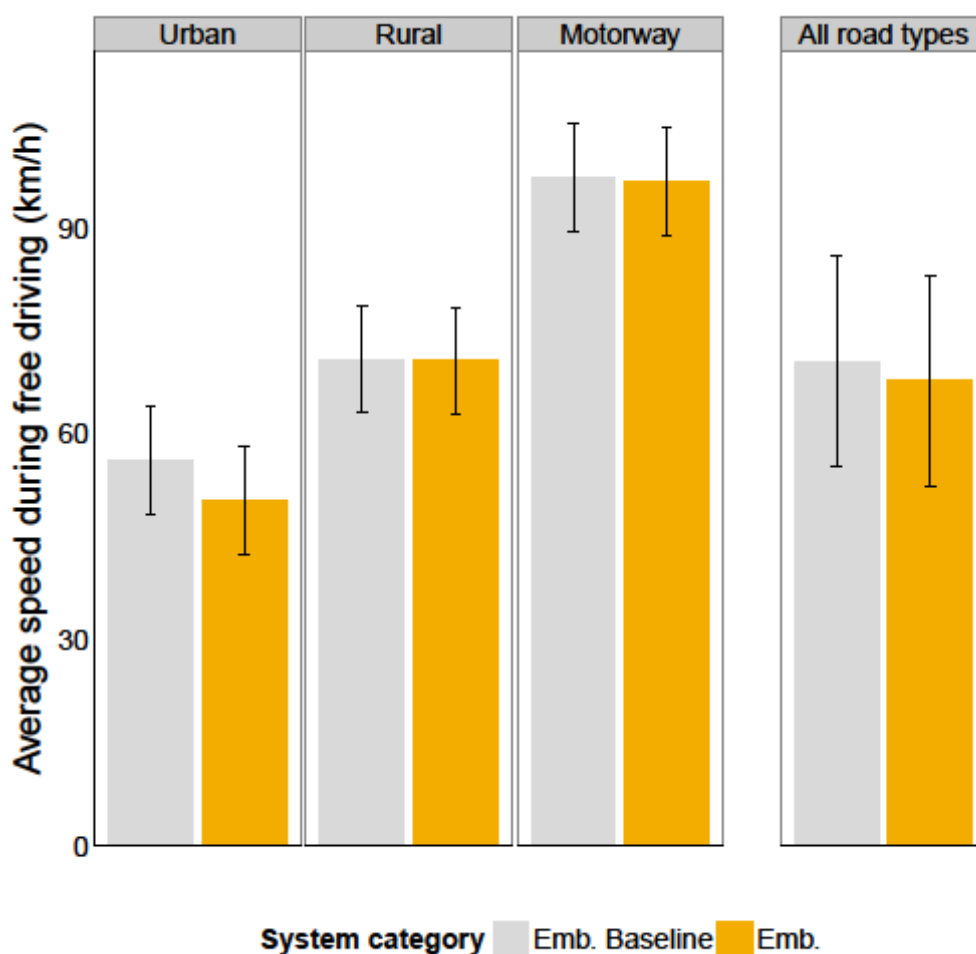


Figure 45: model based average values of average speed during free driving for fixed effects.

Table 84: Average speed during free driving for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	56.25	50.28	5.97	<0.001
Rural	70.90	70.64	0.26	0.999
Motorway	97.35	96.70	0.65	0.960
All road types	70.61	67.74	2.87	<0.001

**Preliminary conclusions:**

For the embedded EcoDriver systems, on urban roads average speed during free driving was greatly reduced.

## 7.2.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 85: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	2361.6	2361.6	1	3964.5	17.1	<0.001
road_type	660466.3	330233.2	2	3920.5	2386.2	<0.001
Main_effect:road_type	3755.1	1877.6	2	3940.3	13.6	<0.001

Table 86: Model summary for type C comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	55.65	50.33	60.96	<0.001
FeDS	-5.47	-7.04	-3.90	<0.001
Rural	16.41	14.48	18.34	<0.001
Motorway	42.05	40.03	44.06	<0.001
FeDS:Rural	5.20	2.90	7.51	<0.001
FeDS:Motorway	4.86	2.72	7.00	<0.001
Random part	N			
Driver_id	10			
Vmc_id	3			
Number of observations	3965			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

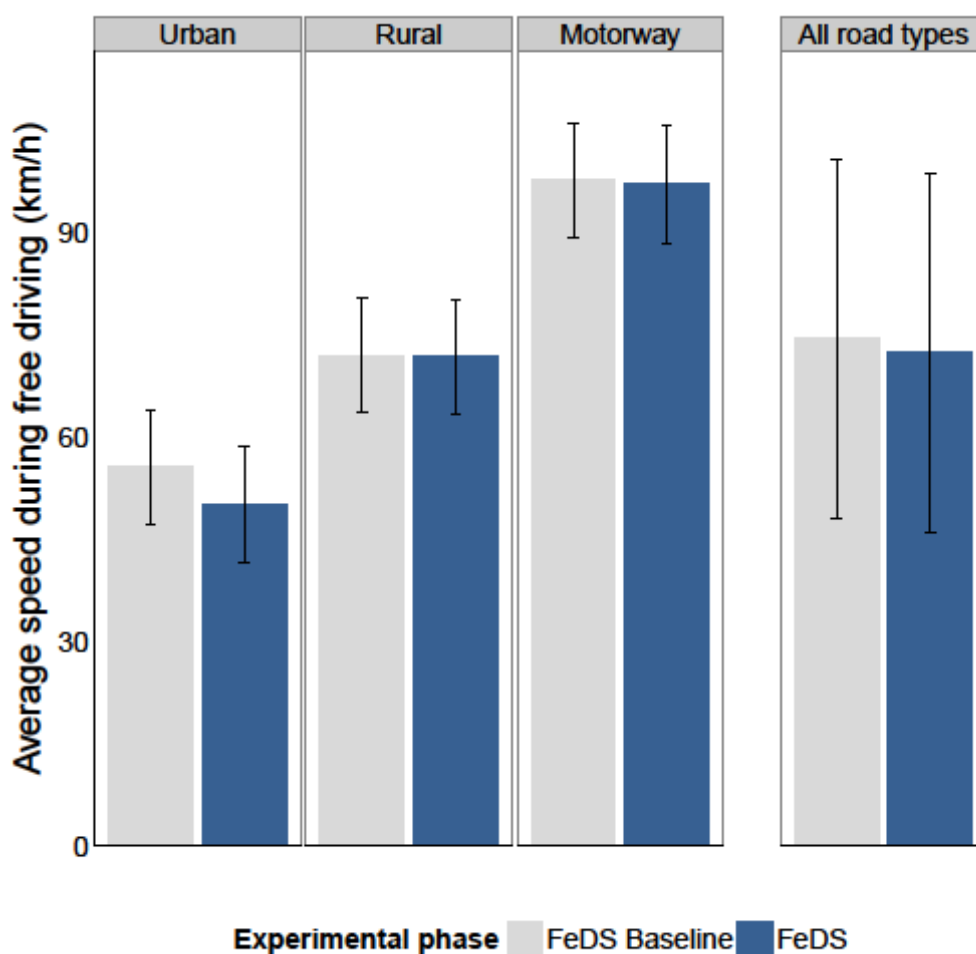


Figure 46: model based average values of average speed during free driving for fixed effects.

Table 87: Average speed during free driving for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	55.65	50.18	5.47	<0.001
Rural	72.05	71.78	0.27	1.000
Motorway	97.69	97.08	0.61	0.968
All road types	74.47	72.40	2.07	0.012

**Preliminary conclusions:**

For the FeDS EcoDriver systems, on urban roads average speed during free driving was greatly reduced.



#### 7.2.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 88: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	79.3	79.3	1	1536.4	0.4	0.522
road_type	760275.8	760275.8	1	1954.1	3936.3	<0.001
Main_effect:road_type	54.6	54.6	1	1952.0	0.3	0.595

Table 89: Model summary for type D comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	19.89	6.09	33.70	0.105
App	-0.09	-2.44	2.26	0.939
Rural	44.45	42.59	46.32	<0.001
App:Rural	-0.75	-3.50	2.00	0.595
Random part	N			
Driver_id	37			
Speed_limit	2			
Number of observations	1959			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

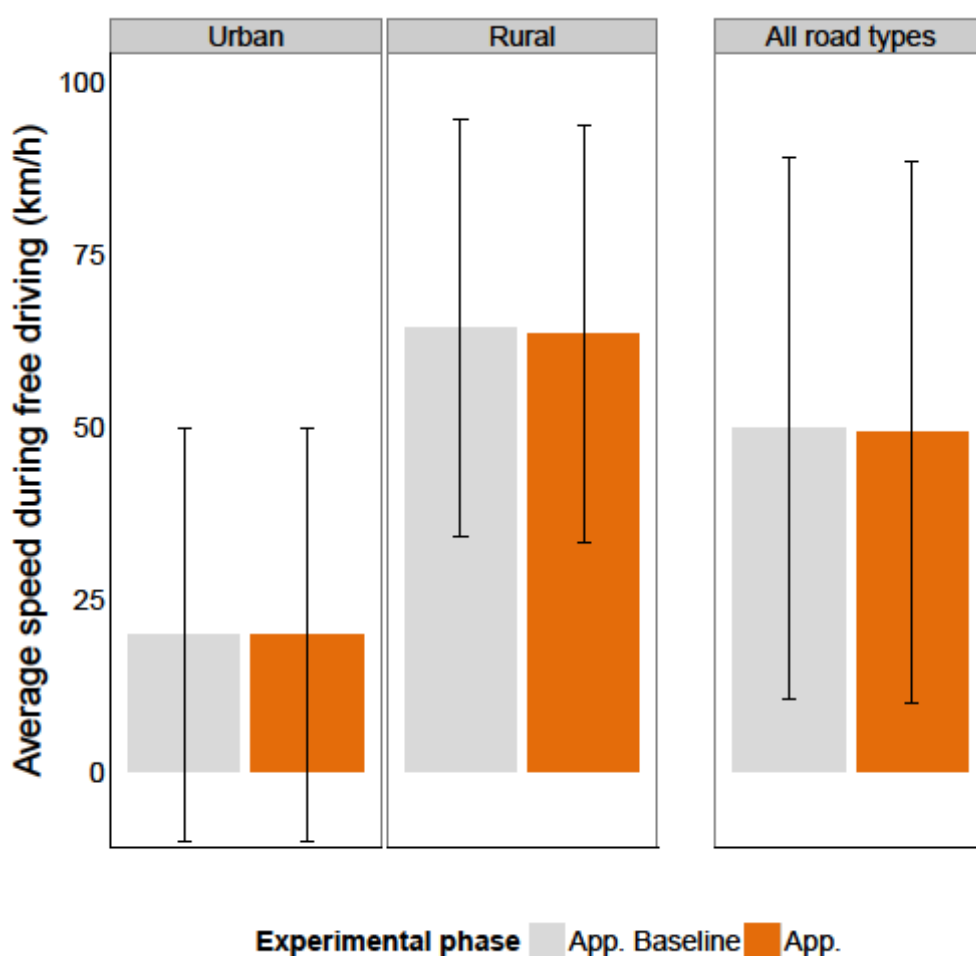


Figure 47: model based average values of average speed during free driving for fixed effects.

Table 90: Average speed during free driving for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	19.89	19.80	0.09	1.000
Rural	64.35	63.51	0.84	0.693
All road types	49.89	49.30	0.59	0.595

#### Preliminary conclusions:

For the Android EcoDriver application (App), average speed during free driving was not significantly reduced.

### 7.2.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 91: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	23.4	23.4	1	26.0	0.4	0.532
road_type	2247.6	2247.6	1	26.0	38.5	<0.001
Main_effect:road_type	22.7	22.7	1	26.0	0.4	0.538

Table 92: Model summary for type D comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	38.09	27.50	48.67	<0.001
Haptic	4.52	-7.48	16.52	0.467
Rural	24.55	12.55	36.56	<0.001
Haptic:Rural	-4.49	-18.58	9.60	0.538
Random part	N			
Driver_id	15			
Number of observations	26			

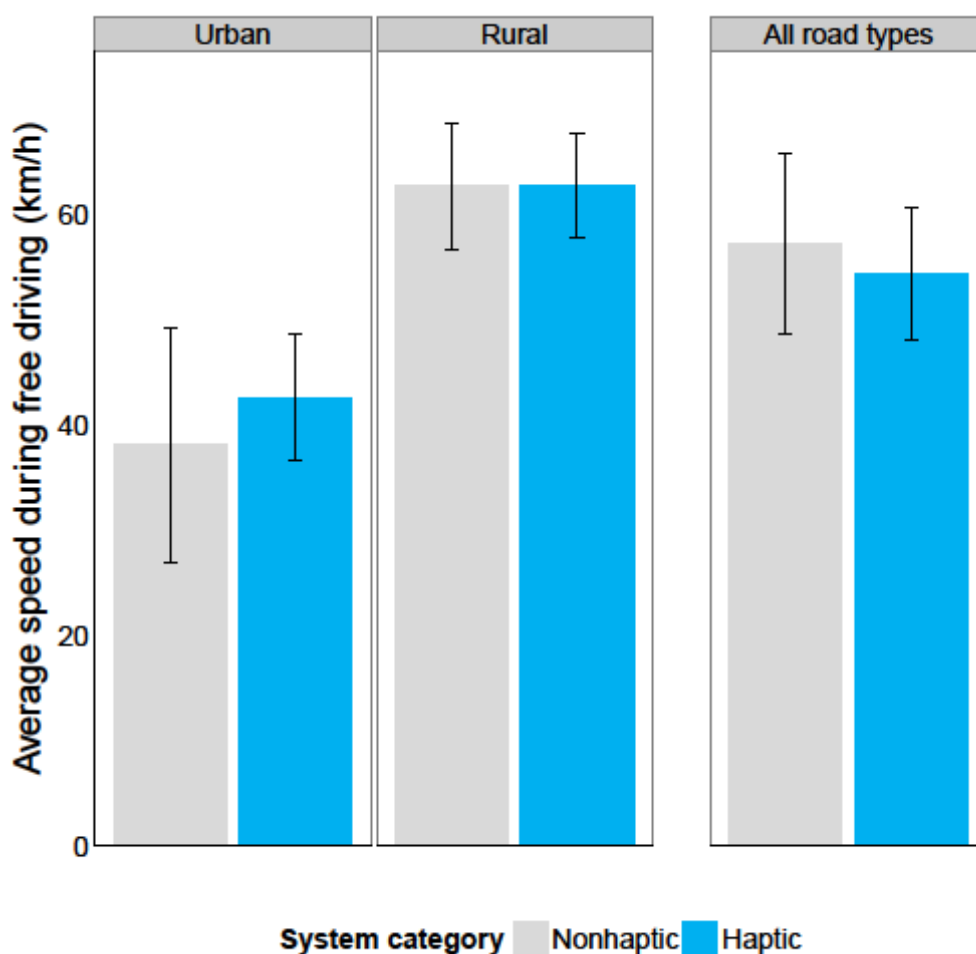


Figure 48: model based average values of average speed during free driving for fixed effects.

Table 93: Average speed during free driving for the different systems and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	38.09	42.61	-4.52	0.878
Rural	62.64	62.67	-0.03	1.000
All road types	57.18	54.41	2.77	0.593

**Preliminary conclusions:**

There was no significant difference between nonhaptic versus haptic for average speed during free driving. Note that there was very little data which met the free driving criteria for this analysis.

## 7.2.2 Naturalistic studies

### 7.2.2.1 TypeA : Baseline vs Treatment

*No free driving average speed data for naturalistic drives.*

### 7.2.3 Results summary

Table 94: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	1.43 (N.S.)	5.97	5.47	0.09 (N.S.)	-4.52 (N.S.)	-
Rural	2.69	0.26 (N.S.)	0.27 (N.S.)	0.84 (N.S.)	-0.03 (N.S.)	-
Motorway	0.54 (N.S.)	0.65 (N.S.)	0.61 (N.S.)	-	-	-
All road types	2.02	2.87	2.07	0.59 (N.S.)	2.77 (N.S.)	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	3.07 (N.S.)	10.61	9.83	0.45 (N.S.)	-11.87 (N.S.)	-
Rural	3.55	0.37 (N.S.)	0.37 (N.S.)	1.31 (N.S.)	-0.05 (N.S.)	-
Motorway	0.57 (N.S.)	0.67 (N.S.)	0.62 (N.S.)	-	-	-
All road types	2.97	4.06	2.78	1.18 (N.S.)	4.84 (N.S.)	-

### 7.2.4 Conclusions and implications

When filtering to keep only segments with >50% free driving, 6,516 segments are used in the analysis (all systems, controlled). This is much less data than for other PIs (e.g., 33,136 for cruising speed, all systems, controlled). This relatively small sample potentially caused the majority of analyses to be statistically insignificant. However, when an effect was significant, it was often quite large, ranging from a 3.6% to a 10.6% reduction in average free-driving speed. This reduction in free driving speed was significant on rural roads (2.7%) when looking at all systems of controlled drives. When considering categories of the systems, the embedded and FeDS ecoDriver systems showed significant reduction in average speed during free driving on urban roads (10.6% and 9.8% respectively). Looking at the effect of the systems on all road types the three categories of all systems, embedded and FeDS also showed a significant reduction in average free driving speed of about 2 km/u. The App data showed no significant difference between treatment and baseline, and neither did the haptic against non-haptic comparison. However, note that even less data was available for these subcategories. When the effects on average free driving speed were found to be significant, they were substantial compared to other speed related driver performance indicators (e.g. hypothesis 9, related to cruising speed). The current results indicate that when the ecoDriver system has effect on driving behaviour during free driving, and it can be substantial in lowering average speeds.

### 7.3 Hypothesis 11: Using an ecoDriver system, the speed will change before intersections without traffic lights

#### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, speed will change when driving before locations where a low speed is recommended by the system: intersections without traffic lights*

1. Compared to baseline, the average speed will be reduced before intersections without traffic lights when using an ecoDriver system. [Type A]
2. Compared to baseline, the average speed will be reduced before intersections without traffic lights when using an embedded system. [Type B]
3. Compared to baseline, the average speed will be reduced before intersections without traffic lights when using the full ecoDriver system. [Type C]
4. Compared to baseline, the average speed will be reduced before intersections without traffic lights when using the ecoDriver application. [Type D]
5. Compared to a non-haptic system, the average speed will be reduced before intersections without traffic lights when using a haptic ecoDriver system. [Type E]

#### Performance indicator (PI):

Avg\_speed\_distance\_based (km/h) for section of road before event (300m)

#### Data reduction method:

Event-based data divided into sub-sections for the analysis: – before 300m, spot, after 300m

Controlled data only.

Where data was available for one road type only; road\_type removed as a fixed effect

Where data was available for one VMC only; Vmc\_id removed as a random effect.

Avg\_speed\_distance\_based between 10-150 km/h

Removed all cases where vehicle was stationary during the event (stationary\_time\_ratio0 <100%)

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment (Type A dataset)</b> For both controlled and naturalistic data	Main effect	<ul style="list-style-type: none"> <li>• Baseline</li> <li>• Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded (Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_embedded</li> <li>• Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id

## Hypothesis analysis summary table

<b>Baseline FeDS vs FeDS (Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline App vs App (Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Vmc_id, Driver_id
<b>Non-haptic vs Haptic (Type E dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 7.3.1 Controlled studies

#### 7.3.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterwhaite approximation for the degrees of freedom.

Table 95: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	30363.8	30363.8	1	95814.4	205.5	<0.001
road_type	8126713.3	4063356.7	2	95856.7	27505.9	<0.001
Main_effect:road_type	120152.0	60076.0	2	95779.7	406.7	<0.001

Table 96: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	44.48	39.46	49.49	<0.001
Treatment	1.40	1.16	1.64	<0.001
Rural	16.80	16.50	17.10	<0.001
Motorway	49.41	48.66	50.16	<0.001
Treatment:Rural	-4.83	-5.18	-4.48	<0.001
Treatment:Motorway	-6.16	-7.04	-5.28	<0.001
Random part	N			
Driver_id	143			
Vmc_id	7			



Number of observations	95911
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Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

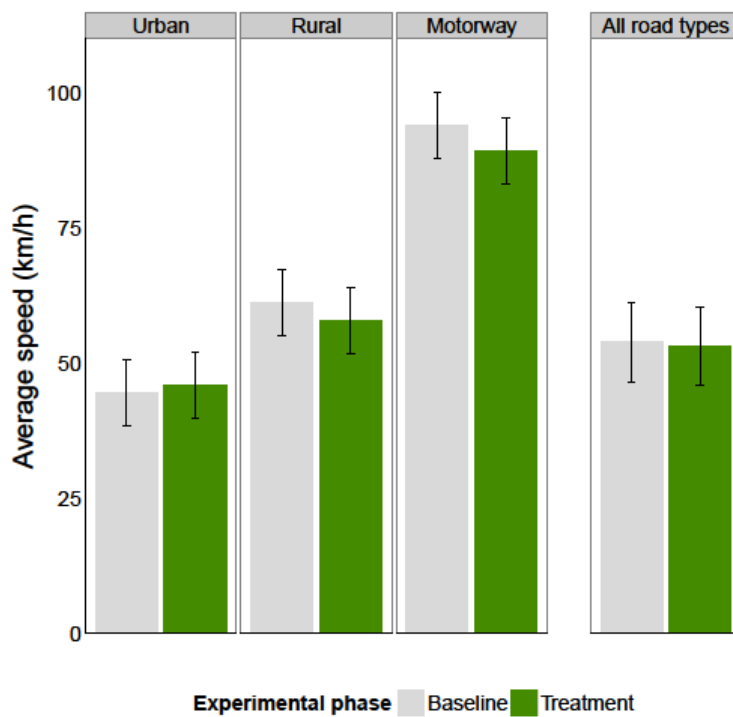


Figure 49: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 97 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	44.48	45.87	-1.40	<0.001
Rural	61.27	57.84	3.43	<0.001
Motorway	93.88	89.12	4.76	<0.001
All road types	53.86	53.15	0.71	<0.001

#### Preliminary conclusions:

Overall, there is a significant positive effect of the ecoDriver systems on vehicle speeds before intersections without traffic lights on rural roads and motorways. Drivers reduced their average speed on the 300m approach to the intersection by 3.4 km/h on rural roads and 4.8 km/h on motorways, when driving with the system. This corresponds to a positive effect of the ecoDriver system on vehicle speed. There is an unexpected increase in speed before urban intersections.

### 7.3.1.2 Type B: Baseline embedded vs embedded

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 98: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	29664.5	29664.5	1	82502.8	211.6	<0.001
road_type	6287250.3	3143625.1	2	82525.8	22426.2	<0.001
Main_effect:road_type	28097.3	14048.6	2	82471.2	100.2	<0.001

Table 99: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	48.18	43.26	53.09	<0.001
Embedded	0.06	-0.20	0.32	0.649
Rural	12.86	12.51	13.21	<0.001
Motorway	47.52	46.79	48.26	<0.001
Embedded:Rural	-2.18	-2.58	-1.79	<0.001
Embedded:Motorway	-4.85	-5.72	-3.99	<0.001
Random part	N			
Driver_id	103			
Vmc_id	6			
Number of observations	82563			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

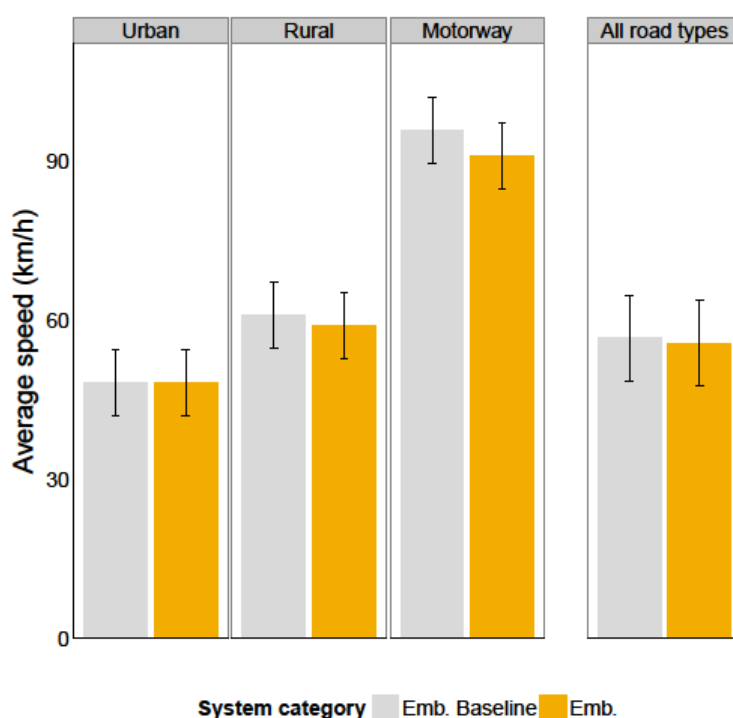


Figure 50: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 100 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	48.18	48.24	-0.06	0.997
Rural	61.03	58.91	2.12	<0.001
Motorway	95.70	90.91	4.79	<0.001
All road types	56.62	55.68	0.94	<0.001

#### Preliminary conclusions:

Overall, there is a significant positive effect of the embedded ecoDriver systems on vehicle speeds before intersections without traffic lights on rural roads and motorways. Drivers reduced their average speed on the 300m approach to the intersection by 2.1 km/h on rural roads and 4.8 km/h on motorways, when driving with the system. This corresponds to a positive effect of the embedded ecoDriver systems on vehicle speed. There is no significant effect of these systems on speed before intersections without traffic lights on urban roads.

### 7.3.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 101: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	9771.4	9771.4	1	28707.2	71.3	<0.001
road_type	5272407.9	2636203.9	2	28707.7	19226.7	<0.001
Main_effect:road_type	970.7	485.3	2	28690.1	3.5	0.029

Table 102: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	45.20	42.80	47.61	<0.001
FeDS	-1.25	-1.69	-0.81	<0.001
Rural	16.18	15.67	16.69	<0.001
Motorway	51.08	50.24	51.93	<0.001
FeDS:Rural	0.13	-0.48	0.74	0.680
FeDS:Motorway	-1.23	-2.25	-0.22	0.017
Random part	N			
Driver_id	59			
Vmc_id	3			
Number of observations	28746			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

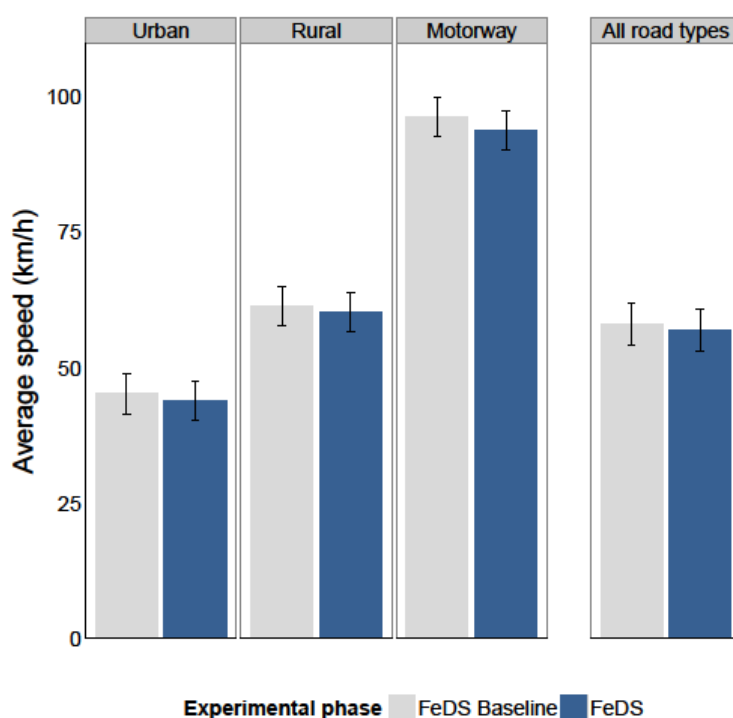


Figure 51: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 103 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	45.20	43.96	1.25	<0.001
Rural	61.39	60.27	1.12	<0.001
Motorway	96.29	93.81	2.48	<0.001
All road types	57.98	57.06	0.92	<0.001

#### Preliminary conclusions:

Overall, there is a significant positive effect of the full ecoDriver system on vehicle speeds before intersections without traffic lights across all road types, with the greatest effect on motorways. This shows a positive effect of the FeDS on vehicle speed at these events. When driving with the system, drivers reduced their average speed on the 300m approach to the intersection by 1.3, 1.1 and 2.5 km/h on urban roads, rural roads and motorway respectively.

#### 7.3.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 104: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	245.9	245.9	1	13343.7	1.5	0.215
road_type	2008721.5	2008721.5	1	13312.4	12533.8	<0.001
Main_effect:road_type	1650.1	1650.1	1	13310.3	10.3	0.001

Table 105: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	30.67	29.27	32.07	<0.001
App	0.43	-0.18	1.04	0.167
Rural	25.74	25.18	26.31	<0.001
App:Rural	-1.43	-2.31	-0.56	0.001
Random part	N			
Driver_id	40			
Vmc_id	2			
Number of observations	13348			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

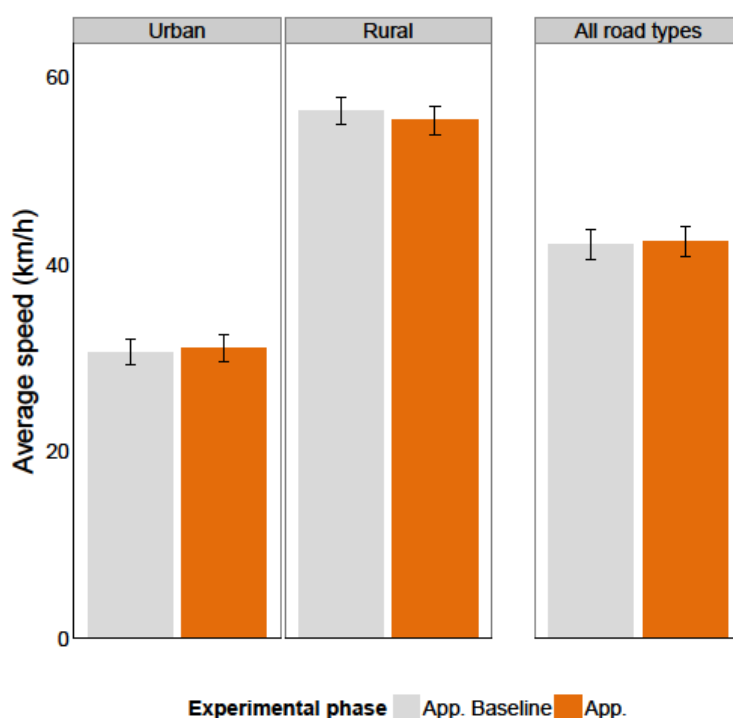


Figure 52: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 106 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	30.67	31.10	-0.43	0.511
Rural	56.41	55.41	1.00	0.013
Motorway	-	-	-	-
All road types	42.17	42.43	-0.26	0.431

#### Preliminary conclusions:

There was evidence that the ecoDriver application significantly reduced vehicle speeds by 1.0 km/h on the approach to intersections without traffic lights, on rural roads. There was no evidence for a significant effect of the ecoDriver application on other road types.

### 7.3.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 107: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	872.0	872.0	1	16787.5	7.5	0.006
road_type	211618.0	211618.0	1	17120.1	1809.1	<0.001
Main_effect:road_type	17.9	17.9	1	17100.6	0.2	0.695

Table 108: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	44.40	43.73	45.07	<0.001
Haptic	-0.49	-0.96	-0.02	0.040
Rural	8.71	8.03	9.40	<0.001
Haptic:Rural	-0.16	-0.94	0.63	0.695
Random part	N			
Driver_id	36			
Number of observations	17127			



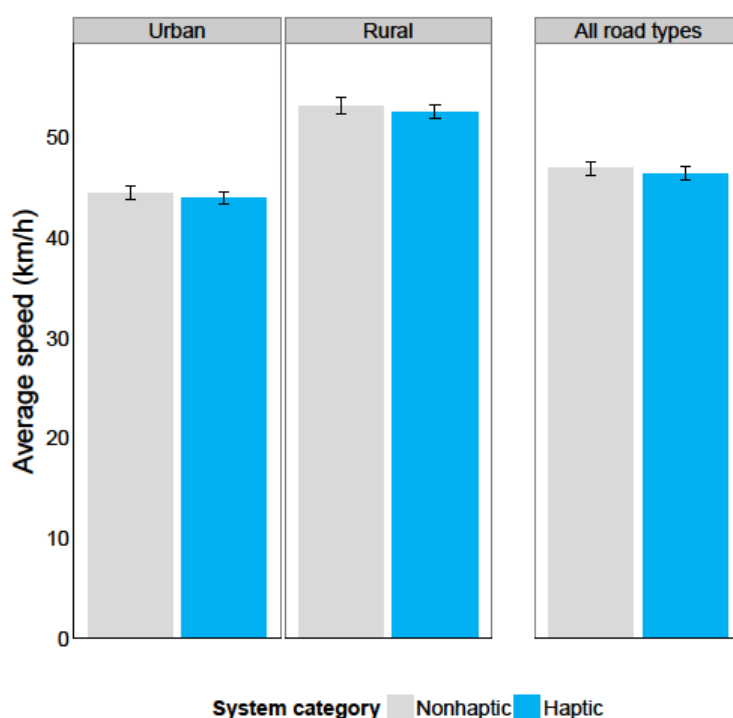


Figure 53: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 109 Average speed for the different systems and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	44.40	43.91	0.49	0.162
Rural	53.11	52.46	0.65	0.201
Motorway	-	-	-	-
All road types	46.84	46.37	0.47	0.026

#### Preliminary conclusions:

Using an ecoDriver system equipped with a haptic pedal reduced vehicle speed before intersections without traffic lights when data was pooled across road types. The effect did not reach significance for any road type alone. There is therefore tentative evidence to suggest an increased reduction in vehicle speed on the approach to intersections without traffic lights with the haptic version of the ecoDriver system.

### 7.3.2 Results summary

Table 110: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-1.40	-0.06 (N.S.)	1.25	-0.43 (N.S.)	0.49 (N.S.)	-
Rural	3.43	2.12	1.12	1.00	0.65 (N.S.)	-
Motorway	4.76	4.79	2.48	-	-	-
All road types	0.71	0.94	0.92	-0.26 (N.S.)	0.47	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-3.14	-0.13 (N.S.)	2.76	-1.4 (N.S.)	1.1 (N.S.)	-
Rural	5.6	3.47	1.82	1.78	1.22 (N.S.)	-
Motorway	5.08	5.01	2.57	-	-	-
All road types	1.32	1.66	1.58	-0.61 (N.S.)	1.00	-

### 7.3.3 Conclusions and implications

If the ecoDriver systems effectively improved green driving behaviour on the approach to intersections without traffic lights, a reduction in average vehicle speed on the 300m approach to this event would be expected. Overall, the use of an ecoDriver system significantly reduced vehicle speed before intersections without traffic lights. Across all systems combined, there was a significant reduction in speed of 0.7 km/h when the data was pooled across all road types. The speed reduction was largest on motorways (4.8 km/h) and second largest on rural roads (3.4 km/h). The full ecoDriver system produced a significant reduction in speeds across all road types, urban, rural and motorway, with the largest effect on motorways. For the comparisons involving all embedded systems, the reduction in approach speeds brought about by these system was significant on rural roads and motorways only. The ecoDriver application also caused a significant reduction in speeds before intersections, however, the effect was significant on rural roads only. The haptic system produced a significant speed reduction when approaching intersections in comparison to the non-haptic system. Overall, there is evidence that all versions of the ecoDriver system can have a positive effect on safety by reducing vehicle speeds on the approach to intersections without traffic lights. This could translate into a significant road safety improvement with wider uptake of the system.

## 7.4 Hypothesis 12: Using an ecoDriver system, the speed will change before zebra crossings

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, speed will change when driving before locations where a low speed is recommended by the system: zebra crossings*

1. Compared to baseline, the average speed will be reduced before zebra crossings when using an ecoDriver system. [Type A]
2. Compared to baseline, the average speed will be reduced before zebra crossings when using an embedded system. [Type B]
3. Compared to baseline, the average speed will be reduced before zebra crossings when using the full ecoDriver system. [Type C]
4. Compared to baseline, the average speed will be reduced before zebra crossings when using the ecoDriver application. [Type D]
5. Compared to a non-haptic system, the average speed will be reduced before zebra crossings when using a haptic ecoDriver system. [Type E]

#### Performance indicator (PI):

Avg\_speed\_distance\_based (km/h) for section of road before event

#### Data reduction method:

Event-based data divided into sub-sections for the analysis: – before 50m, spot, after 50m

Controlled data only; urban and rural roads only.

Where data was available for one road type only; road\_type removed as a fixed effect

Where data was available for one VMC only; Vmc\_id removed as a random effect.

Avg\_speed\_distance\_based between 10-150 km/h

Removed all cases where vehicle was stationary during the event (stationary\_time\_ratio0 <100%)

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment (Type A dataset)</b>  <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline</li> <li>• Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded (Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_embedded</li> <li>• Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id

## Hypothesis analysis summary table

<b>Baseline FeDS vs FeDS (Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline App vs App (Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Vmc_id, Driver_id
<b>Non-haptic vs Haptic (Type E dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 7.4.1 Controlled studies

#### 7.4.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterwhaite approximation for the degrees of freedom.

Table 111: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	145.1	145.1	1	24959.4	1.4	0.240
road_type	494704.1	247352.1	2	24645.3	2354.2	<0.001
Main_effect:road_type	25460.4	12730.2	2	25010.8	121.2	<0.001

Table 112: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	30.04	27.32	32.76	<0.001
Treatment	0.30	-0.01	0.61	0.059
Rural	18.55	17.83	19.27	<0.001
Motorway	5.92	-5.76	17.60	0.320
Treatment:Rural	-6.68	-7.52	-5.84	<0.001
Treatment:Motorway	-3.03	-17.71	11.65	0.686
Random part	N			
Driver_id	117			

Vmc_id	5
Number of observations	25224

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

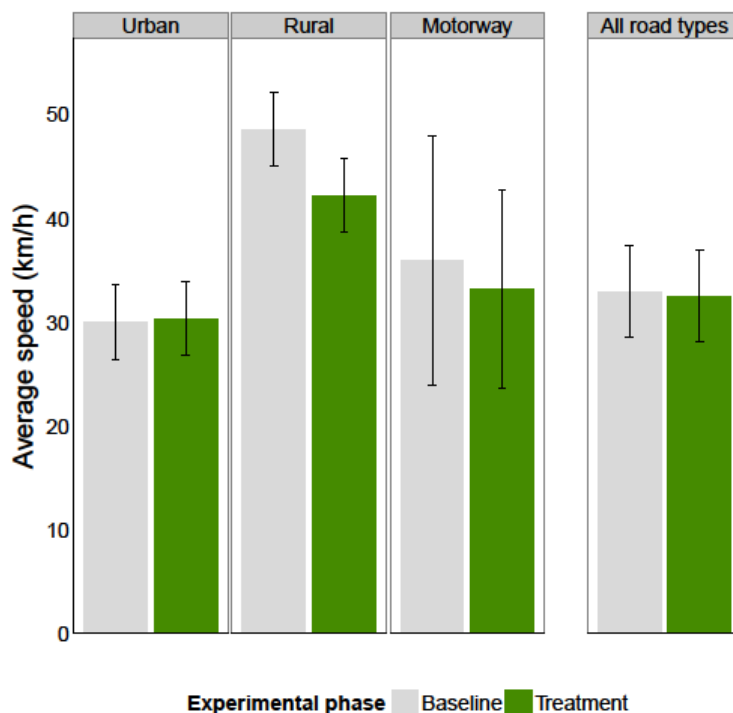


Figure 54: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 113 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	30.04	30.33	-0.3	0.328
Rural	48.59	42.20	6.4	<0.001
Motorway	35.96	33.23	2.7	0.999
All road types	32.96	32.53	0.4	0.01

#### Preliminary conclusions:

The results show a global statistically significant effect of the ecoDriver system on average speed when approaching a zebra crossing. Further analysis showed that when using an ecoDriver system, a significant reduction in speed was only observed when approaching a zebra crossing on rural roads. This effect was considerable, with a reduction in average speed of 6.4 km/h when driving with the system compared to when driving without it.

## 7.4.1.2 Type B: Baseline embedded vs embedded

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 114: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	38.7	38.7	1	13706.2	0.3	0.571
road_type	88771.5	44385.7	2	13732.5	367.6	<0.001
Main_effect:road_type	26.1	13.1	2	13740.0	0.1	0.897

Table 115: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	32.95	29.86	36.03	<0.001
Embedded	-0.77	-1.29	-0.25	0.004
Rural	8.99	7.85	10.12	<0.001
Motorway	3.59	-8.96	16.14	0.575
Embedded:Rural	-0.25	-1.49	0.99	0.692
Embedded:Motorway	-2.00	-17.74	13.74	0.803
Random part	N			
Driver_id	77			
Vmc_id	4			
Number of observations	13802			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

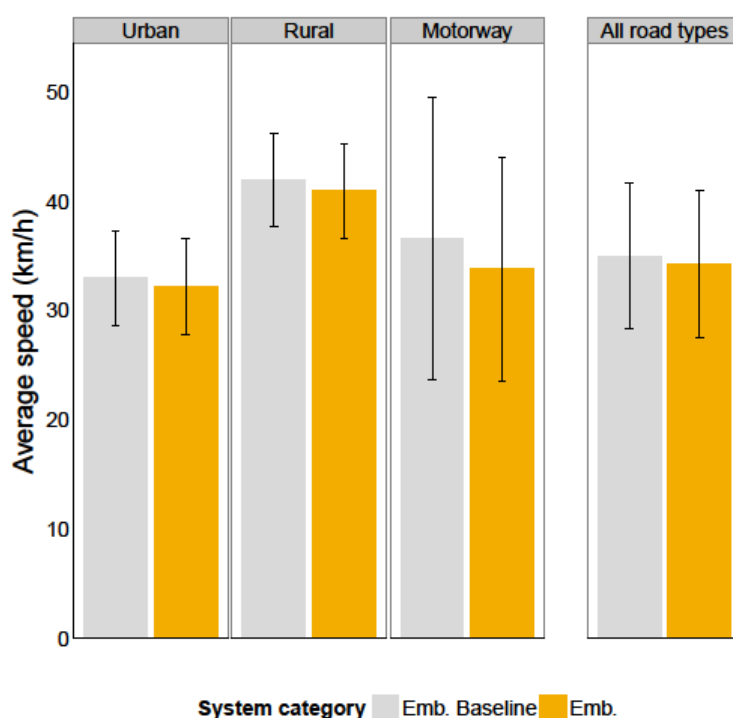


Figure 55: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 116 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	32.9	32.2	0.8	0.028
Rural	41.9	40.9	1.0	0.405
Motorway	36.5	33.8	2.8	0.999
All road types	35.0	34.2	0.8	0.002

#### Preliminary conclusions:

The results show that there was a significant effect of the embedded systems at urban zebra crossings only, with a reduction in vehicle speed of 0.8 km/h observed when driving with the system. There was no effect of the embedded systems on vehicle speed at zebra crossings on other road types, although there was a non-significant tendency for vehicle speeds to be reduced during system use.

## 7.4.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 117: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	60.1	60.1	1	2391.0	0.7	0.396
road_type	10650.2	5325.1	2	2289.0	63.7	<0.001
Main_effect:road_type	3.3	1.6	2	2399.4	0.0	0.980

Table 118: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	35.08	32.59	37.56	<0.001
FeDS	-1.46	-2.33	-0.60	<0.001
Rural	8.48	6.44	10.51	<0.001
Motorway	3.50	-6.97	13.96	0.513
FeDS:Rural	-0.04	-2.28	2.19	0.969
FeDS:Motorway	-1.31	-14.43	11.81	0.845
Random part	N			
Driver_id	41			
Vmc_id	2			
Number of observations	2438			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.



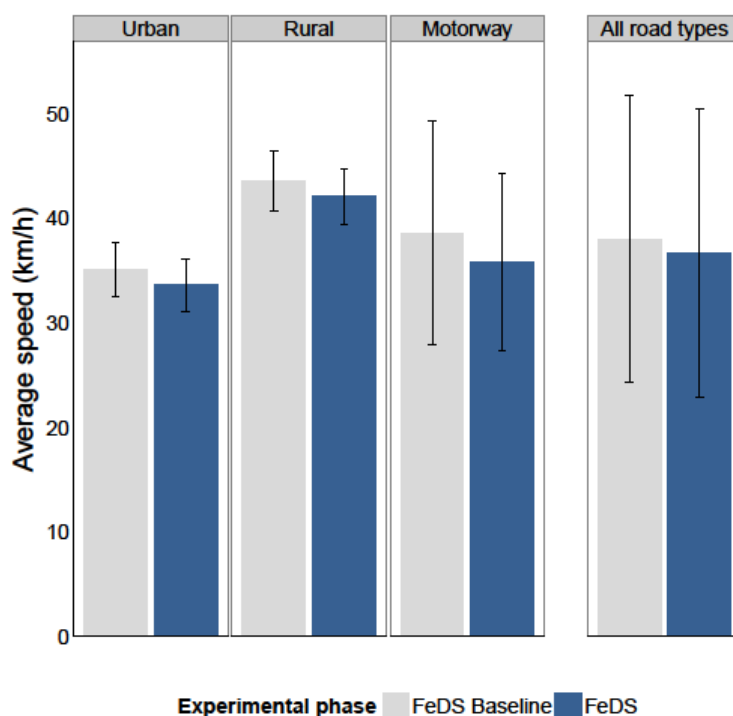


Figure 56: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 119 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	35.08	33.61	1.46	0.008
Rural	43.55	42.04	1.51	0.647
Motorway	38.57	35.80	2.77	0.998
All road types	37.99	36.65	1.34	0.001

#### Preliminary conclusions:

The results show that there was a significant effect of the full ecoDriver system at urban zebra crossings only, with a reduction in vehicle speed of 1.5 km/h observed when driving with the system. There was no effect of the embedded systems on vehicle speed at zebra crossings on other road types, although there was a non-significant tendency for vehicle speeds to be reduced during system use.

## 7.4.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 120: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	595.8	595.8	1	11416.3	8.0	0.005
road_type	478131.2	478131.2	1	11421.9	6459.8	<0.001
Main_effect:road_type	445.4	445.4	1	11390.9	6.0	0.014

Table 121: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	26.52	25.53	27.51	<0.001
App	-0.13	-0.47	0.21	0.453
Rural	26.59	25.75	27.43	<0.001
App:Rural	-1.56	-2.80	-0.31	0.014
Random part	N			
Driver_id	40			
Vmc_id	2			
Number of observations	11422			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

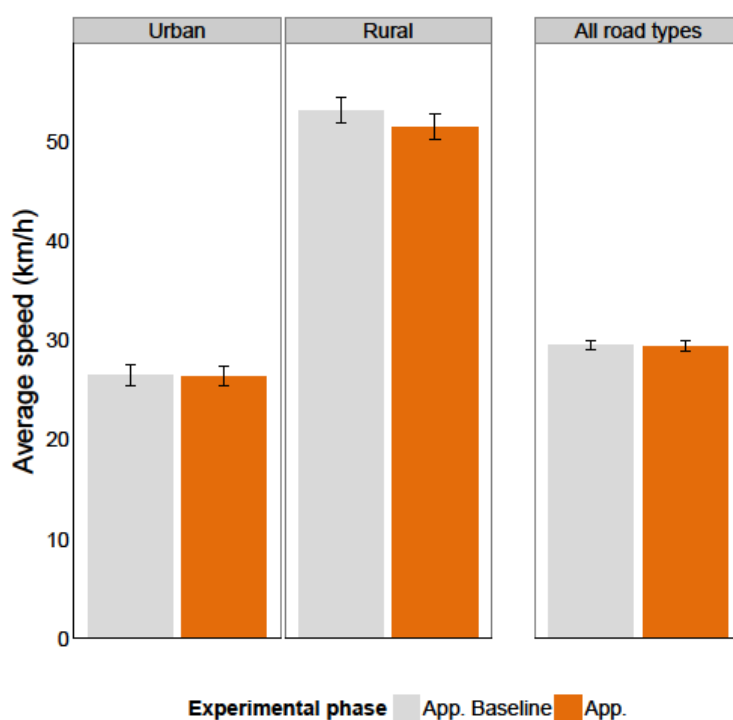


Figure 57: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 122 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	26.52	26.39	0.13	0.864
Rural	53.11	51.42	1.69	0.026
Motorway	-	-	-	-
All road types	29.55	29.38	0.18	0.403

#### Preliminary conclusions:

The results show that there was a significant effect of the ecoDriver application at rural zebra crossings only, with a reduction in vehicle speed of 1.7 km/h observed when driving with the system. There was no effect of the embedded systems on vehicle speed at zebra crossings on other road types.

## 7.4.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 123: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	39.8	39.8	1	3485.7	0.3	0.573
road_type	23560.2	23560.2	1	3499.7	188.4	<0.001
Main_effect:road_type	45.0	45.0	1	3485.4	0.4	0.549

Table 124: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	31.84	30.10	33.59	<0.001
Haptic	-0.02	-1.06	1.01	0.967
Rural	8.30	6.07	10.53	<0.001
Haptic:Rural	0.76	-1.71	3.22	0.549
Random part	N			
Driver_id	36			
Number of observations	3506			

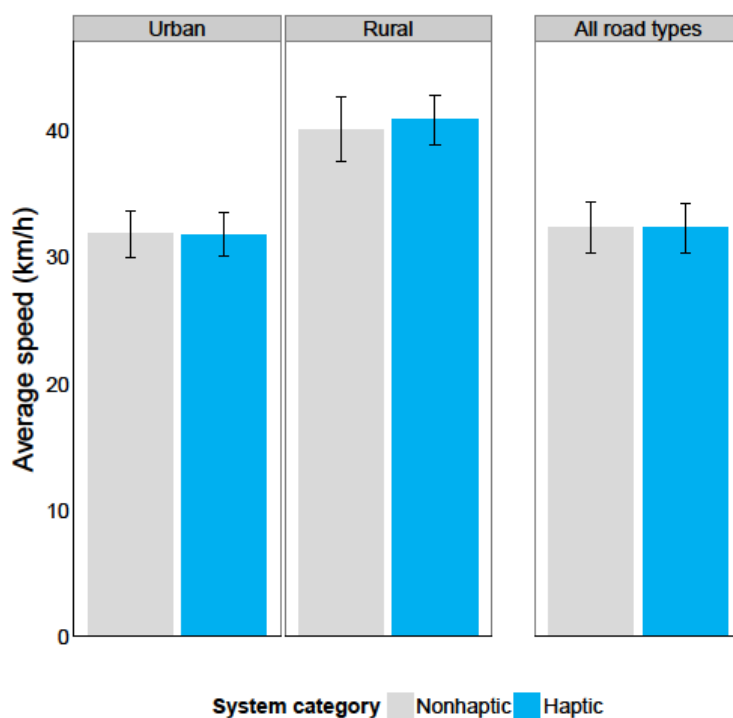


Figure 58: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 125 Average speed for the different systems and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	31.84	31.82	0.02	1
Rural	40.14	40.88	-0.73	0.912
Motorway	-	-	-	-
All road types	32.32	32.35	-0.03	0.958

**Preliminary conclusions:**

There was no significant difference in vehicle speeds on the approach to zebra crossings when using the haptic or non-haptic systems. This was observed for both urban and rural roads.

### 7.4.2 Results summary

Table 126: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-0.3 (N.S.)	0.77	1.46	0.13 (N.S.)	0.02 (N.S.)	-
Rural	6.38	1.02 (N.S.)	1.51 (N.S.)	1.69	-0.73 (N.S.)	-
Motorway	2.73 (N.S.)	2.77 (N.S.)	2.77 (N.S.)	-	-	-
All road types	0.42	0.78	1.34	0.18 (N.S.)	-0.03 (N.S.)	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-0.99 (N.S.)	2.33	4.18	0.49 (N.S.)	0.07 (N.S.)	-
Rural	13.13	2.43 (N.S.)	3.47 (N.S.)	3.18	-1.83 (N.S.)	-
Motorway	7.6 (N.S.)	7.58 (N.S.)	7.19 (N.S.)	-	-	-
All road types	1.29	2.22	3.53	0.59 (N.S.)	-0.08 (N.S.)	-

### 7.4.3 Conclusions and implications

A reduction in speed before zebra crossings was expected if the ecoDriver system was successful in improving green driving behaviour around these events. However, it should be noted that none of the ecoDriver systems gave zebra crossing-specific advice, and so any impact of the system would likely be due to global impacts on green driving behaviour. Overall, the results suggest a positive effect of the ecoDriver systems on average vehicle speed when approaching zebra crossings. The different types of systems show different effects on urban and rural roads. For example, the analysis of all ecoDriver systems shows a significant reduction in vehicle speeds of 6.4 km/h before zebra crossings on rural roads, but no significant effect on vehicle speeds on urban roads. This is mirrored by the effect of the ecoDriver application, whose speed reducing effect was greater on rural roads. In contrast, the impact of the embedded systems was significant on urban roads only, with a speed reduction of 0.8 km/h seen when driving with the system compared to driving without it. The full ecoDriver system showed a similar pattern of effects, with system use causing a 1.5 km/h drop in speed compared to no system use, before urban zebra crossings only. For zebra crossing events, the addition of a haptic pedal to the ecoDriver system did not have an impact on driver behaviour. Overall, there is evidence that all versions of the ecoDriver system can have a positive effect on vehicle speeds at zebra crossings on particular road types, which should translate into a measurable improvement of both driver and pedestrian safety.

## Hypothesis 13: Using an ecoDriver system, the speed will change before speedbumps

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, speed will change when driving before locations where a low speed is recommended by the system: speedbumps*

1. Compared to baseline, the average speed will be reduced before speedbumps when using an ecoDriver system. [Type A]
2. Compared to baseline, the average speed will be reduced before speedbumps when using an embedded system. [Type B]
3. Compared to baseline, the average speed will be reduced before speedbumps when using the full ecoDriver system. [Type C]
4. Compared to baseline, the average speed will be reduced before speedbumps when using the ecoDriver application. [Type D]
5. Compared to a non-haptic system, the average speed will be reduced before speedbumps when using a haptic ecoDriver system. [Type E]

#### Performance indicator (PI):

Avg\_speed\_distance\_based (km/h) for section of road before event

#### Data reduction method:

Event-based data was divided into sub-sections for the analysis: – before 50m, spot, after 50m

Controlled data only; urban and rural roads only.

Where data was available for one road type only; road\_type removed as a fixed effect

Where data was available for one VMC only; Vmc\_id removed as a random effect.

Instantaneous speed between 10-150 km/h

Avg\_speed\_distance\_based between 10-150 km/h

Removed all cases where vehicle was stationary during the event (stationary\_time\_ratio0 <100%)

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> <b>(Type A dataset)</b> <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> <b>(Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id

## Hypothesis analysis summary table

<b>Baseline FeDS vs FeDS (Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline App vs App (Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Vmc_id, Driver_id
<b>Non-haptic vs Haptic (Type E dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 7.4.4 Controlled studies

#### 7.4.4.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterwhaite approximation for the degrees of freedom.

Table 127: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	27.9	27.9	1	2639.8	0.5	0.502
road_type	9517.2	9517.2	1	2632.9	153.8	<0.001
Main_effect:road_type	0.1	0.1	1	2628.3	0.0	0.962

Table 128: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	31.33	26.05	36.61	<0.001
Treatment	-0.34	-1.03	0.34	0.326
Rural	8.59	6.66	10.53	<0.001



Treatment:Rural	-0.05	-2.21	2.10	0.962
Random part	N			
Driver_id	78			
Vmc_id	4			
Number of observations	2684			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

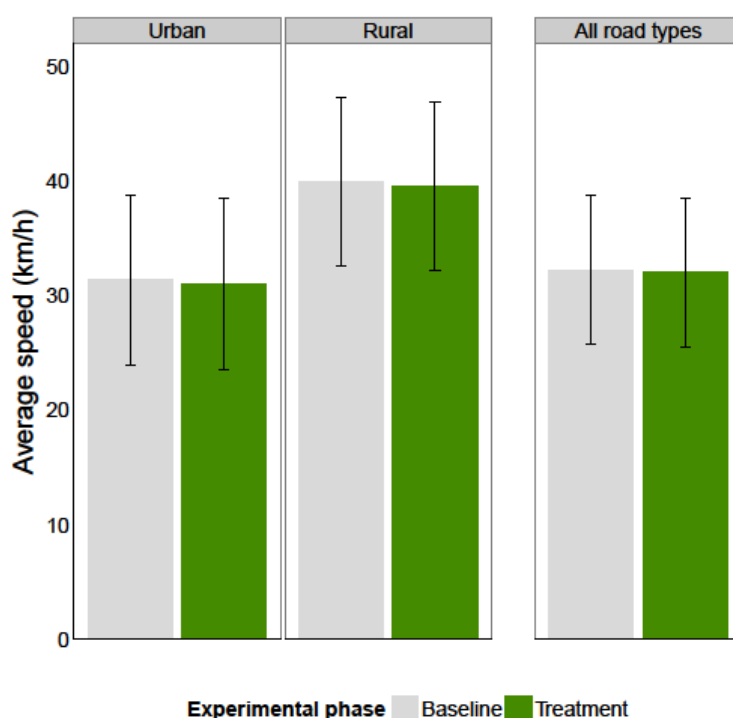


Figure 59: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 129 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	31.33	30.99	0.3	0.743
Rural	39.92	39.53	0.4	0.980
Motorway	-	-	-	-
All road types	32.24	31.99	0.2	0.467

#### Preliminary conclusions:

The results show no significant effect of the ecoDriver systems on average vehicle speed on the approach to speedbump events. This is true for all road types with speedbumps (urban and rural roads).

**Type B: Baseline embedded vs embedded**

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 130: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	55.8	55.8	1	1086.9	0.5	0.467
road_type	6388.0	6388.0	1	1066.7	60.7	<0.001
Main_effect:road_type	0.1	0.1	1	1075.3	0.0	0.980

Table 131: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	33.53	27.90	39.15	<0.001
Embedded	-0.76	-2.33	0.81	0.345
Rural	9.38	5.95	12.82	<0.001
Embedded:Rural	0.05	-3.88	3.98	0.980
Random part	N			
Driver_id	38			
Vmc_id	3			
Number of observations	1103			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

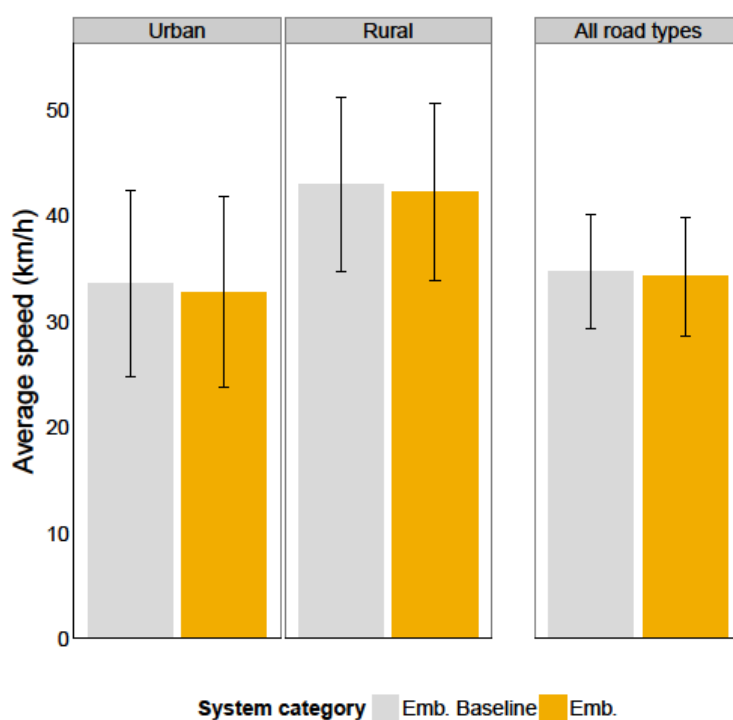


Figure 60: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 132 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	33.5	32.8	0.8	0.770
Rural	42.9	42.2	0.7	0.980
Motorway	-	-	-	-
All road types	34.7	34.2	0.5	0.504

#### Preliminary conclusions:

The results show no significant effect of the embedded ecoDriver systems on average vehicle speed on the approach to speedbump events. This is true for all road types with speedbumps (urban and rural roads).

#### 7.4.4.2 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 133: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	33.6	33.6	1	509.1	0.8	0.360
road_type	6506.0	6506.0	1	498.3	162.4	<0.001
Main_effect:road_type	3.0	3.0	1	501.5	0.1	0.785

Table 134: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	32.93	24.38	41.48	0.016
FeDS	-0.44	-1.81	0.94	0.535
Rural	9.76	7.56	11.97	<0.001
FeDS:Rural	-0.37	-2.99	2.26	0.785
Random part	N			
Driver_id	26			
Vmc_id	2			
Number of observations	523			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

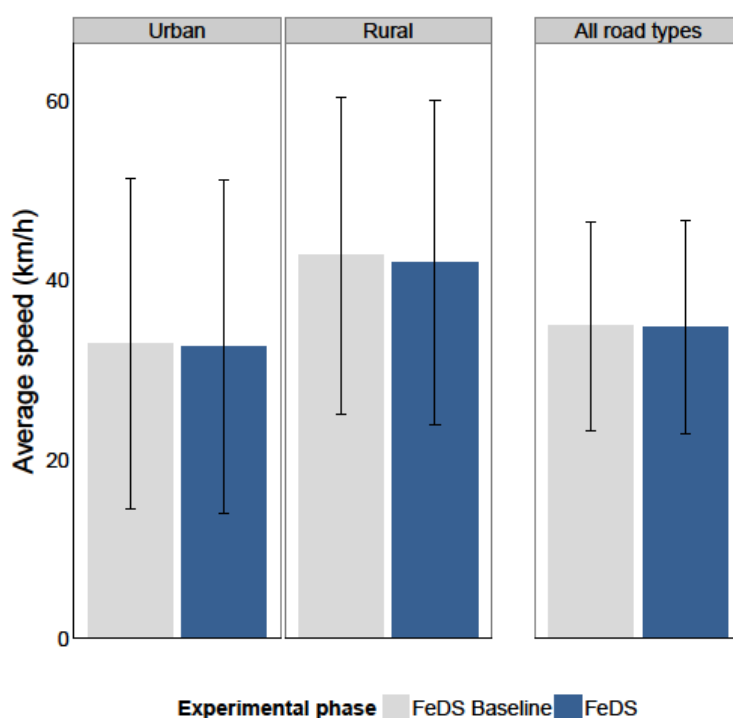


Figure 61: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 135 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	32.9	32.5	0.4	0.923
Rural	42.7	41.9	0.8	0.895
Motorway	-	-	-	-
All road types	34.8	34.7	0.1	0.852

#### Preliminary conclusions:

The results show no significant effect of the full ecoDriver system on average vehicle speed on the approach to speedbump events. This is true for all road types with speedbumps (urban and rural roads).

## 7.4.4.3 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 136: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.3	0.3	1	1550.9	0.0	0.920
road_type	4200.0	4200.0	1	653.8	131.3	<0.001
Main_effect:road_type	0.9	0.9	1	1549.8	0.0	0.867

Table 137: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	25.88	25.33	26.44	<0.001
App	-0.15	-0.75	0.44	0.612
Rural	7.37	5.45	9.30	<0.001
App:Rural	0.19	-2.06	2.45	0.867
Random part	N			
Driver_id	40			
Vmc_id	2			
Number of observations	1581			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

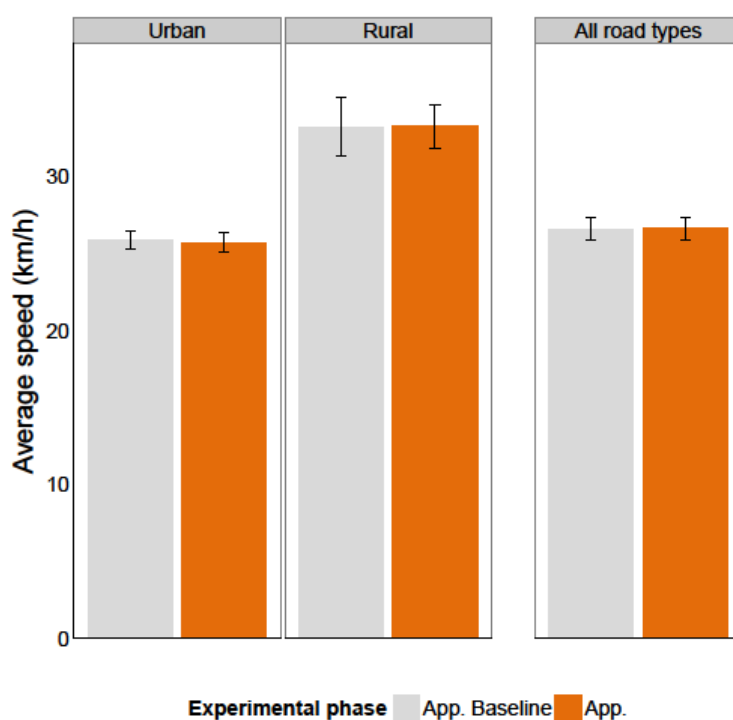


Figure 62: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 138 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	25.88	25.73	0.15	0.953
Rural	33.26	33.29	-0.04	1.000
Motorway	-	-	-	-
All road types	26.60	26.63	-0.03	0.917

#### Preliminary conclusions:

The results show no significant effect of the ecoDriver application on average vehicle speed on the approach to speedbump events. This is true for all road types with speedbumps (urban and rural roads).

## 7.4.4.4 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 139: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	112.3	112.3	1	179.0	0.7	0.401
road_type	-	-	-	-	-	-
Main_effect:road_type	-	-	-	-	-	-

Table 140: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	32.05	27.55	36.55	<0.001
Haptic	2.12	-2.81	7.05	0.401
Random part	N			
Driver_id	12			
Number of observations	179			



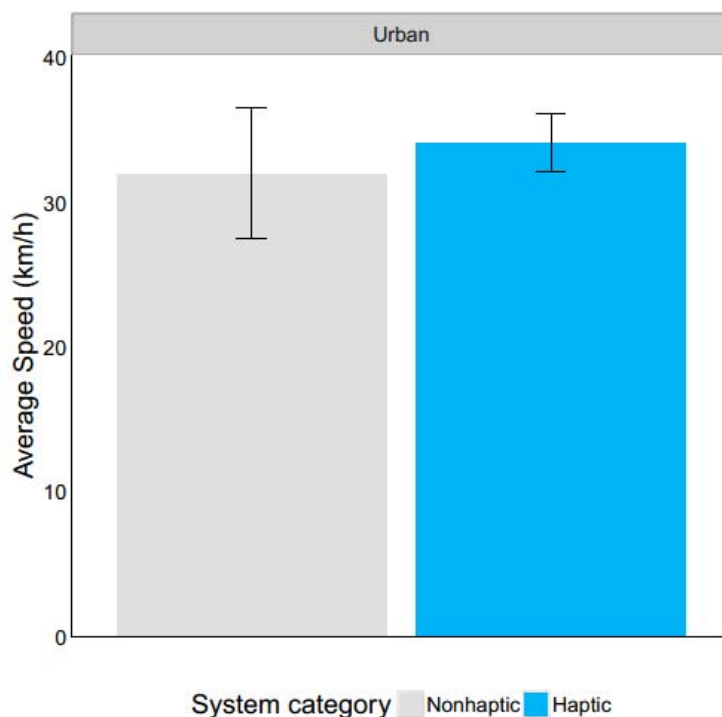


Figure 63: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 141 Average speed for the different systems and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	32.05	34.17	-2.12	0.399
Rural	-	-	-	-
Motorway	-	-	-	-
All road types	32.05	34.17	-2.12	0.399

**Preliminary conclusions:**

There was no significant difference in vehicle speeds before speedbumps when using the haptic ecoDriver system compared to the non-haptic system. There was a non-significant tendency for vehicle speeds to increase with the haptic pedal system however (+2.1 km/h).

### 7.4.5 Results summary

Table 142: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	0.34 (N.S.)	0.76 (N.S.)	0.44 (N.S.)	0.15 (N.S.)	-2.12 (N.S.)	-
Rural	0.4 (N.S.)	0.71 (N.S.)	0.8 (N.S.)	-0.04 (N.S.)	-	-
Motorway	-	-	-	-	-	-
All road types	0.25 (N.S.)	0.51 (N.S.)	0.13 (N.S.)	-0.03 (N.S.)	-2.12 (N.S.)	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	1.1 (N.S.)	2.26 (N.S.)	1.32 (N.S.)	0.6 (N.S.)	-6.61 (N.S.)	-
Rural	0.99 (N.S.)	1.65 (N.S.)	1.88 (N.S.)	-0.12 (N.S.)	-	-
Motorway	-	-	-	-	-	-
All road types	0.77 (N.S.)	1.46 (N.S.)	0.37 (N.S.)	-0.12 (N.S.)	-6.61 (N.S.)	-

### 7.4.6 Conclusions and implications

None of the ecoDriver systems provided advice that was specific to speedbump events, and so no a priori predictions were made regarding the expected impact of the system on vehicle speeds when approaching these events. Overall, there was no significant impact of any ecoDriver system type on average vehicle speed immediately before a speedbump. Interestingly, an analysis of spot speeds at the speedbump showed a non-significant tendency for vehicle speeds to be higher at speedbumps when driving with the system compared to driving without it. This was true across all system types, with the increase in speed being as large as 1.9 km/h on urban roads when using the FeDS. This perhaps suggests that drivers were choosing to maintain their speed rather than slowing down for the speedbumps, in keeping with one of the golden rules of eco-driving, to maintain a steady speed at low RPM. There was a significant impact of the haptic pedal on vehicle speeds on the approach to speedbumps. However, a trend for slightly higher speeds (a 2.1 km/h increase) was observed on urban roads when driving with the haptic pedal compared to without it. This analysis may have suffered from the low statistical power brought about from the small number of cases involved ( $n = 179$ ). In fact, more generally, each analysis of vehicle speeds before speedbumps had a low number of cases ( $n = 523$ -2684 cases), which will have reduced the likelihood of detecting small significant effects of system on driver behaviour.

## 7.5 Hypothesis 14: Using an ecoDriver system, the speed will change before sharp curves

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, speed will change when driving before locations where a low speed is recommended by the system: sharp curves*

1. Compared to baseline, the average speed will be reduced before sharp curves when using an ecoDriver system. [Type A]
2. Compared to baseline, the average speed will be reduced before sharp curves when using an embedded system. [Type B]
3. Compared to baseline, the average speed will be reduced before sharp curves when using the full ecoDriver system. [Type C]
4. Compared to baseline, the average speed will be reduced before sharp curves when using the ecoDriver application. [Type D]
5. Compared to a non-haptic system, the average speed will be reduced before sharp curves when using a haptic ecoDriver system. [Type E]

#### Performance indicator (PI):

Avg\_speed\_distance\_based (km/h) for section of road before event

#### Data reduction method:

Event-based data was divided into sub-sections for the analysis: – curve entry, curve, curve exit

Controlled data only; urban and rural roads only.

Where data was available for one road type only; road\_type removed as a fixed effect

Where data was available for one VMC only; Vmc\_id removed as a random effect.

Avg\_speed\_distance\_based between 10-150 km/h

Removed all cases where vehicle was stationary during the event (stationary\_time\_ratio0 <100%)

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> <b>(Type A dataset)</b> <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline</li> <li>• Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> <b>(Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_embedded</li> <li>• Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id

## Hypothesis analysis summary table

<b>Baseline FeDS vs FeDS (Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline App vs App (Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Vmc_id, Driver_id
<b>Non-haptic vs Haptic (Type E dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 7.5.1 Controlled studies

#### 7.5.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterwhaite approximation for the degrees of freedom.

Table 143: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	19.0	19.0	1	10530.2	0.2	0.687
road_type	286872.4	143436.2	2	10486.2	1226.5	<0.001
Main_effect:road_type	4565.6	2282.8	2	10467.3	19.5	<0.001

Table 144: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	42.15	37.93	46.37	<0.001
Treatment	1.00	0.23	1.78	0.011
Rural	13.82	12.98	14.66	<0.001
Motorway	23.77	18.26	29.29	<0.001
Treatment:Rural	-3.09	-4.06	-2.12	<0.001
Treatment:Motorway	-1.29	-7.90	5.31	0.701
Random part	N			
Driver_id	143			

Vmc_id	7
Number of observations	10536

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

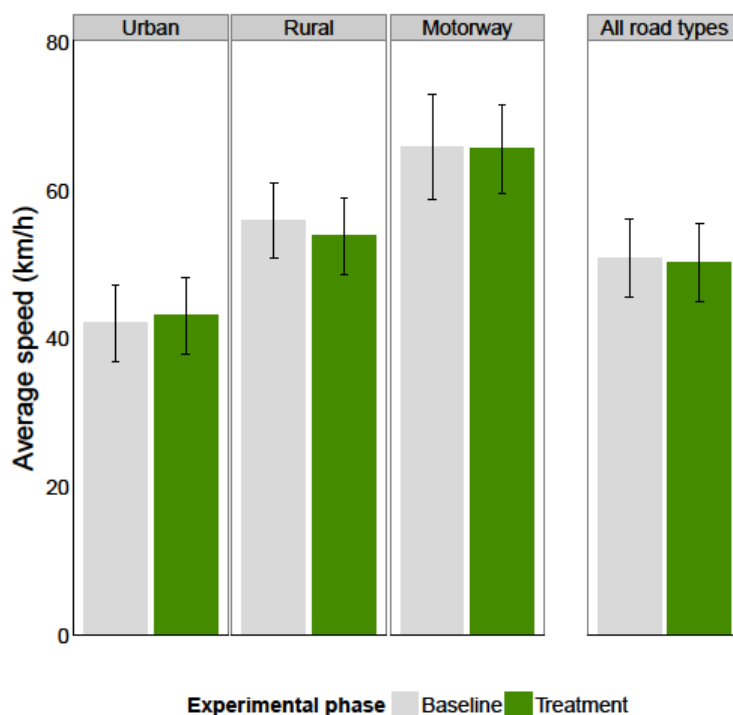


Figure 64: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 145 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	42.15	43.16	-1.0	0.082
Rural	55.97	53.89	2.1	<0.001
Motorway	65.93	65.64	0.3	1.000
All road types	50.97	50.29	0.7	0.018

#### Preliminary conclusions:

Overall, there is a significant positive effect of the ecoDriver systems on average vehicle speed before sharp curves on rural roads. Drivers reduced their average speed on the approach to the curve by 2.1 km/h when driving with the system. This corresponds to a positive effect of the ecoDriver system on vehicle speed. There was no significant effect of the ecoDriver systems on other road types.

## 7.5.1.2 Type B: Baseline embedded vs embedded

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 146: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	46.7	46.7	1	9445.0	0.4	0.512
road_type	164897.6	82448.8	2	9408.7	758.6	<0.001
Main_effect:road_type	236.9	118.5	2	9399.5	1.1	0.336

Table 147: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	45.70	41.63	49.76	<0.001
Embedded	-0.61	-1.43	0.20	0.138
Rural	10.59	9.66	11.52	<0.001
Motorway	21.84	16.51	27.17	<0.001
Embedded:Rural	-0.77	-1.80	0.27	0.148
Embedded:Motorway	0.46	-5.92	6.85	0.887
Random part	N			
Driver_id	103			
Vmc_id	6			
Number of observations	9450			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

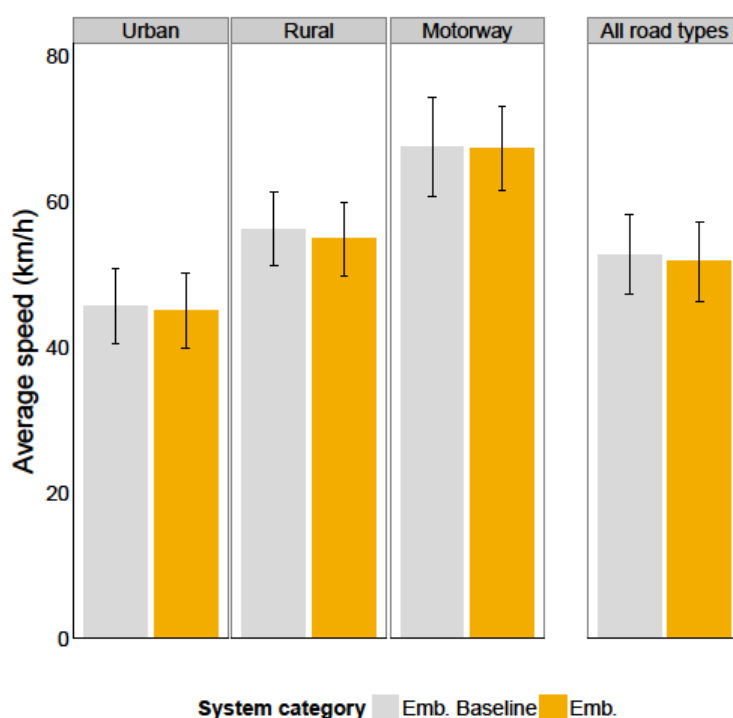


Figure 65: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 148 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	45.7	45.1	0.6	0.613
Rural	56.3	54.9	1.4	<0.001
Motorway	67.5	67.4	0.2	1
All road types	52.7	51.8	1.0	<0.001

#### Preliminary conclusions:

Overall, there is a significant positive effect of the embedded ecoDriver systems on average vehicle speed before sharp curves on rural roads. Drivers reduced their average speed on the approach to the curve by 1.4 km/h when driving with the system. This corresponds to a positive effect of the ecoDriver system on vehicle speed. There was no effect of the embedded systems on average speed before curves on other road types.

### 7.5.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 149: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	299.9	299.9	1	2103.1	3.7	0.056
road_type	84494.3	42247.1	2	2105.6	515.2	<0.001
Main_effect:road_type	168.6	84.3	2	2093.2	1.0	0.358

Table 150: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	41.72	37.80	45.65	<0.001
FeDS	-0.77	-2.22	0.67	0.294
Rural	15.02	13.53	16.52	<0.001
Motorway	27.70	22.26	33.13	<0.001
FeDS:Rural	-1.15	-2.91	0.61	0.199
FeDS:Motorway	-2.77	-9.07	3.53	0.390
Random part	N			
Driver_id	59			
Vmc_id	3			
Number of observations	2137			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.



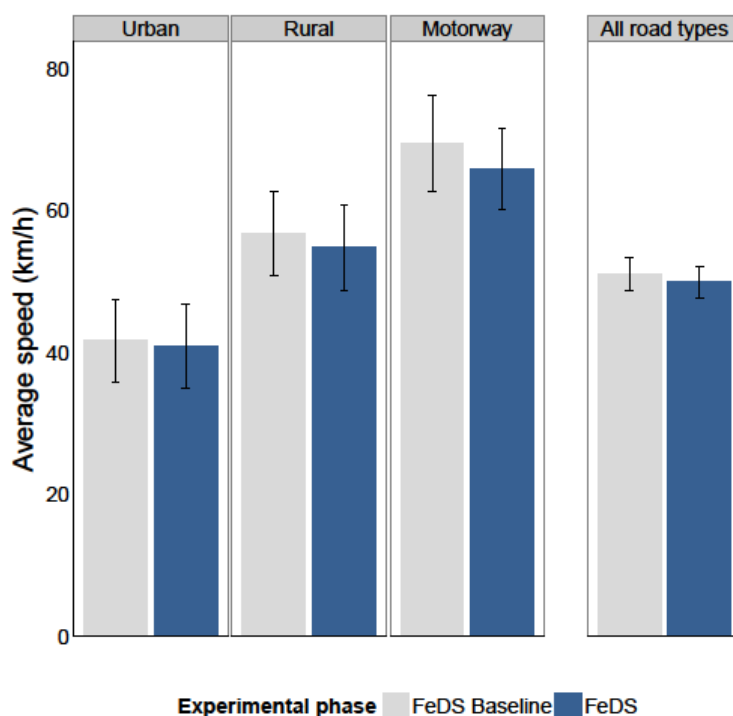


Figure 66: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 151 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	41.7	40.9	0.8	0.881
Rural	56.7	54.8	1.9	0.003
Motorway	69.4	65.9	3.5	0.843
All road types	51.1	50.0	1.1	0.034

#### Preliminary conclusions:

Overall, there is a significant positive effect of the full ecoDriver system on average vehicle speed before sharp curves on rural roads. Drivers reduced their average speed on the approach to the curve by 1.9 km/h when driving with the system. This corresponds to a positive effect of the ecoDriver system on vehicle speed. There was no effect of the full system on average speed before curves on other road types.

## 7.5.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 152: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	149.9	149.9	1	1085.4	1.0	0.319
road_type	142569.9	142569.9	1	1043.1	943.9	<0.001
Main_effect:road_type	2.4	2.4	1	1037.2	0.0	0.899

Table 153: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	27.88	26.08	29.68	<0.001
App	-0.91	-3.46	1.64	0.485
Rural	24.42	22.41	26.42	<0.001
App:Rural	0.20	-2.92	3.32	0.899
Random part	N			
Driver_id	40			
Vmc_id	2			
Number of observations	1086			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

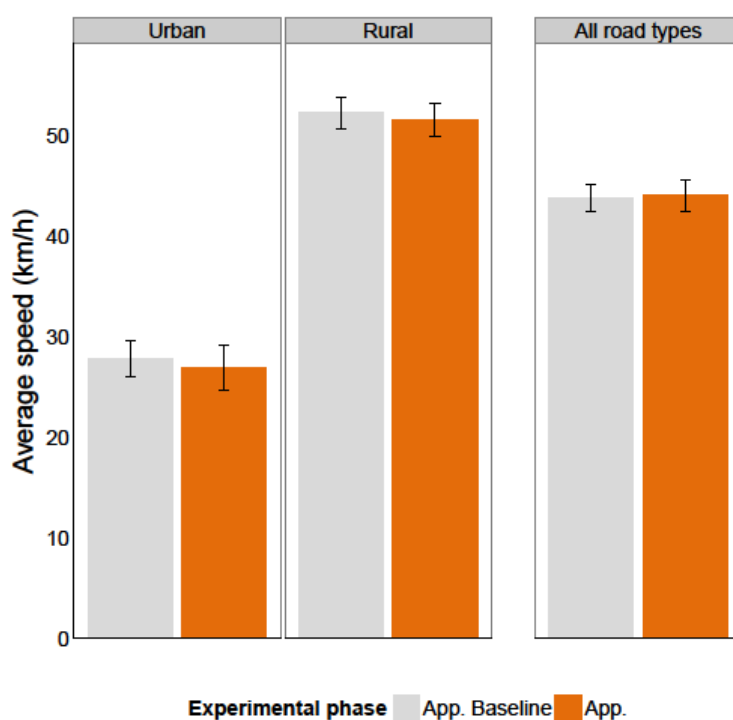


Figure 67: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 154 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	27.88	26.97	0.91	0.896
Rural	52.30	51.59	0.71	0.876
Motorway	-	-	-	-
All road types	43.79	44.13	-0.35	0.742

**Preliminary conclusions:**

The results show no significant effects of the ecoDriver application on vehicle speeds before curves on any road type.

### 7.5.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 155: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	257.0	257.0	1	2576.4	2.7	0.102
road_type	33730.9	33730.9	1	2669.0	351.8	<0.001
Main_effect:road_type	1129.5	1129.5	1	2646.1	11.8	<0.001

Table 156: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	44.23	42.96	45.49	<0.001
Haptic	-2.19	-3.53	-0.86	0.001
Rural	6.63	5.20	8.05	<0.001
Haptic:Rural	2.94	1.26	4.61	<0.001
Random part	N			
Driver_id	36			
Number of observations	2670			

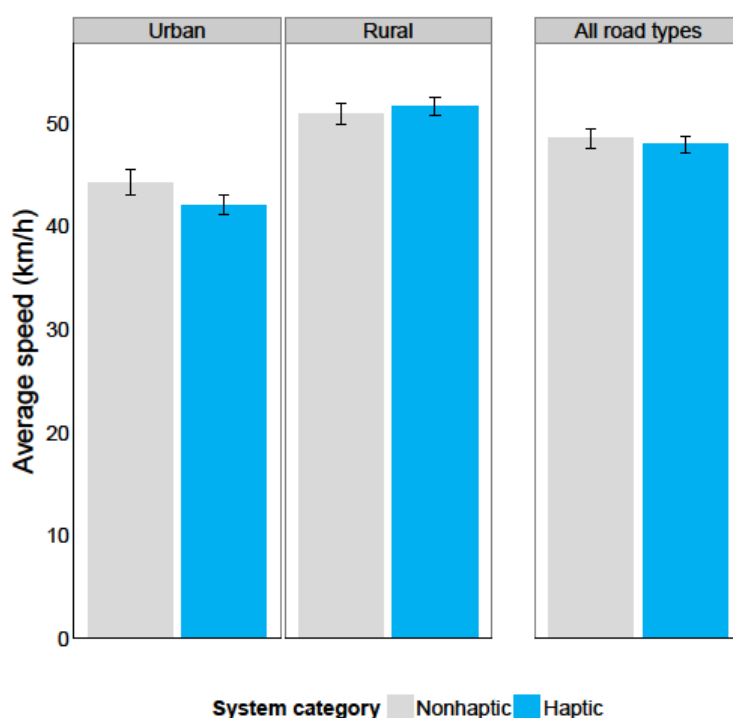


Figure 68: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 157 Average speed for the different systems and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	44.23	42.03	2.19	0.007
Rural	50.85	51.60	-0.74	0.518
Motorway	-	-	-	-
All road types	48.50	47.93	0.57	0.226

#### Preliminary conclusions:

There is a significant reduction in average curve approach speed in urban areas when using a system with a haptic pedal. A speed reduction of 2.2 km/h was seen when using the haptic pedal system. In rural areas, using an ecoDriver system equipped with a haptic pedal had no impact on vehicle speeds on sharp curves compared to using an ecoDriver system without a haptic pedal.

### 7.5.2 Results summary

Table 158: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-1 (N.S.)	0.61 (N.S.)	0.77 (N.S.)	0.91 (N.S.)	2.19	-
Rural	2.08	1.38	1.93	0.71 (N.S.)	-0.74 (N.S.)	-
Motorway	0.29 (N.S.)	0.15 (N.S.)	3.54 (N.S.)	-	-	-
All road types	0.68	0.97	1.14	-0.35 (N.S.)	0.57 (N.S.)	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-2.38 (N.S.)	1.35 (N.S.)	1.85 (N.S.)	3.26 (N.S.)	4.96	-
Rural	3.72	2.45	3.4	1.35 (N.S.)	-1.46 (N.S.)	-
Motorway	0.44 (N.S.)	0.22 (N.S.)	5.1 (N.S.)	-	-	-
All road types	1.33	1.83	2.24	-0.79 (N.S.)	1.18 (N.S.)	-

### 7.5.3 Conclusions and implications

A reduction in average speed on the approach to sharp curves would be expected if the ecoDriver system was successful in improving green driving behaviour around these events. Overall, there was evidence that the use of an ecoDriver system had a significant impact on vehicle speeds on the approach to sharp curves. A significant reduction in vehicle speeds was observed on rural road curve approaches in the all systems analysis (-2.1 km/h), the embedded systems analysis (-1.4 km/h), and the full ecoDriver system analysis (-1.9 km/h). Across all analyses there was no significant reduction in curve approach speed when using an ecoDriver system on urban roads or motorways. Additionally, there was a significant reduction in approach speeds when using the haptic system compared to the non-haptic system on urban roads. It appears that on rural roads especially, the ecoDriver system lowers the speed at which drivers approach sharp curves. This could lead to a substantial improvement in road safety around these events.

## 7.6 Hypothesis 15: Using an ecoDriver system, the speed will change at crests

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, speed will change when driving at locations where a low speed is recommended by the system: crests*

1. Using an ecoDriver system, the average speed will be reduced at crests. [Type A]
2. Using an embedded ecoDriver system, the average speed will be reduced at crests. [Type B]
3. Using the full ecoDriver system (FeDS), the average speed will be reduced at crests. [Type C]
4. Using the ecoDriver application (App), the average speed will be reduced at crests. [Type D]
5. Using a haptic ecoDriver system, the average speed will be reduced at crests. [Type E]

Performance indicator (PI):

Average speed (avg\_speed\_distance\_based, km/h) for uphill, crest and downhill road sections combined

Data reduction method:

Event-based data – no sub-division, full event analysed

Controlled data only.

Where data was available for one road type only; road\_type removed as a fixed effect

Where data was available for one VMC only; Vmc\_id removed as a random effect.

Avg\_speed\_distance\_based between 10-150 km/h

Removed all cases where vehicle was stationary during the event (stationary\_time\_ratio0 <100%)

Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

Statistical analysis information

Baseline vs Treatment (Type A dataset) For both controlled and naturalistic data	Main effect	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
Baseline Emb. vs Embedded (Type B dataset)	Main effect	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
Baseline FeDS vs FeDS (Type C dataset)	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id

## Hypothesis analysis summary table

Baseline App vs App (Type D dataset)	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Vmc_id, Driver_id
Non-haptic vs Haptic (Type E dataset)	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 7.6.1 Controlled studies

#### 7.6.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 159: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	4.3	4.3	1	1313.8	0.1	0.730
road_type	35703.6	17851.8	2	1320.0	494.6	<0.001
Main_effect:road_type	30.7	15.3	2	1323.1	0.4	0.654

Table 160: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	47.69	42.70	52.69	<0.001
Treatment	-0.41	-1.86	1.03	0.576
Rural	12.87	11.39	14.36	<0.001
Motorway	47.97	41.90	54.04	<0.001
Treatment:Rural	-0.35	-1.99	1.30	0.680
Treatment:Motorway	2.96	-4.81	10.73	0.455
Random part	N			
Driver_id	110			
Vmc_id	7			
Number of observations	1386			



Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

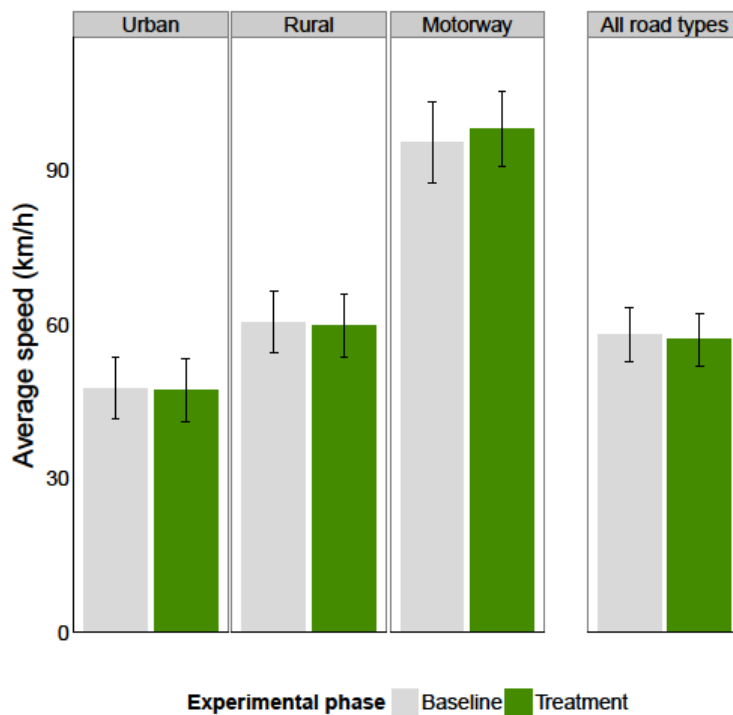


Figure 69: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 161 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	47.69	47.28	0.4	0.991
Rural	60.57	59.81	0.8	0.376
Motorway	95.66	98.21	-2.5	0.982
All road types	58.11	57.14	1.0	0.042

#### Preliminary conclusions:

There was no significant effect of the ecoDriver systems on vehicle speeds when driving on gradients (uphill, crest, downhill).

## 7.6.1.2 Type B: Baseline embedded vs embedded

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 162: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	4.7	4.7	1	1144.0	0.1	0.730
road_type	35715.7	17857.9	2	1148.6	453.2	<0.001
Main_effect:road_type	25.6	12.8	2	1149.9	0.3	0.723

Table 163: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	48.29	42.50	54.09	<0.001
Embedded	-0.45	-1.96	1.06	0.557
Rural	12.85	11.28	14.43	<0.001
Motorway	48.00	41.66	54.34	<0.001
Embedded:Rural	-0.21	-1.98	1.56	0.816
Embedded:Motorway	3.00	-5.11	11.12	0.468
Random part	N			
Driver_id	80			
Vmc_id	6			
Number of observations	1197			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

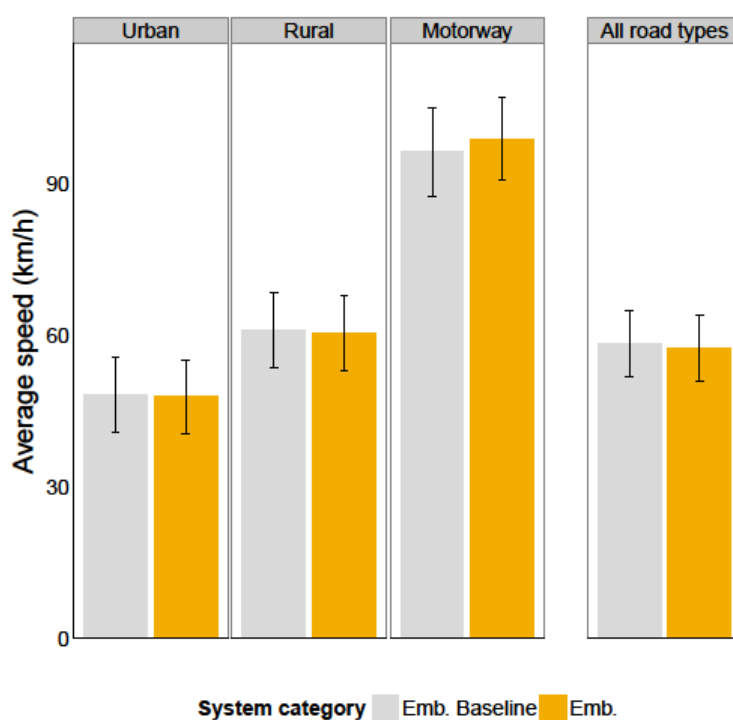


Figure 70: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 164 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates			Tukey multiple comparisons significance test
	Baseline	Embedded	Difference (B-E)	
Urban	48.3	47.8	0.5	0.989
Rural	61.1	60.5	0.7	0.695
Motorway	96.3	98.8	-2.6	0.986
All road types	58.3	57.4	0.9	0.094

**Preliminary conclusions:**

There was no significant effect of the embedded ecoDriver systems on vehicle speeds when driving on gradients.

## 7.6.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 165: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	9.1	9.1	1	813.0	0.2	0.659
road_type	34986.6	17493.3	2	760.9	376.0	<0.001
Main_effect:road_type	19.5	9.7	2	815.7	0.2	0.811

Table 166: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	49.82	47.23	52.41	<0.001
FeDS	-0.34	-2.01	1.32	0.686
Rural	12.61	10.82	14.41	<0.001
Motorway	48.04	41.15	54.94	<0.001
FeDS:Rural	0.13	-1.94	2.20	0.903
FeDS:Motorway	2.91	-5.91	11.73	0.518
Random part	N			
Driver_id	43			
Vmc_id	3			
Number of observations	842			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

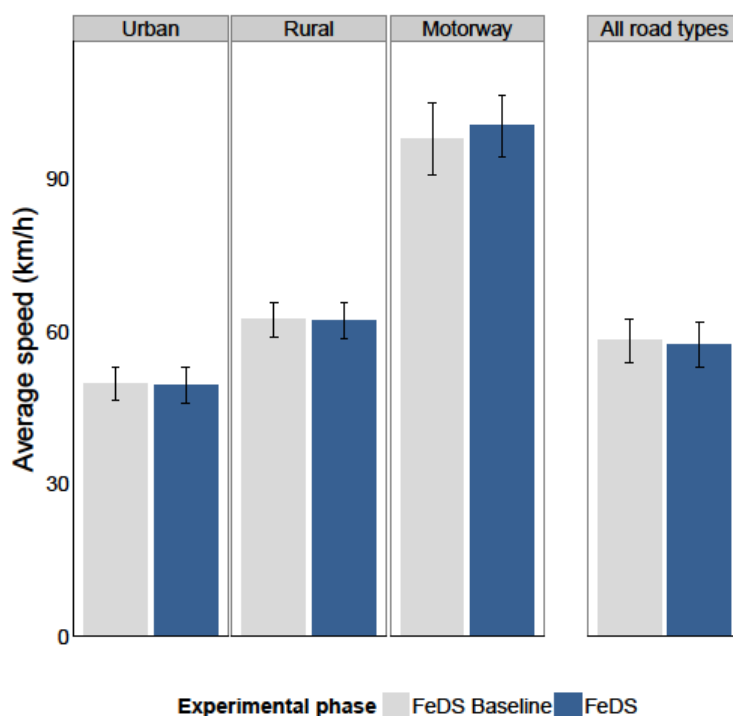


Figure 71: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 167 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	49.8	49.5	0.3	0.998
Rural	62.4	62.2	0.2	0.999
Motorway	97.9	100.4	-2.6	0.990
All road types	58.2	57.5	0.8	0.298

**Preliminary conclusions:**

There was no significant effect of the full ecoDriver system on vehicle speeds when driving on gradients.

## 7.6.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 168: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	61.9	61.9	1	166.6	4.9	0.029
road_type	-	-	-	-	-	-
Main_effect:road_type	-	-	-	-	-	-

Table 169: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	57.42	56.41	58.42	<0.001
App	-1.20	-2.27	-0.13	0.029
Random part	N			
Driver_id	30			
Vmc_id	1			
Number of observations	189			

Reference of the model is the App baseline during rural driving condition. The estimated effect is the change on average when current condition is compared to the reference.

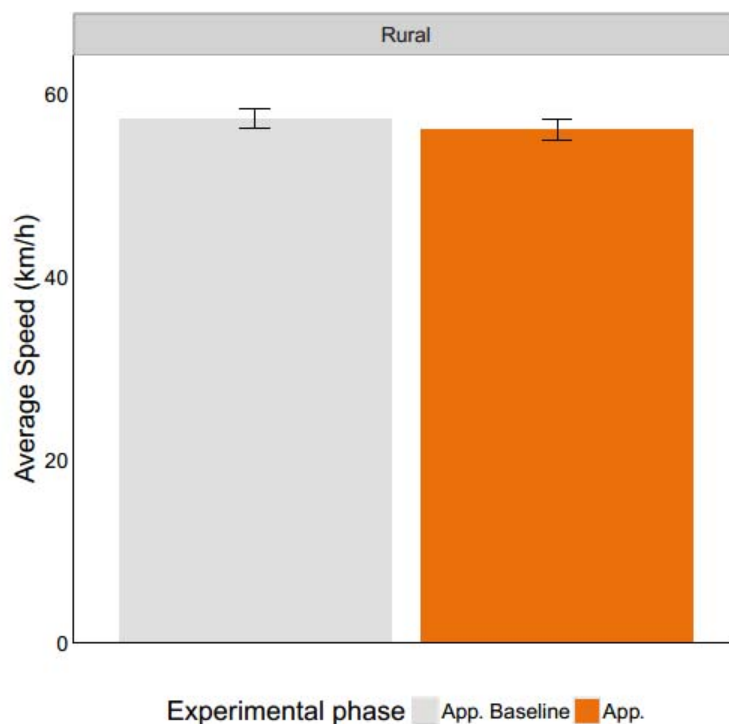


Figure 72: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 170 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	-	-	-	-
Rural	57.4	56.2	1.2	<0.001
Motorway	-	-	-	-
All road types	57.4	56.2	1.2	<0.001

#### Preliminary conclusions:

The results show a statistically significant effect of the ecoDriver application on vehicle speeds on crests on rural roads. A speed reduction of 1.2 km/h was observed when using the app compared to when not using it.

## 7.6.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 171: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	1.9	1.9	1	120.3	0.1	0.708
road_type	204.5	204.5	1	120.1	15.4	<0.001
Main_effect:road_type	0.1	0.1	1	120.3	0.0	0.917

Table 172: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	47.93	41.92	53.93	<0.001
Haptic	-1.20	-10.92	8.52	0.809
Rural	9.47	3.81	15.12	0.001
Haptic:Rural	0.52	-9.29	10.33	0.917
Random part	N			
Driver_id	36			
Number of observations	153			



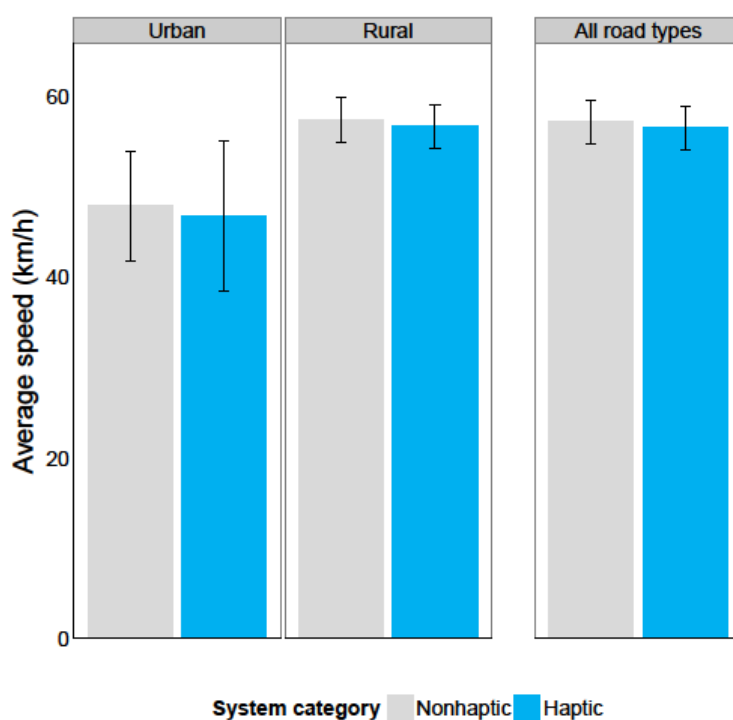


Figure 73: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 173 Average speed for the different systems and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	47.9	46.7	1.2	0.994
Rural	57.4	56.7	0.7	0.697
Motorway	-	-	-	-
All road types	57.2	56.6	0.6	0.388

**Preliminary conclusions:**

There was no significant difference in vehicle speeds when driving on gradients when using either the haptic or non-haptic ecoDriver system.

### 7.6.2 Results summary

Table 174: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	0.41 (N.S.)	0.45 (N.S.)	0.34 (N.S.)	1.24 (N.S.)	1.2 (N.S.)	-
Rural	0.76 (N.S.)	0.66 (N.S.)	0.21 (N.S.)	1.24	0.68 (N.S.)	-
Motorway	-2.55 (N.S.)	-2.55 (N.S.)	-2.57 (N.S.)	-	-	-
All road types	0.97	0.93 (N.S.)	0.75 (N.S.)	1.27	0.61 (N.S.)	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	0.87 (N.S.)	0.94 (N.S.)	0.69 (N.S.)	2.25 (N.S.)	2.5 (N.S.)	-
Rural	1.25 (N.S.)	1.08 (N.S.)	0.34 (N.S.)	2.16	1.18 (N.S.)	-
Motorway	-2.66 (N.S.)	-2.65 (N.S.)	-2.62 (N.S.)	-	-	-
All road types	1.68	1.59 (N.S.)	1.29 (N.S.)	2.21	1.06 (N.S.)	-

### 7.6.3 Conclusions and implications

Few ecoDriver systems provided guidance that was specific to driving on gradients, hence limited predictions were made about the expected effects of the system on vehicle speeds. Overall, it was observed that the use of most ecoDriver systems did not have a significant impact on vehicle speeds on gradients. There was one significant effect, with the ecoDriver application leading to significantly lower speeds on rural roads compared to the baseline condition. The application does not provide guidance relating to driving on gradients, so this effect is likely to be due to a more global impact on the drivers' green driving behaviour. There was no evidence that the addition of the haptic pedal changed vehicle speed on gradients. However, it should be noted that these analyses were conducted on a low number of cases, and as such may lack the statistical power necessary to detect small effects of the ecoDriver systems on driver performance.

## 7.7 Hypothesis 16: Using an ecoDriver system, the speed will change before speed limit changes

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, speed will change when driving before locations where a low speed is recommended by the system: speed limit changes*

6. Compared to baseline, the average speed will be reduced before speed limit changes when using an ecoDriver system. [Type A]
7. Compared to baseline, the average speed will be reduced before speed limit changes when using an embedded system. [Type B]
8. Compared to baseline, the average speed will be reduced before speed limit changes when using the full ecoDriver system. [Type C]
9. Compared to baseline, the average speed will be reduced before speed limit changes when using the ecoDriver application. [Type D]
10. Compared to a non-haptic system, the average speed will be reduced before speed limit changes when using a haptic ecoDriver system. [Type E]

#### Performance indicator (PI):

Avg\_speed\_distance\_based (km/h) for section of road before event

#### Data reduction method:

Event-based data was divided into sub-sections for the analysis: – before 300m, spot, after 300m

Controlled data only; cases with a decrease in speed limit only

Where data was available for one road type only; road\_type removed as a fixed effect

Where data was available for one VMC only; Vmc\_id removed as a random effect.

Avg\_speed\_distance\_based between 10-150 km/h

Removed all cases where vehicle was stationary during the event (stationary\_time\_ratio0 <100%)

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment (Type A dataset)</b>  <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded (Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id

## Hypothesis analysis summary table

<b>Baseline FeDS vs FeDS (Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline App vs App (Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Vmc_id, Driver_id
<b>Non-haptic vs Haptic (Type E dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 7.7.1 Controlled studies

#### 7.7.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterwhaite approximation for the degrees of freedom.

Table 175: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	6951.9	6951.9	1	9963.6	49.5	<0.001
road_type	549006.4	274503.2	2	9922.0	1953.3	<0.001
Main_effect:road_type	3261.4	1630.7	2	9899.7	11.6	<0.001

Table 176: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	51.52	46.91	56.13	<0.001
Treatment	-0.73	-1.68	0.22	0.133
Rural	10.47	9.47	11.47	<0.001
Motorway	35.94	34.18	37.70	<0.001

Treatment:Rural	-0.70	-1.85	0.45	0.235
Treatment:Motorway	-4.89	-6.89	-2.88	<0.001
Random part	<b>N</b>			
Driver_id	143			
Vmc_id	7			
Number of observations	10026			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

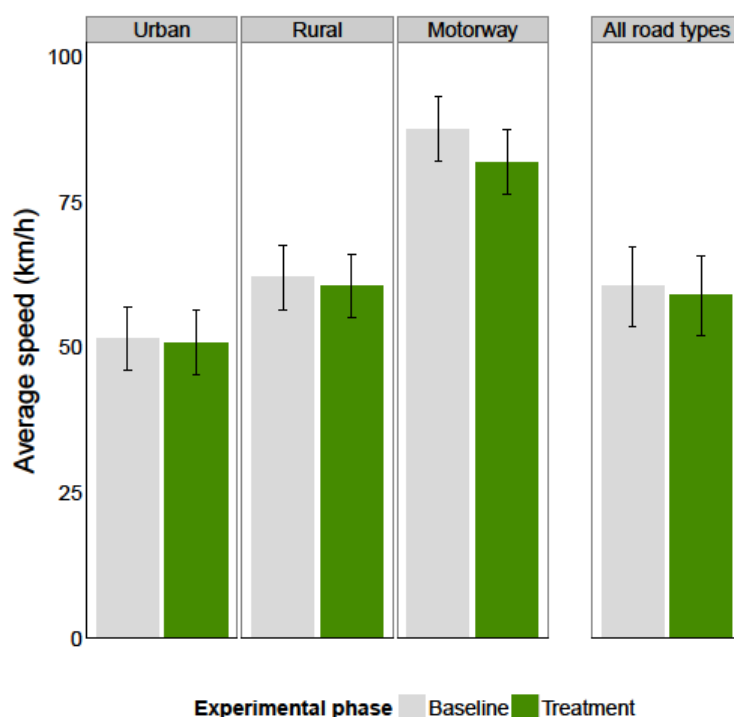


Figure 74: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 177 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	51.5	50.8	0.7	0.639
Rural	62.0	60.6	1.4	<0.001
Motorway	87.5	81.8	5.6	<0.001
All road types	60.4	58.9	1.5	<0.001

**Preliminary conclusions:**

Overall, there is a significant positive effect of the ecoDriver systems on average vehicle speed on the 300m approach to a speed limit decrease. This effect was significant across all road types. On rural roads, average speed was 1.4 km/h lower on the approach to a speed limit decrease when using an ecoDriver system, compared to when not using a system. This reduction in speed resulting from system use was larger on motorways (5.6 km/h reduction). There was a non-significant tendency for speed to decrease with system use on urban roads (0.7 km/h reduction).

### 7.7.1.2 Type B: Baseline embedded vs embedded

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 178: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	7878.4	7878.4	1	8634.0	54.4	<0.001
road_type	496778.7	248389.4	2	8263.1	1714.5	<0.001
Main_effect:road_type	2657.1	1328.6	2	8587.6	9.2	<0.001

Table 179: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	54.36	49.80	58.92	<0.001
Treatment	-1.38	-2.41	-0.35	0.009
Rural	9.50	8.34	10.66	<0.001
Motorway	34.65	32.84	36.46	<0.001
Treatment:Rural	-0.13	-1.43	1.18	0.850
Treatment:Motorway	-4.24	-6.31	-2.17	<0.001
Random part	N			
Driver_id	103			
Vmc_id	6			
Number of observations	8639			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

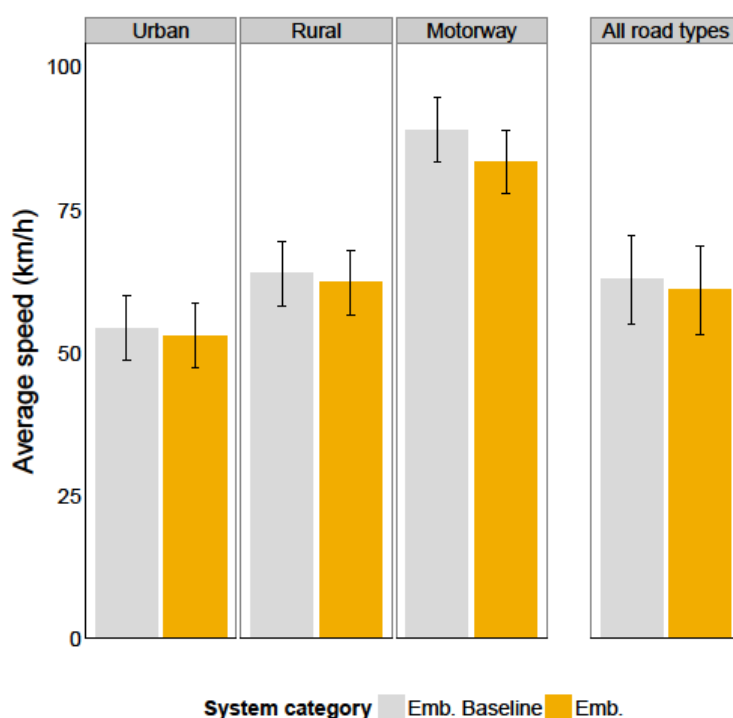


Figure 75: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 180 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	54.4	53.0	1.4	0.083
Rural	63.9	62.4	1.5	0.004
Motorway	89.0	83.4	5.6	<0.001
All road types	62.8	61.0	1.9	<0.001

#### Preliminary conclusions:

Overall, there is a significant positive effect of the embedded systems on average vehicle speed on the 300m approach to a speed limit decrease. This effect was significant across all road types, with the largest effect on motorways. On rural roads, system use reduced average speed by 1.5 km/h compared to baseline. On motorways, the reduction in speed due to embedded system use was 5.6 km/h. There was a non-significant tendency for speed to decrease with system use on urban roads (1.4 km/h reduction).



### 7.7.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 181: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
<b>Main_effect</b>	3870.6	3870.6	1	3162.4	23.2	<0.001
<b>road_type</b>	398448.3	199224.1	2	3024.0	1195.5	<0.001
<b>Main_effect:road_type</b>	540.3	270.1	2	3123.3	1.6	0.198

Table 182: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
<b>(Intercept)</b>	55.35	53.05	57.65	<0.001
<b>Treatment</b>	-2.32	-4.04	-0.61	0.008
<b>Rural</b>	10.21	8.37	12.06	<0.001
<b>Motorway</b>	37.47	35.11	39.82	<0.001
<b>Treatment:Rural</b>	0.78	-1.41	2.97	0.487
<b>Treatment:Motorway</b>	-1.61	-4.39	1.16	0.255
<b>Random part</b>	<b>N</b>			
<b>Driver_id</b>	59			
<b>Vmc_id</b>	3			
<b>Number of observations</b>	3167			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

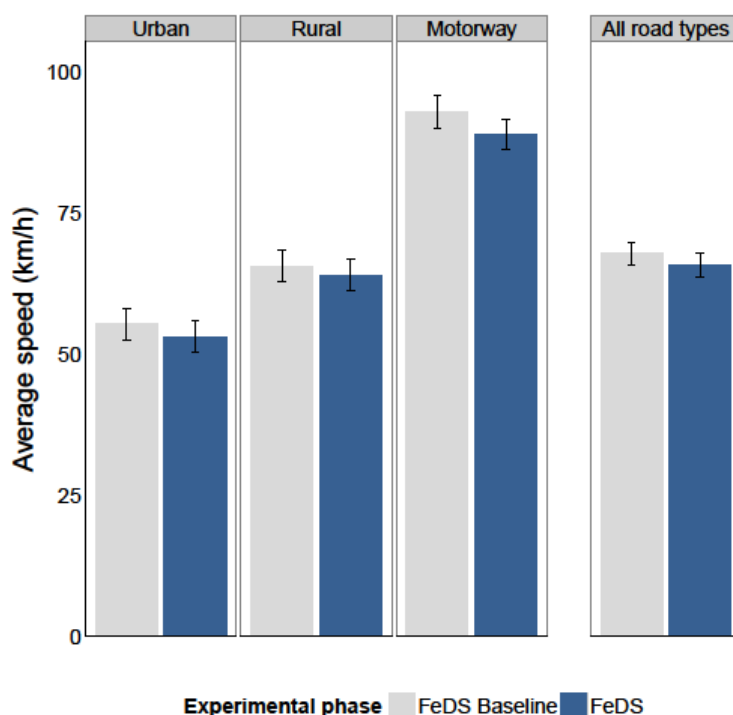


Figure 76: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 183 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	55.3	53.0	2.3	0.081
Rural	65.6	64.0	1.5	0.251
Motorway	92.8	88.9	3.9	0.006
All road types	67.8	65.7	2.1	0.002

#### Preliminary conclusions:

Overall, there is a significant positive effect of the full ecoDriver system on average vehicle speed on the 300m approach to a speed limit decrease. This effect reached significant on motorways only, where approach speeds during system use were reduced by 3.9 km/h compared to baseline. On urban and rural roads, there was a tendency for speeds to decrease when using the full ecoDriver system (2.3 and 1.5 km/h respectively), but these effects did not reach statistical significance.

## 7.7.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 184: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	112.8	112.8	1	1364.2	1.1	0.303
road_type	44658.1	44658.1	1	1348.1	419.6	<0.001
Main_effect:road_type	28.8	28.8	1	1340.8	0.3	0.603

Table 185: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	37.71	35.50	39.93	<0.001
Treatment	-1.16	-3.81	1.49	0.391
Rural	14.88	12.96	16.79	<0.001
Treatment:Rural	0.77	-2.14	3.68	0.603
Random part	N			
Driver_id	40			
Vmc_id	2			
Number of observations	1387			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

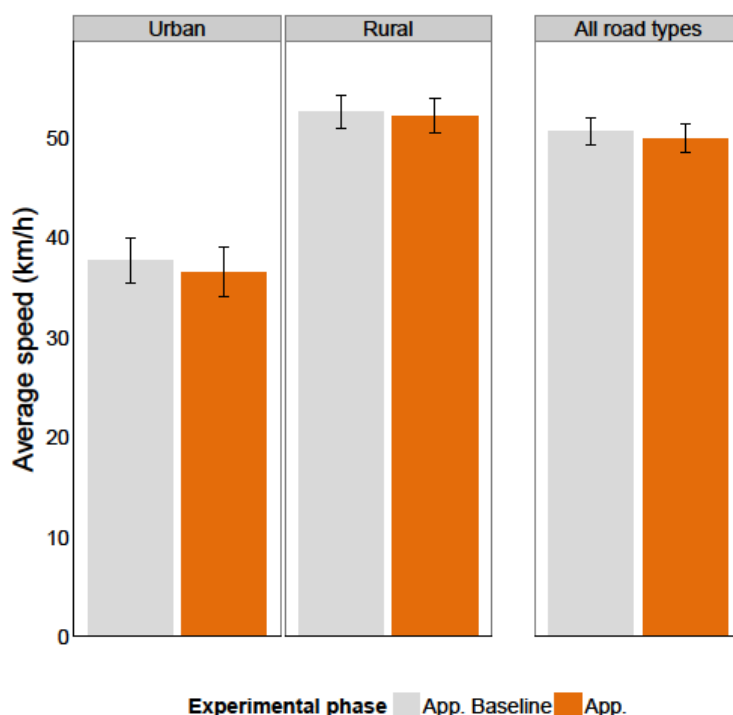


Figure 77: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 186 Average speed for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	37.7	36.6	1.2	0.819
Rural	52.6	52.2	0.4	0.924
Motorway	-	-	-	-
All road types	50.7	49.9	0.7	0.264

#### Preliminary conclusions:

The results show no significant effects of the ecoDriver application on the approach to a speed limit decrease. There was a non-significant tendency for the app to reduce vehicle speeds on the approach to a speed limit change in urban areas. This analysis may suffer from the reduced statistical power associated with a low number of cases available for inclusion.

## 7.7.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 187: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	51.7	51.7	1	1521.5	0.5	0.494
road_type	15050.4	15050.4	1	1513.7	136.1	<0.001
Main_effect:road_type	257.0	257.0	1	1524.2	2.3	0.128

Table 188: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	47.58	45.68	49.48	<0.001
Treatment	-0.54	-2.50	1.41	0.588
Rural	6.78	4.52	9.05	<0.001
Treatment:Rural	1.99	-0.57	4.55	0.128
Random part	N			
Driver_id	36			
Number of observations	1532			

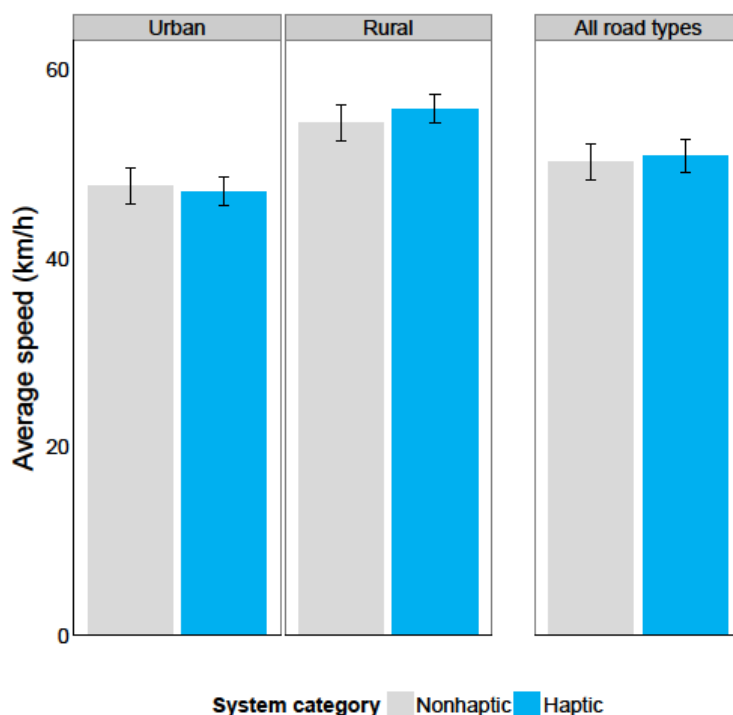


Figure 78: model based average values of avg\_speed\_distanced\_based for fixed effects.

Table 189 Average speed for the different systems and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	47.6	47.0	0.5	0.947
Rural	54.4	55.8	-1.5	0.323
Motorway	-	-	-	-
All road types	50.2	50.8	-0.6	0.380

**Preliminary conclusions:**

There was no difference between the haptic and non-haptic version of a system in terms of their effects on average vehicle speed on the approach to a speed limit decrease.

### 7.7.2 Results summary

Table 190: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	0.73 (N.S.)	1.38 (N.S.)	2.32 (N.S.)	1.16 (N.S.)	0.54 (N.S.)	-
Rural	1.43	1.51	1.54 (N.S.)	0.39 (N.S.)	-1.45 (N.S.)	-
Motorway	5.62	5.62	3.94	-	-	-
All road types	1.55	1.87	2.07	0.74 (N.S.)	-0.62 (N.S.)	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	1.41 (N.S.)	2.54 (N.S.)	4.2 (N.S.)	3.08 (N.S.)	1.14 (N.S.)	-
Rural	2.30	2.36	2.35 (N.S.)	0.74 (N.S.)	-2.67 (N.S.)	-
Motorway	6.42	6.31	4.24	-	-	-
All road types	2.56	2.98	3.06	1.45 (N.S.)	-1.23 (N.S.)	-

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	2.88	2.42	2.68	1.48 (N.S.)	0.41 (N.S.)	-
Rural	0.93	1.60	2.17	0.09 (N.S.)	-0.25 (N.S.)	-
Motorway	3.91	4.05	4.79	-	-	-

### 7.7.3 Conclusions and implications

The average speed on the approach to a speed limit decrease would be expected to be lower if the ecoDriver systems are effective in encouraging green driving behaviour (such as earlier adoption of coasting as a speed reduction strategy) during these events. Overall, there was evidence to suggest that the ecoDriver systems cause the driver to drive significantly slower on the approach to a speed limit decrease, compared to when they are not using a system. This effect was observed for the complete dataset, the full ecoDriver system data, and the embedded systems data. In each of these cases, approach speed was decreased on all road types, with this effect reaching significance on rural roads and motorways. There was no impact of using the ecoDriver application on vehicle speeds when approaching a speed limit decrease. The addition of a haptic component to the ecoDriver systems did

not have a further impact on vehicle speeds for these speed limit change events. Overall, there is evidence that most versions of the ecoDriver system can have a positive effect on vehicle speeds on the approach to a decrease in the speed limit. This could be through encouraging drivers to release the accelerator and coast earlier during the approach phase. This effect could have a substantial positive impact on both fuel consumption and road safety with wider uptake of the system.



## 7.8 Hypothesis 17: Using an ecoDriver system, the time headway distribution to leading vehicle will change

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, the time headway distribution to leading vehicle will change*

6. Using an ecoDriver system, the time headway distribution to leading vehicle will change. [Type A]
7. Using an embedded ecoDriver system, the time headway distribution to leading vehicle will change. [Type B]
8. Using the full ecoDriver system (FeDS), the time headway distribution to leading vehicle will change. [Type C]
9. Using the ecoDriver application (App), the time headway distribution to leading vehicle will change. [Type D]
10. Using a haptic ecoDriver system, the time headway distribution to leading vehicle will change. [Type E]

#### Performance indicator (PI):

Average time headway (THW)

#### Data reduction method:

500m sections

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.  
Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> <b>(Type A dataset)</b> <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> <b>(Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b> <b>(Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline App vs App</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>

## Hypothesis analysis summary table

<b>(Type D dataset)</b>	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Vmc_id, Driver_id
<b>Non-haptic vs Haptic (Type E dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Non-haptic</li> <li>• Haptic</li> </ul>
	Additional fixed effect	Road_type*Main_effect
	Random effects	Driver_id

### Standard Filter:

- Exclude N/A's and obvious outliers.

### Filtering due to available amount of data:

- Only controlled data (no front sensor available in naturalistic studies)
- Type A-C: 3 road types (urban, rural, motorway)
- Type D: 2 road types (urban, rural)
- Type E: 1 road type (urban + rural)

### Extra Filtering:

- Filtering segments with avg\_speed < 10 and > 200 km/h
- Filtering segments with avg\_distance\_headway < 1 m
- Filtering segments with avg\_time\_headway > 10s

### 7.8.1 Controlled studies

#### 7.8.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 191: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	73.3	73.3	1	12848.0	34.0	<0.001
road_type	1096.5	548.3	2	12214.4	254.5	<0.001
Main_effect:road_type	2.6	1.3	2	13134.4	0.6	0.547

Table 192: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	3.23	2.29	4.16	<0.001
Treatment	0.21	0.12	0.30	<0.001
Rural	-0.67	-0.77	-0.57	<0.001
Motorway	-0.65	-0.80	-0.50	<0.001
Treatment:Rural	-0.06	-0.18	0.06	0.322
Treatment:Motorway	0.01	-0.15	0.17	0.929
Random part	N			
Driver_id	130			
Vmc_id	6			
Number of observations	13164			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

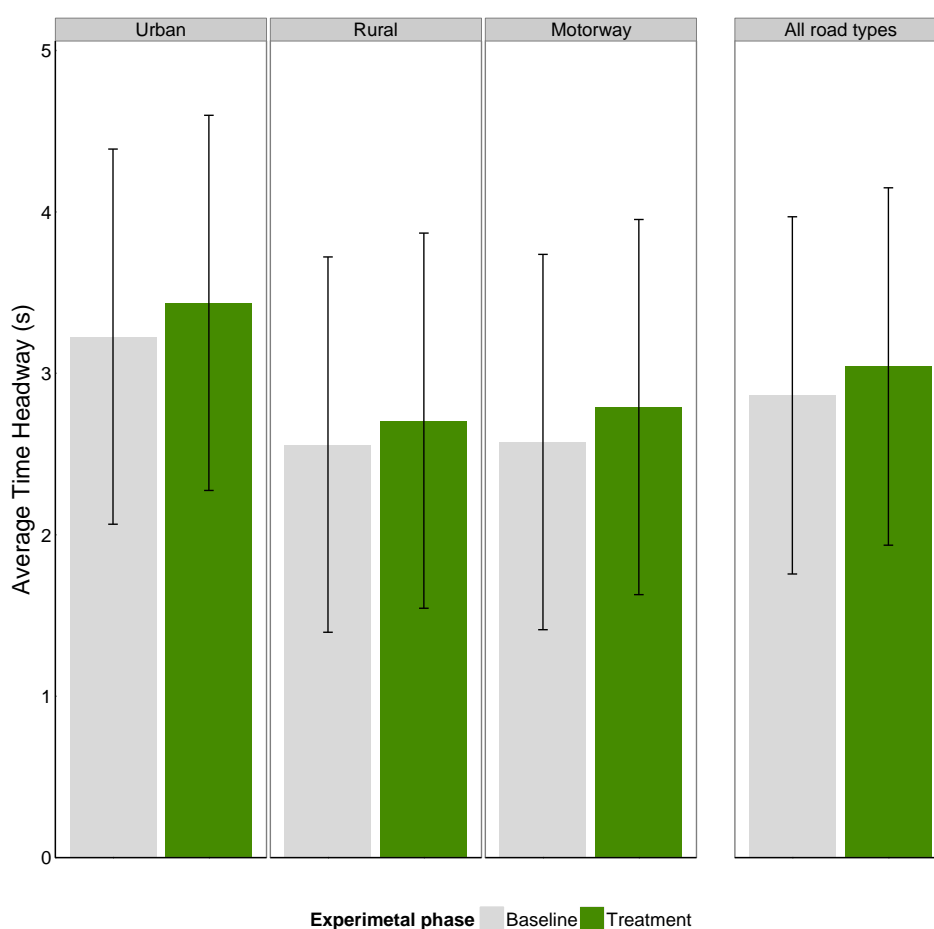


Figure 79: Model based average values of the average THW (s) for fixed effects.

Table 193: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	3.23	3.44	-0.21	<0.001
Rural	2.56	2.71	-0.15	0.020
Motorway	2.57	2.79	-0.22	0.023
All road types	2.86	3.04	-0.18	<0.001

**Preliminary conclusions:**

The main effect of experimental phase is significant with increased THW in the treatment condition. The interaction between road type and phase is not significant, indicating that the effect of treatment on THW is consistent for all road types analysed. Overall, the mean THW increases within a range of 0.15 (rural roads) up to 0.22 seconds (motorways) in the treatment phase compared to the baseline.

## 7.8.1.2 Type B: Baseline embedded vs embedded

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 194: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	83.2	83.2	1	10298.1	50.1	<0.001
road_type	381.8	190.9	2	9909.7	115.1	<0.001
Main_effect:road_type	11.8	5.9	2	10396.7	3.5	0.029

Table 195: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	2.87	1.83	3.91	0.003
Embedded	0.32	0.23	0.41	<0.001
Rural	-0.39	-0.50	-0.27	<0.001
Motorway	-0.47	-0.61	-0.33	<0.001
Treatment:Rural	-0.18	-0.32	-0.05	0.008
Treatment:Motorway	-0.10	-0.25	0.05	0.190
Random part	N			
Driver_id	91			
Vmc_id	5			
Number of observations	10419			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

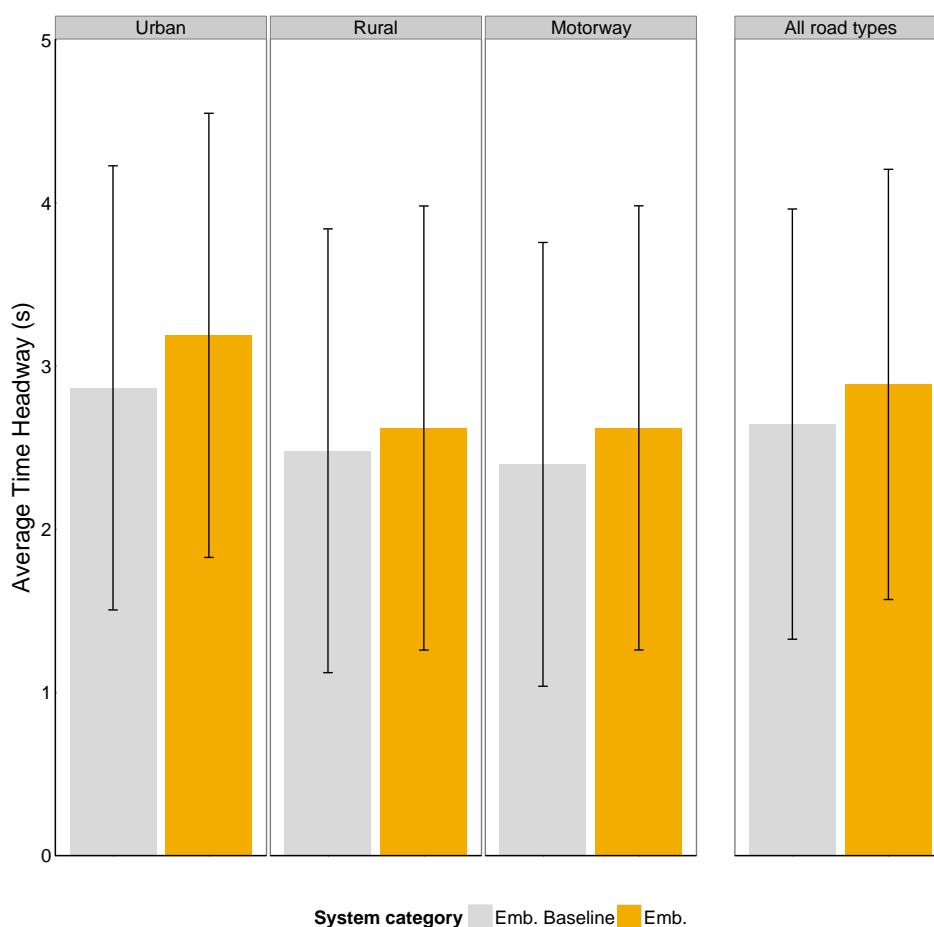


Figure 80: Model based average values of the average THW (s) for fixed effects.

Table 196: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates			Tukey multiple comparisons significance test
	Baseline	Embedded	Difference (B-E)	
Urban	2.87	3.19	-0.32	<b>&lt;0.001</b>
Rural	2.48	2.62	-0.14	0.102
Motorway	2.40	2.62	-0.22	<b>0.004</b>
All road types	2.65	2.89	-0.24	<b>&lt;0.001</b>

#### Preliminary conclusions:

For the embedded systems, the main effect of experimental phase is significant with increased THW in the treatment condition. Furthermore, the THW differs significantly for different road types. The interaction between road type and phase is significant, post-hoc Tukey multiple comparison tests revealed significant effects of treatment on THW for urban roads, motorways and the all road types category. Overall, the mean THW increases within a range of 0.14 (rural roads) up to 0.32 seconds (urban roads) in the treatment phase compared to the Baseline.

## 7.8.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 197: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
<b>Main_effect</b>	52.8	52.8	1	8931.4	33.2	<b>&lt;0.001</b>
<b>road_type</b>	325.2	162.6	2	8646.7	102.2	<b>&lt;0.001</b>
<b>Main_effect:road_type</b>	9.9	5.0	2	9032.7	3.1	<b>0.044</b>

Table 198: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	2.29	2.05	2.53	<b>&lt;0.001</b>
FeDS	0.28	0.19	0.38	<b>&lt;0.001</b>
Rural	-0.38	-0.52	-0.25	<b>&lt;0.001</b>
Motorway	-0.51	-0.65	-0.36	<b>&lt;0.001</b>
FeDS:Rural	-0.19	-0.35	-0.04	<b>0.013</b>
FeDS:Motorway	-0.06	-0.21	0.09	0.421
<b>Random part</b>	<b>N</b>			
Driver_id	59			
Vmc_id	3			
<b>Number of observations</b>	9051			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

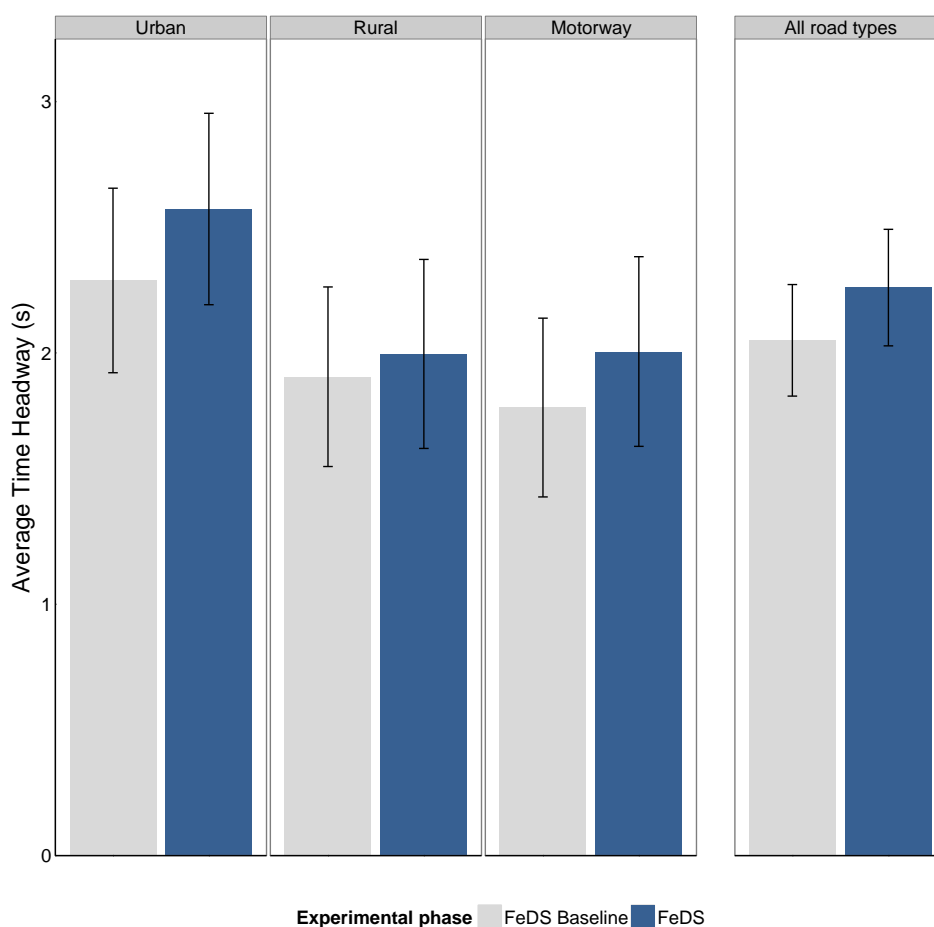


Figure 81: Model based average values of the average THW (s) for fixed effects.

Table 199: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	2.29	2.57	-0.28	<0.001
Rural	1.91	2.00	-0.09	0.682
Motorway	1.78	2.01	-0.22	0.003
All road types	2.05	2.26	-0.21	<0.001

**Preliminary conclusions:**

For the FeDS, the main effect of experimental phase is significant with increased THW in the treatment condition. Furthermore, the THW differs significantly for different road types. The interaction between road type and phase is also significant. post-hoc Tukey multiple comparison tests revealed significant effects of treatment on THW for urban roads, motorways and the all road types category. Overall, the mean THW increases within a range of 0.09 (rural roads) up to 0.28 seconds (urban roads) in the treatment phase compared to the Baseline.



## 7.8.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterwhaite approximation for the degrees of freedom.

Table 200: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	1.6	1.6	1	2003.8	0.4	0.528
road_type	948.6	948.6	1	2735.8	239.9	<0.001
Main_effect:road_type	6.4	6.4	1	2726.8	1.6	0.204

Table 201: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	3.78	2.81	4.75	0.015
App	0.15	-0.10	0.40	0.230
Rural	-1.12	-1.33	-0.91	<0.001
App:Rural	-0.20	-0.51	0.11	0.204
Random part	N			
Driver_id	39			
Vmc_id	2			
Number of observations	2745			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

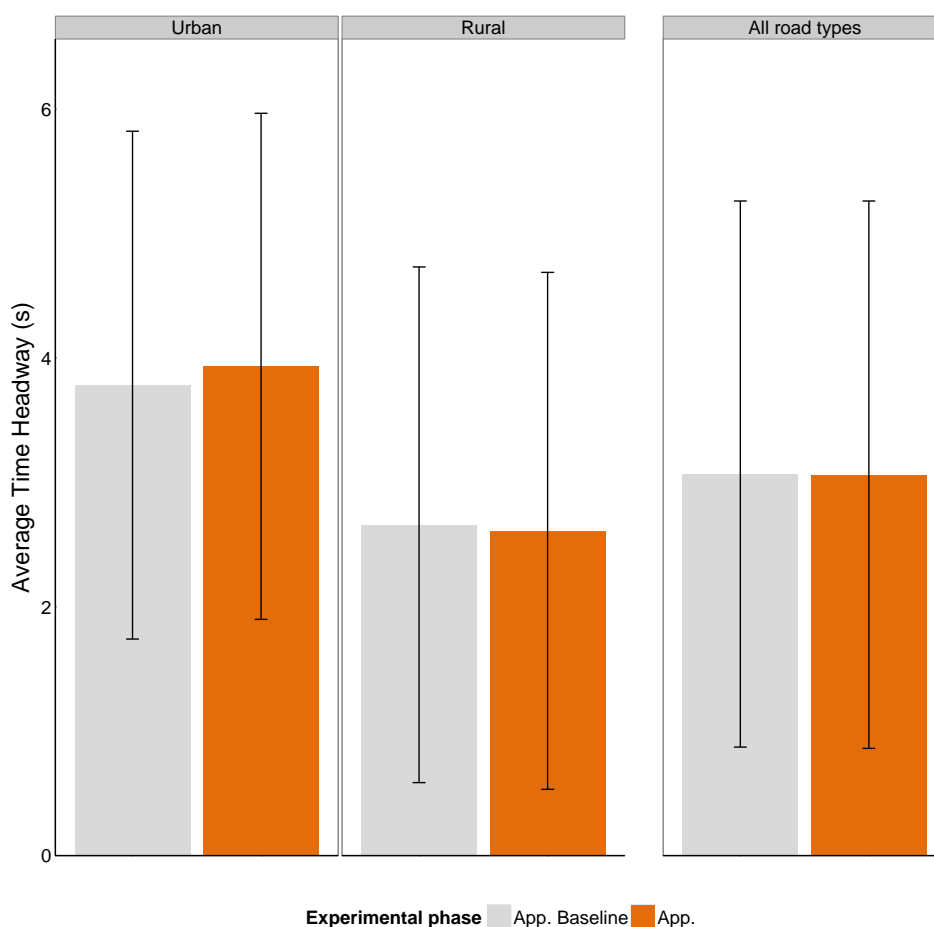


Figure 82: Model based average values of the average THW (s) for fixed effects.

Table 202: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	3.78	3.93	-0.15	0.625
Rural	2.66	2.61	0.05	0.960
All road types	3.07	3.06	0.01	0.945

#### Preliminary conclusions:

For the App, the main effect of experimental phase is not significant with increased THW in the treatment condition. However, the THW differs significantly for different road types.

### 7.8.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 203: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	3.7	3.7	1	311.0	0.8	0.359

Table 204: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	4.94	4.60	5.29	<0.001
Haptic	0.22	-0.25	0.69	0.359
Random part	N			
Driver_id	24			
Number of observations	311			

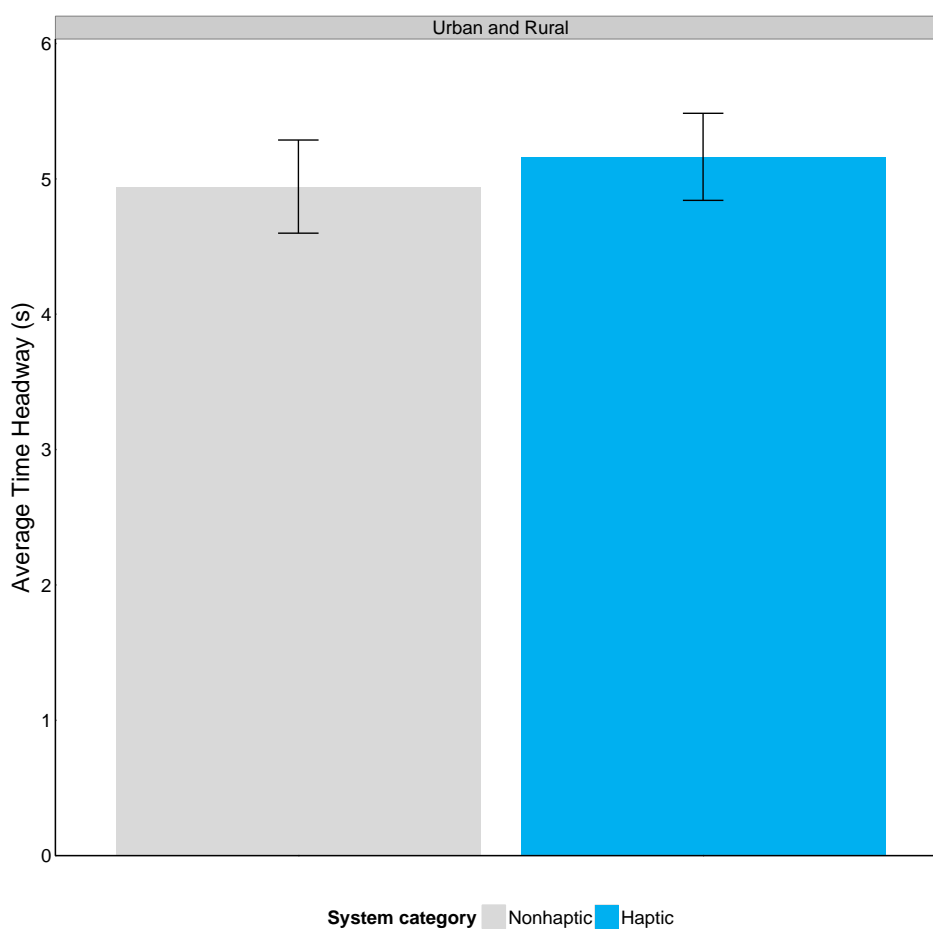


Figure 83: Model based average values of the average THW (s) for fixed effects.

Table 205: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
One road type (Urban and Rural)	4.94	5.16	-0.22	0.358

**Preliminary conclusions:**

No significant effects on THW for different road types and experimental phase were found.

### 7.8.2 Results summary

Table 206: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-0.21	-0.32	-0.28	-0.15 (N.S.)	-	-
Rural	-0.15	-0.14 (N.S.)	-0.09 (N.S.)	0.05 (N.S.)	-	-
Motorway	-0.22	-0.22	-0.22	-	-	-
All road types	-0.18	-0.24	-0.21	0.01 (N.S.)	-0.22 (N.S.)	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-6.5	-11.15	-12.23	-3.97 (N.S.)	-	-
Rural	-5.86	-5.65 (N.S.)	-4.71 (N.S.)	1.88 (N.S.)	-	-
Motorway	-8.56	-9.17	-12.36	-	-	-
All road types	-6.29	-9.06	-10.24	0.33 (N.S.)	-4.45 (N.S.)	-

### 7.8.3 Conclusions and implications

Overall, THW increases in the treatment condition compared to baseline driving. This effect can be observed on all road types, but is largest on urban roads. When analysing the four different sub sets of ecoDriver systems separately, significant differences between baseline and treatment condition could only be shown for embedded systems and the FeDS. No significant differences in THW were observed for the ecoDriver App and the haptic vs. non-haptic treatment conditions.

An increase of the average THW implies an increase of the average distance headway (shown as negative effect size in Table 206). This means that drivers extend the gap to the vehicles in front for a better anticipation of the traffic which can improve both safety and eco-friendly predictive driving. However, this effect can only be shown for two out of four different system categories tested.

## 7.9 Hypothesis 18: Using an ecoDriver system, there will be shorter distances to vehicles before intersections

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, there will be shorter distances to vehicles before intersections*

1. Using an ecoDriver system, there will be shorter distances to vehicles before intersections. [Type A]
2. Using an embedded ecoDriver system, there will be shorter distances to vehicles before intersections. [Type B]
3. Using the full ecoDriver system (FeDS), there will be shorter distances to vehicles before intersections. [Type C]
4. Using the ecoDriver application, (App), there will be shorter distances to vehicles before intersections. [Type D]
5. Using a haptic ecoDriver, there will be shorter distances to vehicles before intersections. [Type E]

#### Performance indicator (PI):

Average time headway (THW)

(Average distance headway (DHW) is dependent on speed → average THW, see H17)

#### Data reduction method:

500m sections

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> <b>(Type A dataset)</b> <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> <b>(Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b> <b>(Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id

## Hypothesis analysis summary table

<b>Baseline App vs App (Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Vmc_id, Driver_id
<b>Non-haptic vs Haptic (Type E dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type*Main_effect
	Random effects	Driver_id

### Standard Filter:

- Exclude N/A's and obvious outliers.

### Filtering due to available amount of data:

- Only controlled data (no front sensor available in naturalistic studies)
- Type A-D: 2 road types (urban, rural)
- Type E: 1 road type (urban + rural)

### Extra Filtering:

- Filtering segments with avg\_speed < 10 and > 200 km/h
- Filtering segments with avg\_distance\_headway < 1 m
- Filtering segments with avg\_time\_headway > 10 s
- Only before safety critical location
- Excluding motorways
- Only first intersection, following intersections if distance between them of less than 100m skipped

### 7.9.1 Controlled studies

#### 7.9.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 207: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	69.6	69.6	1	13155.1	28.9	<0.001
road_type	1020.5	1020.5	1	13272.6	423.8	<0.001
Main_effect:road_type	27.5	27.5	1	13191.5	11.4	<0.001

Table 208: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	3.21	2.26	4.17	<0.001
Treatment	0.26	0.18	0.34	<0.001
Rural	-0.52	-0.61	-0.43	<0.001
Treatment:Rural	-0.19	-0.30	-0.08	<0.001
Random part	N			
Driver_id	130			
Vmc_id	6			
Number of observations	13285			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.



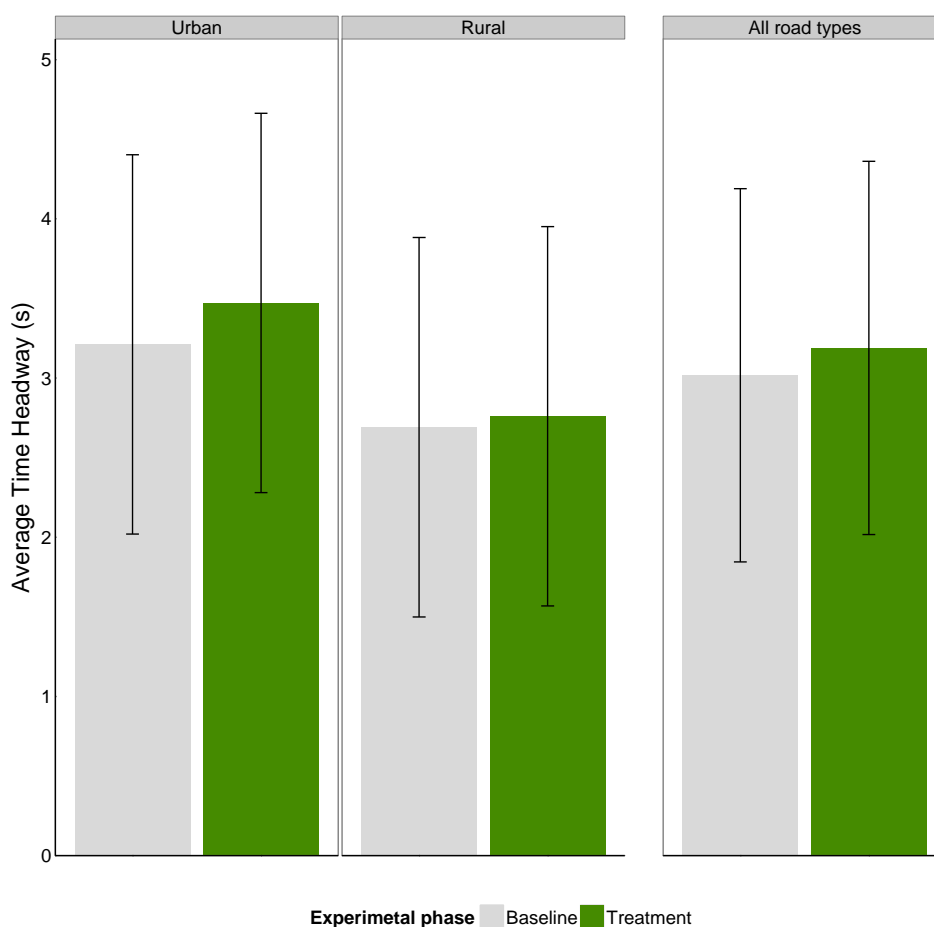


Figure 84: Model based average values of the average THW (s) for fixed effects.

Table 209: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	3.21	3.47	-0.26	<0.001
Rural	2.69	2.76	-0.07	0.407
All road types	3.02	3.19	-0.17	<0.001

#### Preliminary conclusions:

The main effect of experimental phase is significant with increased THW in the treatment condition. Furthermore, the THW differs significantly for different road types. The interaction between road type and phase is significant, post-hoc Tukey multiple comparison tests revealed significant effects of treatment on THW for urban roads and the all road types category. Overall, the mean THW increases within a range of 0.07 (rural roads) up to 0.26 seconds (motorways) in the treatment phase compared to the baseline.

## 7.9.1.2 Type B: Baseline embedded vs embedded

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 210: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	106.5	106.5	1	9461.5	65.1	<0.001
road_type	328.8	328.8	1	9456.0	200.9	<0.001
Main_effect:road_type	33.0	33.0	1	9395.6	20.1	<0.001

Table 211: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	2.94	1.86	4.02	0.003
Embedded	0.38	0.30	0.45	<0.001
Rural	-0.32	-0.41	-0.22	<0.001
Treatment:Rural	-0.26	-0.37	-0.15	<0.001
Random part	N			
Driver_id	91			
Vmc_id	5			
Number of observations	9471			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

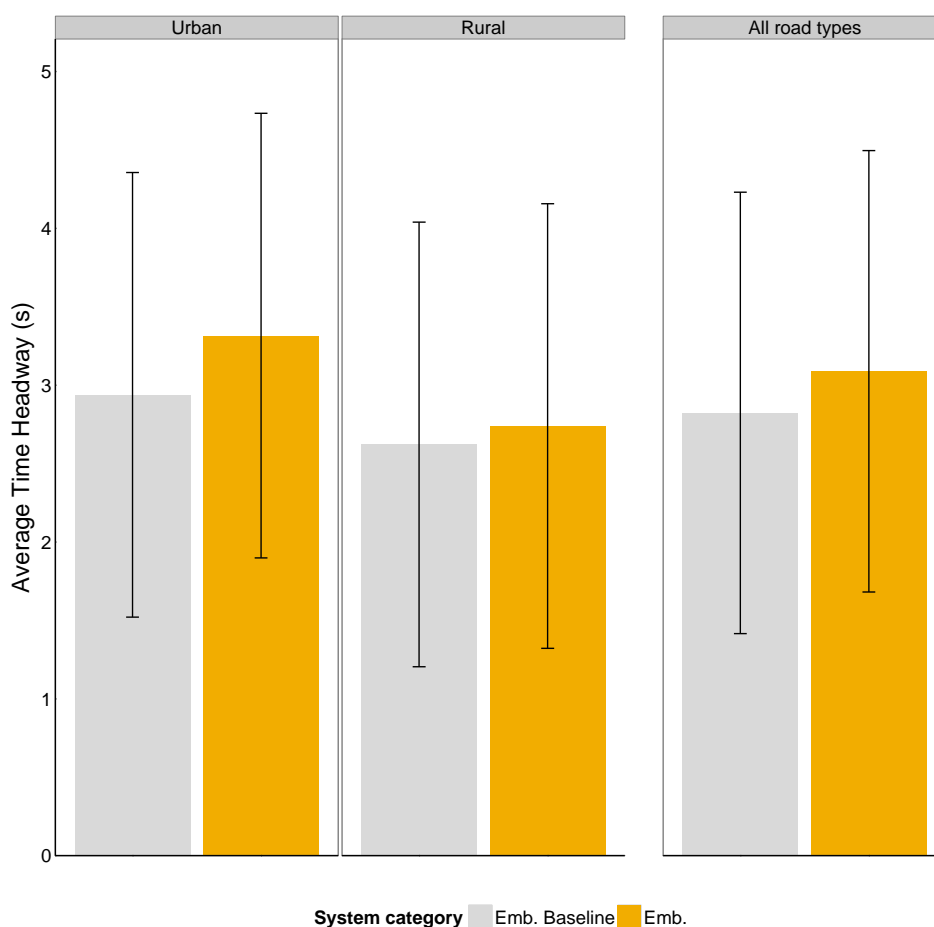


Figure 85: Model based average values of the average THW (s) for fixed effects.

Table 212: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	2.94	3.32	-0.38	<0.001
Rural	2.62	2.74	-0.12	0.046
All road types	2.82	3.09	-0.27	<0.001

#### Preliminary conclusions:

For the embedded systems, the main effect of experimental phase is significant with increased THW in the treatment condition. Furthermore, the THW differs significantly for different road types. The interaction between road type and phase is significant, post-hoc Tukey multiple comparison tests revealed significant effects of treatment on THW for all road types. Overall, the mean THW increases within a range of 0.12 (rural roads) up to 0.38 seconds (urban roads) in the treatment phase compared to the Baseline.

### 7.9.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 213: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
<b>Main_effect</b>	71.6	71.6	1	8059.0	44.0	<b>&lt;0.001</b>
<b>road_type</b>	299.3	299.3	1	7954.4	184.0	<b>&lt;0.001</b>
<b>Main_effect:road_type</b>	19.8	19.8	1	8011.6	12.2	<b>&lt;0.001</b>

Table 214: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	2.38	2.17	2.58	<b>&lt;0.001</b>
FeDS	0.33	0.25	0.42	<b>&lt;0.001</b>
Rural	-0.36	-0.47	-0.25	<b>&lt;0.001</b>
FeDS:Rural	-0.22	-0.35	-0.10	<b>&lt;0.001</b>
<b>Random part</b>	<b>N</b>			
Driver_id	59			
Vmc_id	3			
Number of observations	8061			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

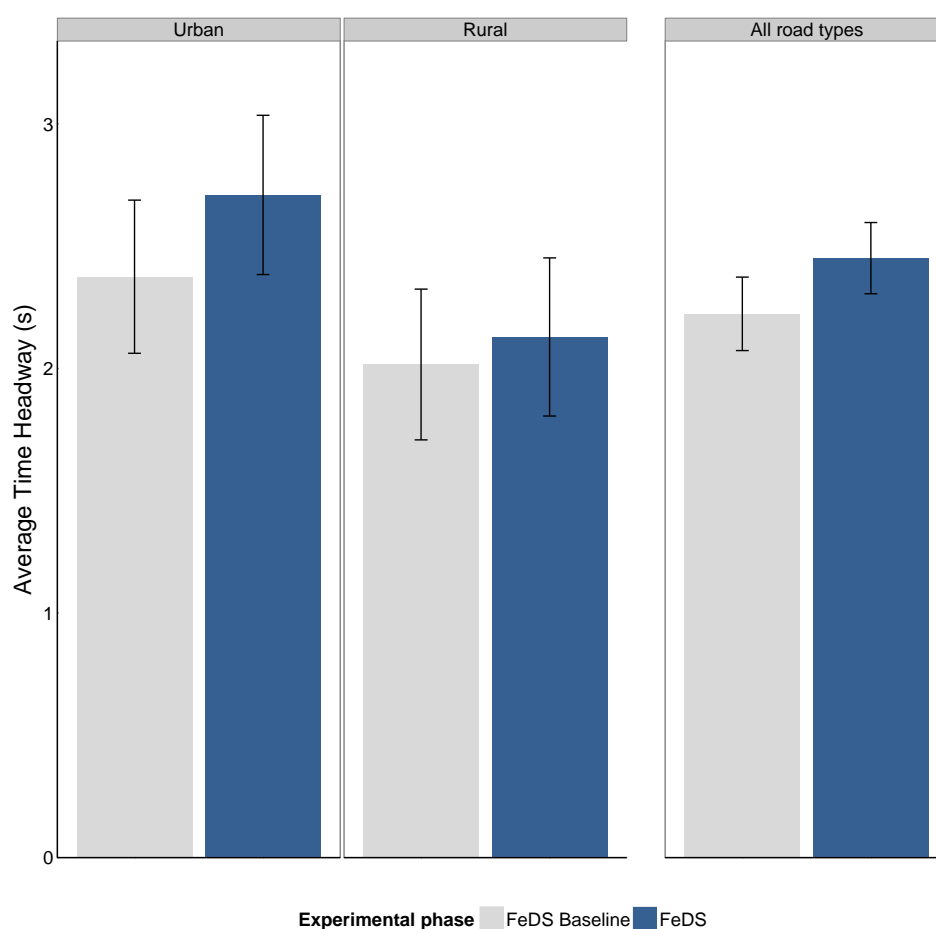


Figure 86: Model based average values of the average THW (s) for fixed effects.

Table 215: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	2.38	2.71	-0.33	<0.001
Rural	2.02	2.13	-0.11	0.091
All road types	2.22	2.45	-0.23	<0.001

#### Preliminary conclusions:

For the FeDS, the main effect of experimental phase is significant with increased THW in the treatment condition. Furthermore, the THW differs significantly for different road types. The interaction between road type and phase is significant, post-hoc Tukey multiple comparison tests revealed significant effects of treatment on THW for urban roads and the all road types category. Overall, the mean THW increases within a range of 0.11 (rural roads) up to 0.33 seconds (urban roads) in the treatment phase compared to the Baseline.

## 7.9.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 216: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.9	0.9	1	2696.0	0.2	0.648
road_type	812.3	812.3	1	3805.1	190.5	<0.001
Main_effect:road_type	22.8	22.8	1	3798.7	5.3	0.021

Table 217: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	3.27	1.93	4.61	0.040
App	0.12	-0.06	0.30	0.178
Rural	-0.78	-0.96	-0.60	<0.001
App:Rural	-0.31	-0.58	-0.05	0.021
Random part	N			
Driver_id	39			
Vmc_id	2			
Number of observations	3814			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

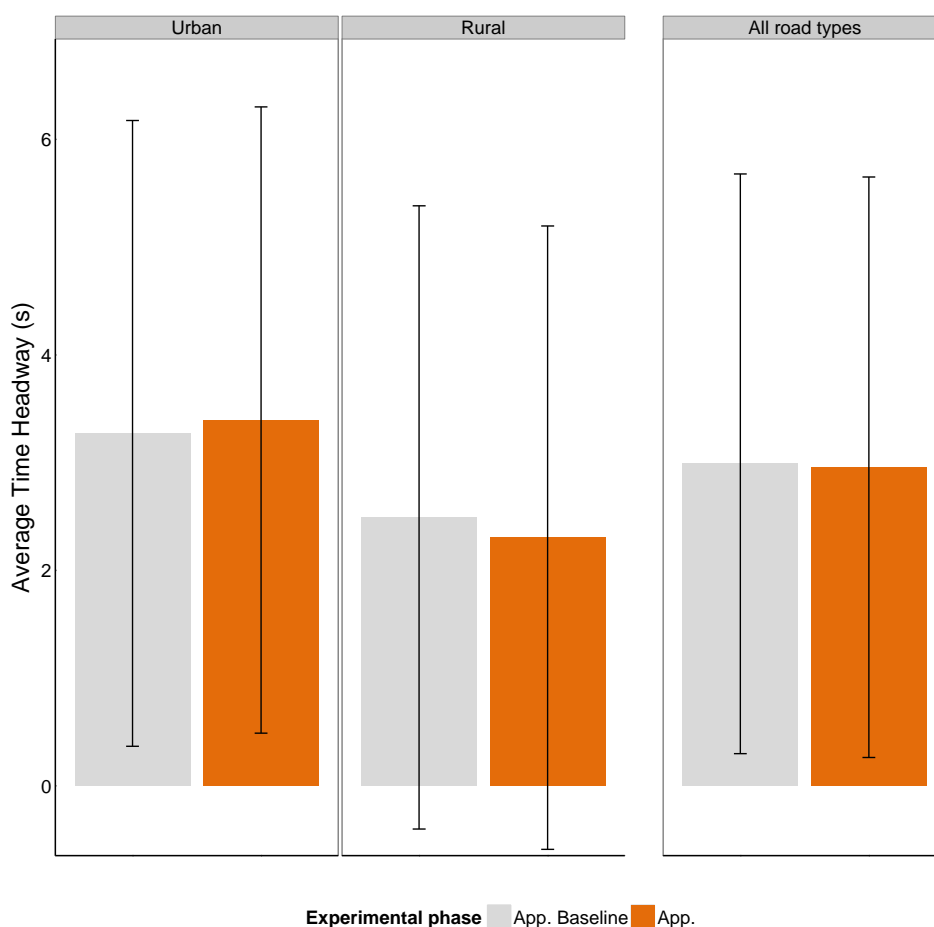


Figure 87: Model based average values of the average THW (s) for fixed effects.

Table 218: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	3.27	3.40	-0.12	0.533
Rural	2.49	2.30	0.19	0.256
All road types	2.99	2.96	0.03	0.648

#### Preliminary conclusions:

For the FeDS, the main effect of experimental phase is not significant with increased THW in the treatment condition. However, the THW differs significantly for different road types.

## 7.9.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 219: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	28.6	28.6	1	210.0	7.2	0.008

Table 220: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	4.86	4.48	5.23	<0.001
Haptic	0.74	0.20	1.28	0.008
Random part	N			
Driver_id	24			
Number of observations	210			



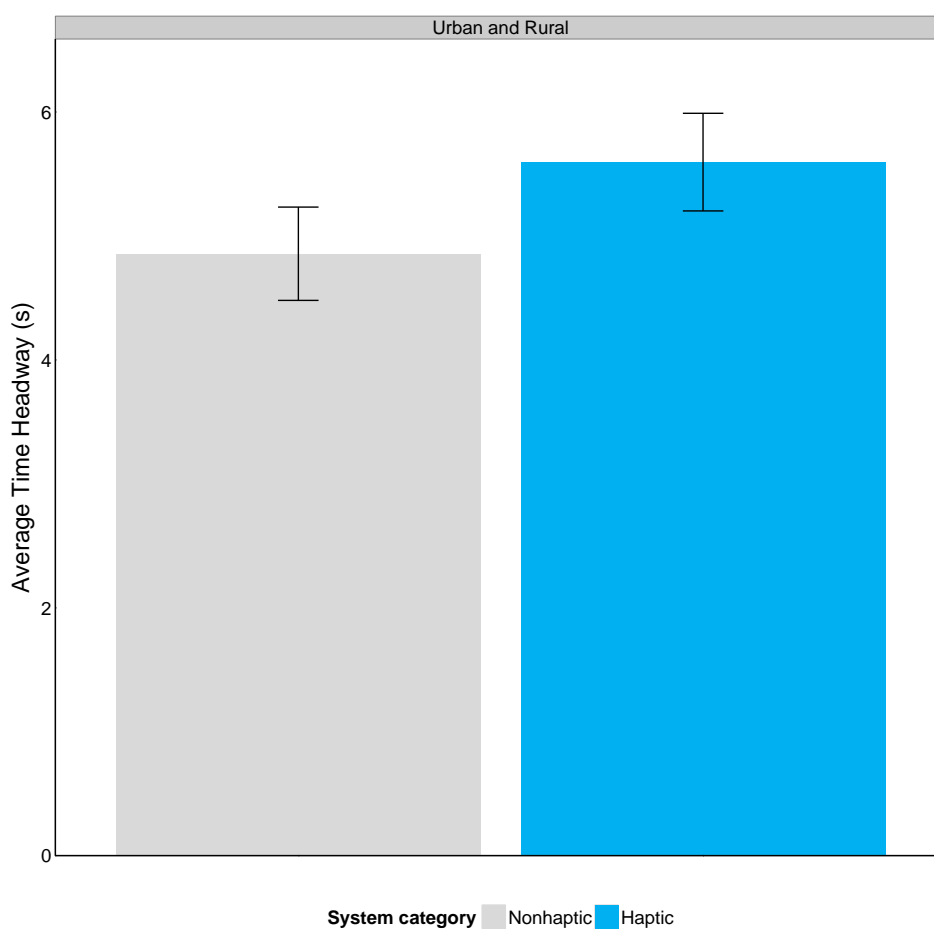


Figure 88: Model based average values of the average THW (s) for fixed effects.

Table 221: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
All road types (urban and rural)	4.86	5.60	-0.74	0.007

**Preliminary conclusions:**

Using a haptic pedal additional to an ecoDriver non-haptic system significantly decreases the average THW before intersections.

### 7.9.2 Results summary

Table 222: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-0.26	-0.38	-0.33	-0.12 (N.S.)	-	-
Rural	-0.07 (N.S.)	-0.12	-0.11 (N.S.)	0.19 (N.S.)	-	-
Motorway	-	-	-	-	-	-
All road types	-0.17	-0.27	-0.23	0.03 (N.S.)	-0.74	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-8.1	-12.93	-13.87	-3.67 (N.S.)	-	-
Rural	-2.6 (N.S.)	-4.58	-5.45 (N.S.)	7.63 (N.S.)	-	-
Motorway	-	-	-	-	-	-
All road types	-5.63	-9.57	-10.36	1 (N.S.)	-15.23	-

### 7.9.3 Conclusions and implications

Before upcoming intersections, the average THW increases in the treatment condition compared to baseline driving which implies an increase of distance to front vehicles. This effect can be observed on all road types, but is largest on urban roads. When analysing the four different subsets of ecoDriver systems separately, significant differences between baseline and treatment condition could be shown for embedded systems, the FeDS and the haptic vs. non-haptic treatment conditions. No significant differences in THW were observed for the ecoDriver App. The by far largest effect could be observed for the haptic vs. non-haptic comparison.

An increase of the average THW implies an increase of the average distance headway (shown as negative effect size in Table 222). This means that drivers extend the gap to the vehicles in front for a better anticipation of the traffic which can improve both safety and eco-friendly predictive driving. This effect can be shown for three out of four different systems tested.

## 7.10 Hypothesis 19: Using an ecoDriver system, there will be shorter distances to vehicles before zebra crossings

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, there will be shorter distances to vehicles before zebra crossings*

6. Using an ecoDriver system, there will be shorter distances to vehicles before zebra crossings. [Type A]
7. Using an embedded ecoDriver system, there will be shorter distances to vehicles before zebra crossings. [Type B]
8. Using the full ecoDriver system (FeDS), there will be shorter distances to vehicles before zebra crossings. [Type C]
9. Using the ecoDriver application, (App), there will be shorter distances to vehicles before zebra crossings. [Type D]
10. Using a haptic ecoDriver, there will be shorter distances to vehicles before zebra crossings. [Type E]

#### Performance indicator (PI):

Average time headway (THW)

(Average distance headway (DHW) is dependent on speed → average THW, see H17)

#### Data reduction method:

500m sections

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> <b>(Type A dataset)</b> <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> <b>(Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b> <b>(Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id

## Hypothesis analysis summary table

<b>Baseline App vs App (Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Vmc_id, Driver_id
<b>Non-haptic vs Haptic (Type E dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type*Main_effect
	Random effects	Driver_id

### Standard Filter:

- Exclude N/A's and obvious outliers.

### Filtering due to available amount of data:

- Only controlled data (no front sensor available in naturalistic studies)
- Type A-E: 2 road types (urban, rural)
- Type E: road type (urban)

### Extra Filtering:

- Filtering segments with avg\_speed < 10 and > 200 km/h
- Filtering segments with avg\_distance\_headway < 1 m
- Filtering segments with avg\_time\_headway > 10 s
- Only before safety critical location
- Excluding motorways

### 7.10.1 Controlled studies

#### 7.10.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 223: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.017	0.017	1	7281.6	0.004	0.949
road_type	10.0	10.0	1	7224.7	2.3	0.128
Main_effect:road_type	1.7	1.7	1	7258.4	0.4	0.524

Table 224: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	3.52	2.79	4.25	<0.001
Treatment	-0.05	-0.16	0.06	0.390
Rural	0.08	-0.16	0.32	0.507
Treatment:Rural	0.11	-0.22	0.43	0.524
Random part	N			
Driver_id	104			
Vmc_id	4			
Number of observations	7285			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

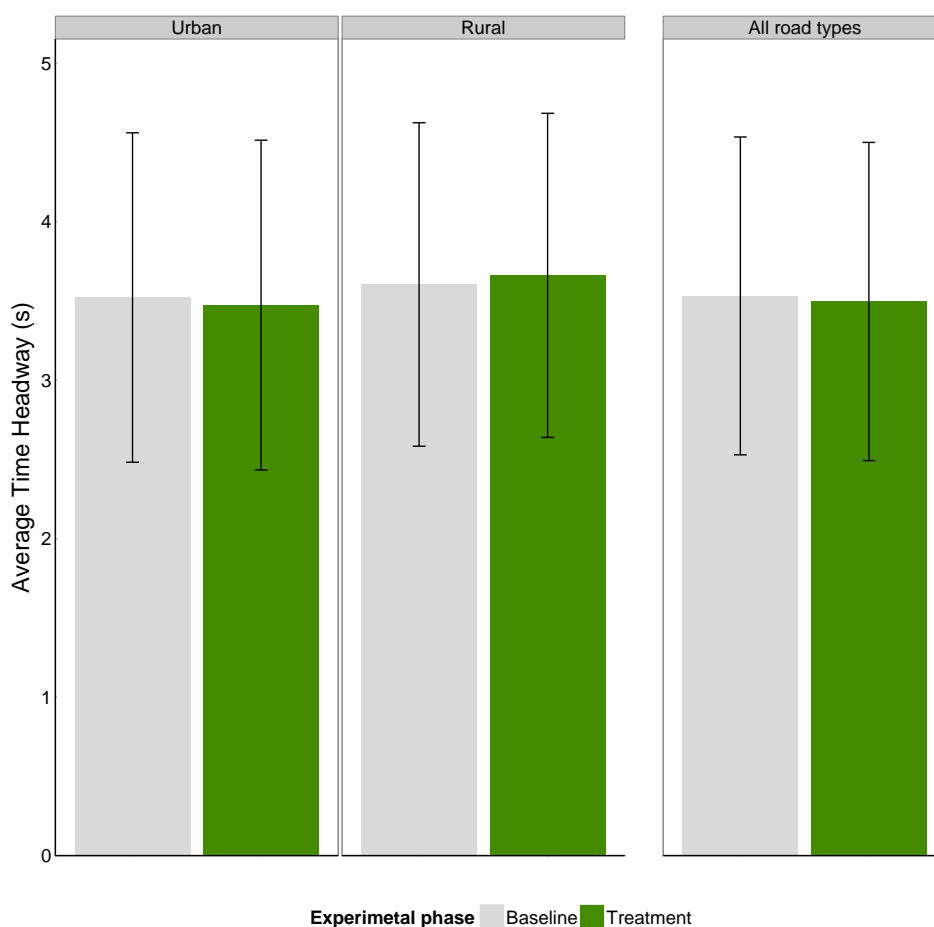


Figure 89: Model based average values of the average THW (s) for fixed effects.

Table 225: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	3.52	3.47	0.05	0.813
Rural	3.60	3.66	-0.06	0.981
All road types	3.53	3.50	0.04	0.501

**Preliminary conclusions:**

No significant effects on THW for different road types and experimental phase were found.

## 7.10.1.2 Type B: Baseline embedded vs embedded

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 226: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.0011	0.0011	1	1035.4	0.0004	0.985
road_type	0.1	0.1	1	897.0	0.0240	0.877
Main_effect:road_type	1.5	1.5	1	1031.6	0.5	0.490

Table 227: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	3.48	2.62	4.33	<b>0.003</b>
Treatment	0.10	-0.20	0.40	0.504
Rural	0.08	-0.43	0.59	0.771
Treatment:Rural	-0.21	-0.80	0.38	0.490
Random part	N			
Driver_id	65			
Vmc_id	3			
Number of observations	1040			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

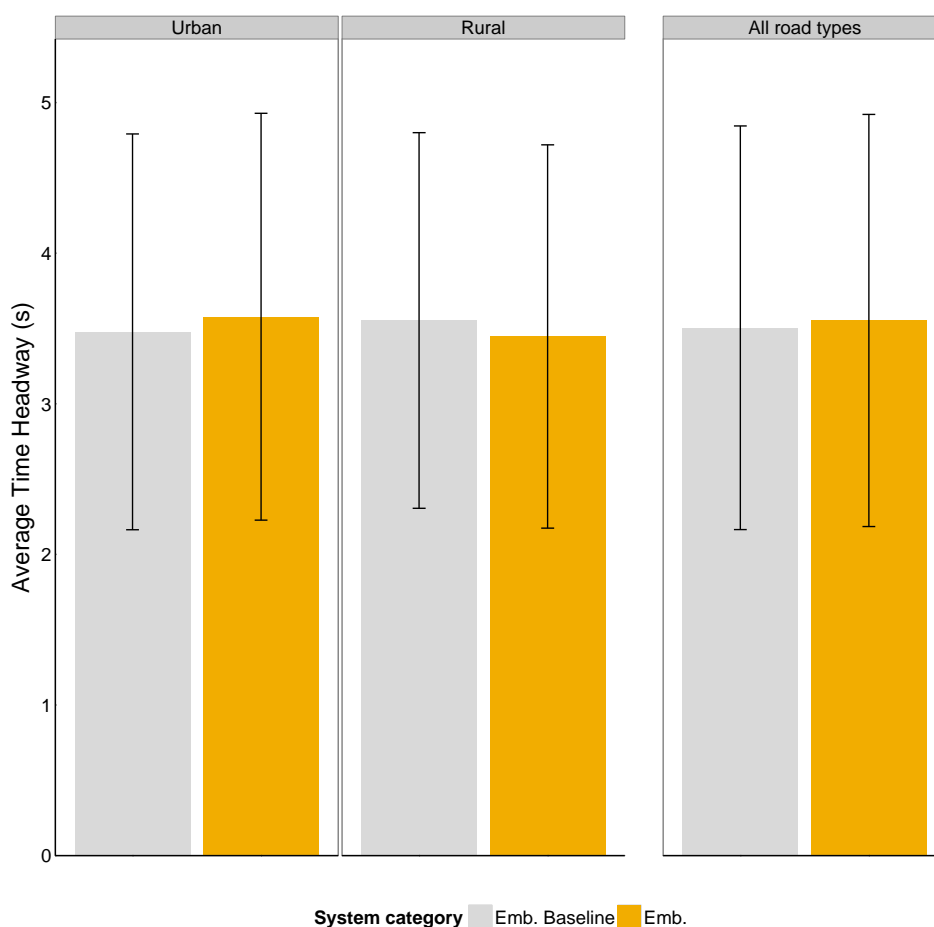


Figure 90: Model based average values of the average THW (s) for fixed effects.

Table 228: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	3.48	3.58	-0.10	0.906
Rural	3.55	3.45	0.11	0.976
All road types	3.51	3.55	-0.05	0.715

**Preliminary conclusions:**

No significant effects on THW for different road types and experimental phase were found.



### 7.10.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 229: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.1	0.1	1	961.7	0.03	0.870
road_type	0.1	0.1	1	723.5	0.05	0.831
Main_effect:road_type	0.9	0.9	1	958.7	0.3	0.590

Table 230: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	3.07	2.39	3.74	0.006
FeDS	0.06	-0.26	0.38	0.723
Rural	0.04	-0.48	0.57	0.868
FeDS:Rural	-0.17	-0.78	0.44	0.590
Random part	N			
Driver_id	41			
Vmc_id	2			
Number of observations	963			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

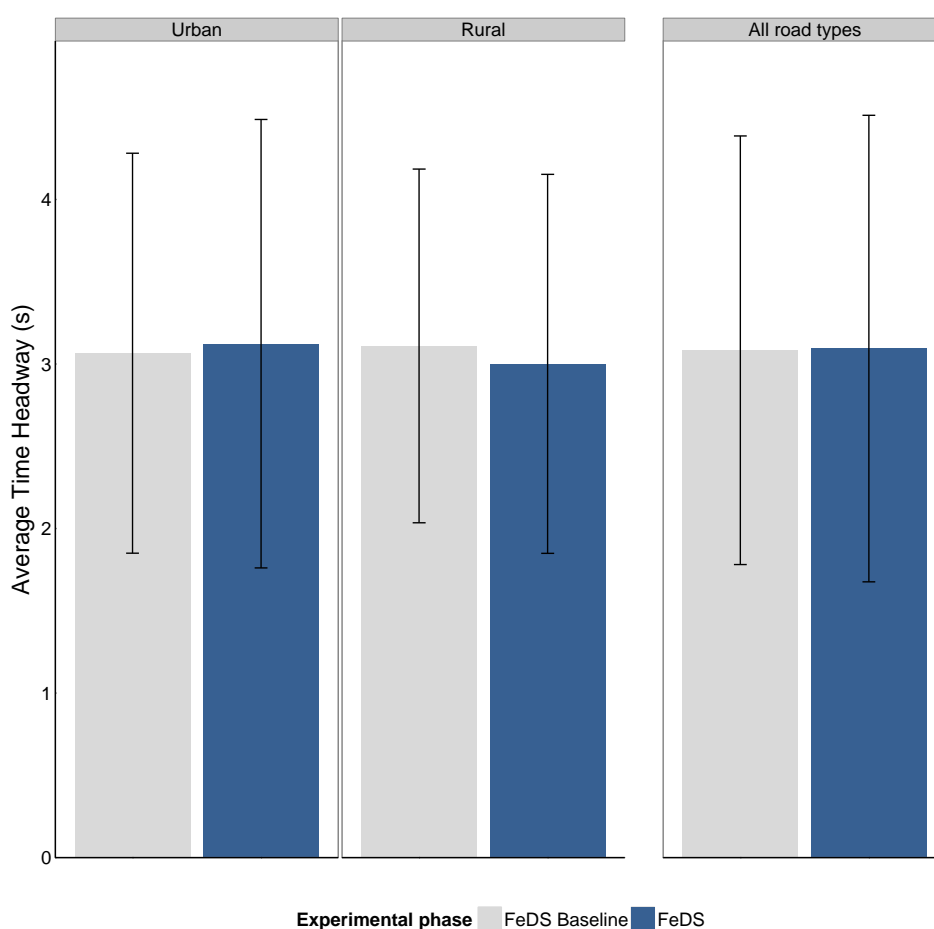


Figure 91: Model based average values of the average THW (s) for fixed effects.

Table 231: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	3.07	3.12	-0.06	0.984
Rural	3.11	3.00	0.11	0.976
All road types	3.08	3.09	-0.01	0.942

**Preliminary conclusions:**

No significant effects on THW for different road types and experimental phase were found.

## 7.10.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 232: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.4	0.4	1	6234.8	0.1	0.753
road_type	12.4	12.4	1	6216.0	2.7	0.097
Main_effect:road_type	4.3	4.3	1	6211.0	1.0	0.328

Table 233: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	2.85	1.68	4.02	0.041
App	-0.06	-0.18	0.05	0.273
Rural	0.07	-0.20	0.34	0.613
App:Rural	0.19	-0.19	0.58	0.328
Random part	N			
Driver_id	39			
Vmc_id	2			
Number of observations	6245			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

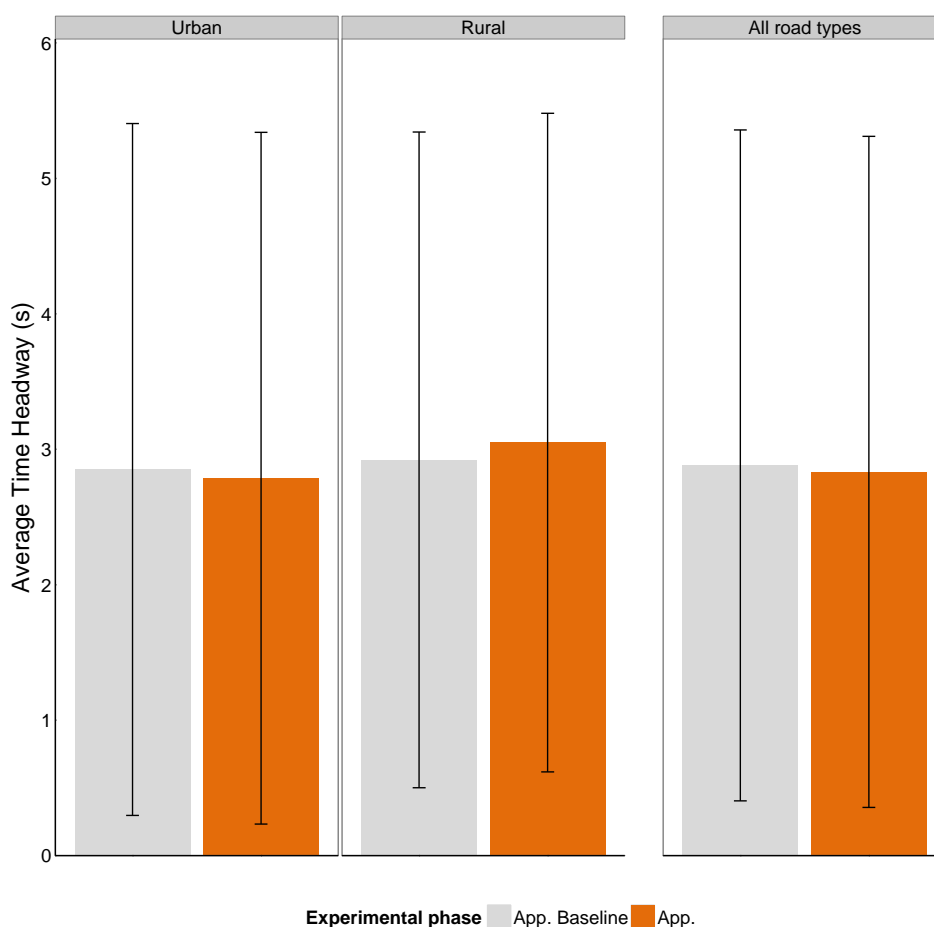


Figure 92: Model based average values of the average THW (s) for fixed effects.

Table 234: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	2.85	2.79	0.06	0.670
Rural	2.92	3.05	-0.13	0.898
All road types	2.88	2.83	0.05	0.402

**Preliminary conclusions:**

No significant effects on THW for different road types and experimental phase were found.

## 7.10.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 235: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	3.3	3.3	1	51.0	1.8	0.180

Table 236: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	4.38	3.86	4.89	<0.001
Haptic	0.51	-0.22	1.24	0.180
Random part	N			
Driver_id	22			
Number of observations	51			

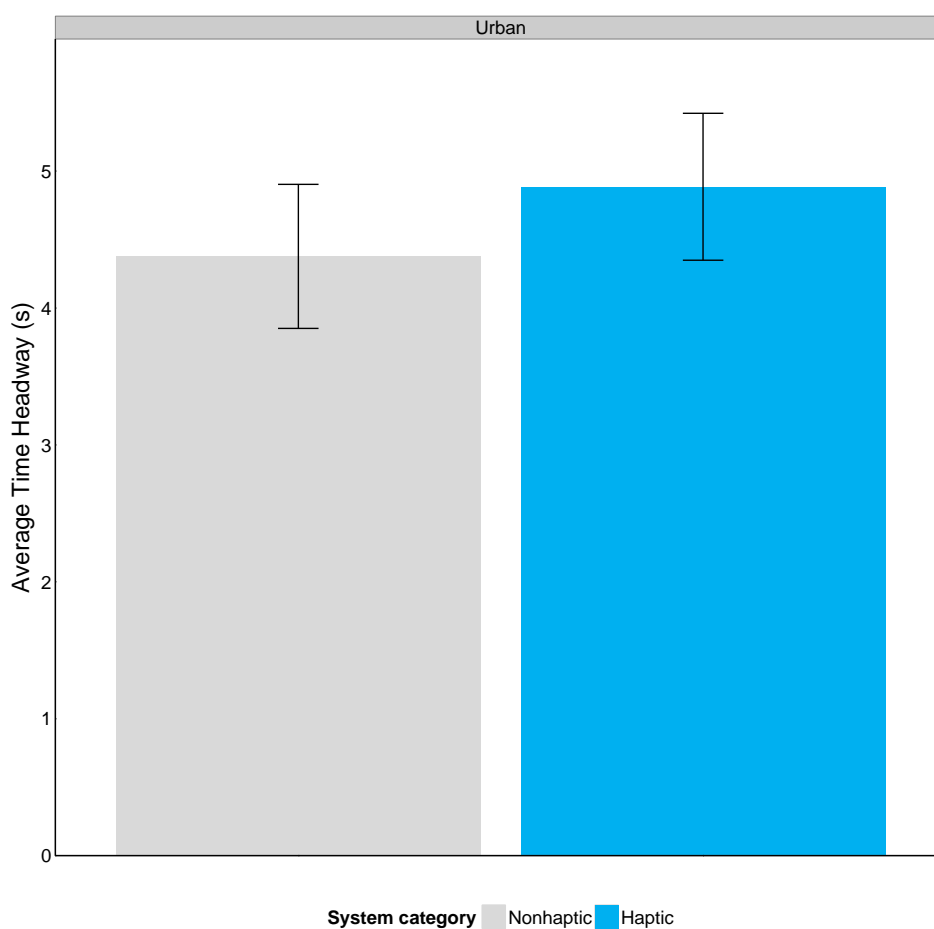


Figure 93: Model based average values of the average THW (s) for fixed effects.

Table 237: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	4.38	4.89	-0.51	0.174

**Preliminary conclusions:**

No significant effects on THW for different road types and experimental phase were found.

### 7.10.2 Results summary

Table 238: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	0.05 (N.S.)	-0.1 (N.S.)	-0.06 (N.S.)	0.06 (N.S.)	-	-
Rural	-0.06 (N.S.)	0.11 (N.S.)	0.11 (N.S.)	-0.13 (N.S.)	-	-
All road types	0.04 (N.S.)	-0.05 (N.S.)	-0.01 (N.S.)	0.05 (N.S.)	-0.51 (N.S.)	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	1.42 (N.S.)	-2.87 (N.S.)	-1.95 (N.S.)	2.11 (N.S.)	-	-
Rural	-1.67 (N.S.)	3.1 (N.S.)	3.54 (N.S.)	-4.45 (N.S.)	-	-
All road types	1.13 (N.S.)	-1.42 (N.S.)	-0.32 (N.S.)	1.74 (N.S.)	-11.64 (N.S.)	-

### 7.10.3 Conclusions and implications

Around zebra crossings, no significant effects for changes in average THW in treatment compared to baseline driving could be observed. When analysing the four different subsets of ecoDriver systems separately, also no significant differences in THW were found.

An increase of the average THW implies an increase of the average distance headway. This means that drivers extend the gap to the vehicles in front for a better anticipation of the traffic which can improve both safety and eco-friendly predictive driving. However, this effect cannot be shown for any of the tested systems within the range of zebra crossings.

## 7.11 Hypothesis 20: Using an ecoDriver system, there will be shorter distances to vehicles before speed bumps

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, there will be shorter distances to vehicles before speed bumps*

1. Using an ecoDriver system, there will be shorter distances to vehicles before speed bumps. [Type A]
2. Using an embedded ecoDriver system, there will be shorter distances to vehicles before speed bumps. [Type B]
3. Using the full ecoDriver system (FeDS), there will be shorter distances to vehicles before speed bumps. [Type C]
4. Using the ecoDriver application, (App), there will be shorter distances to vehicles before speed bumps. [Type D]
5. Using a haptic ecoDriver, there will be shorter distances to vehicles before speed bumps. [Type E]

#### Performance indicator (PI):

Average time headway (THW)

(Average distance headway (DHW) is dependent on speed → average THW, see H17)

#### Data reduction method:

500m sections

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> <b>(Type A dataset)</b> <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> <b>(Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b> <b>(Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id



## Hypothesis analysis summary table

<b>Baseline App vs App (Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Vmc_id, Driver_id
<b>Non-haptic vs Haptic (Type E dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### Standard Filter:

- Exclude N/A's and obvious outliers.

### Filtering due to available amount of data:

- Only controlled data (no front sensor available in naturalistic studies)
- Type A-E: 2 road types (urban, rural)
- Type E: no data available

### Extra Filtering:

- Filtering segments with avg\_speed < 10 and > 200 km/h
- Filtering segments with avg\_distance\_headway < 1 m
- Filtering segments with avg\_time\_headway > 10 s
- Only before safety critical location
- Excluding motorways

### 7.11.1 Controlled studies

#### 7.11.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 239: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	1.5	1.5	1	631.0	0.4	0.521
road_type	0.8	0.8	1	603.2	0.2	0.633
Main_effect:road_type	1.3	1.3	1	627.1	0.4	0.544

Table 240: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	3.10	2.31	3.90	0.002
Treatment	0.21	-0.16	0.57	0.269
Rural	0.01	-0.54	0.56	0.977
Treatment:Rural	-0.20	-0.85	0.45	0.544
Random part	N			
Driver_id	60			
Vmc_id	4			
Number of observations	652			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

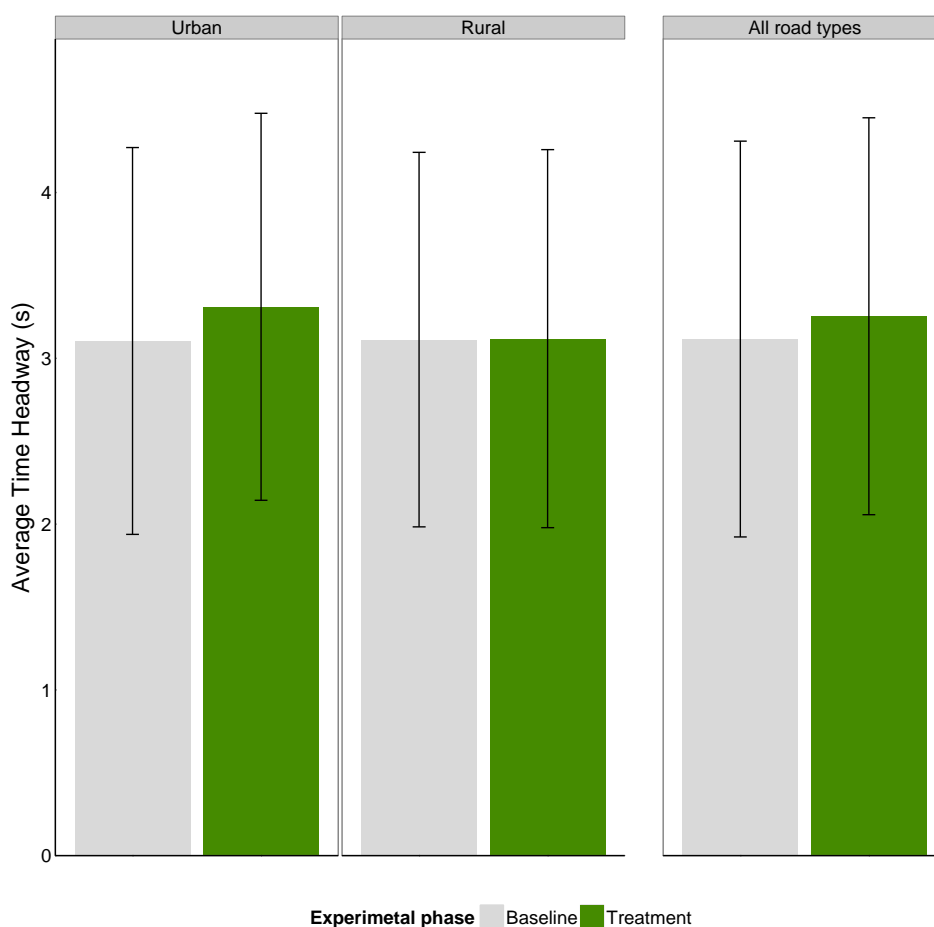


Figure 94: Model based average values of the average THW (s) for fixed effects.

Table 241: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	3.10	3.31	-0.21	0.681
Rural	3.11	3.12	-0.01	1.000
All road types	3.12	3.25	-0.14	0.372

**Preliminary conclusions:**

No significant effects on THW for different road types and experimental phase were found.

### 7.11.1.2 Type B: Baseline embedded vs embedded

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 242: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.0003	0.0003	1	218.0	0.0001	0.991
road_type	1.4	1.4	1	216.1	0.5	0.460
Main_effect:road_type	2.3	2.3	1	214.7	0.9	0.350

Table 243: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	2.71	2.14	3.28	<0.001
Treatment	0.22	-0.40	0.83	0.493
Rural	0.38	-0.32	1.09	0.290
Treatment:Rural	-0.43	-1.32	0.47	0.350
Random part	N			
Driver_id	21			
Vmc_id	3			
Number of observations	226			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

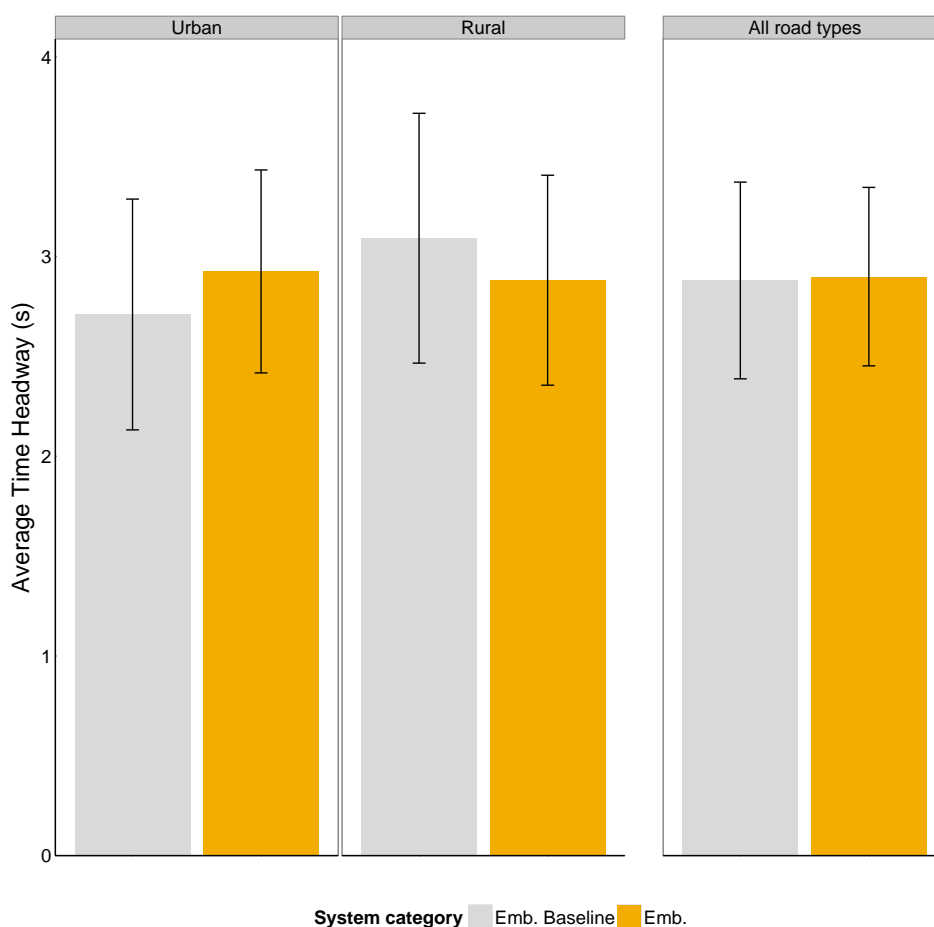


Figure 95: Model based average values of the average THW (s) for fixed effects.

Table 244: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	2.71	2.93	-0.22	0.902
Rural	3.09	2.88	0.21	0.920
All road types	2.88	2.90	-0.02	0.934

**Preliminary conclusions:**

No significant effects on THW for different road types and experimental phase were found.

### 7.11.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 245: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.0003	0.0003	1	218.0	0.0001	0.991
road_type	1.4	1.4	1	216.1	0.5	0.460
Main_effect:road_type	2.3	2.3	1	214.7	0.9	0.350

Table 246: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	2.71	2.14	3.28	<0.001
FeDS	0.22	-0.40	0.83	0.493
Rural	0.38	-0.32	1.09	0.290
FeDS:Rural	-0.43	-1.32	0.47	0.350
Random part	N			
Driver_id	21			
Vmc_id	2			
Number of observations	226			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

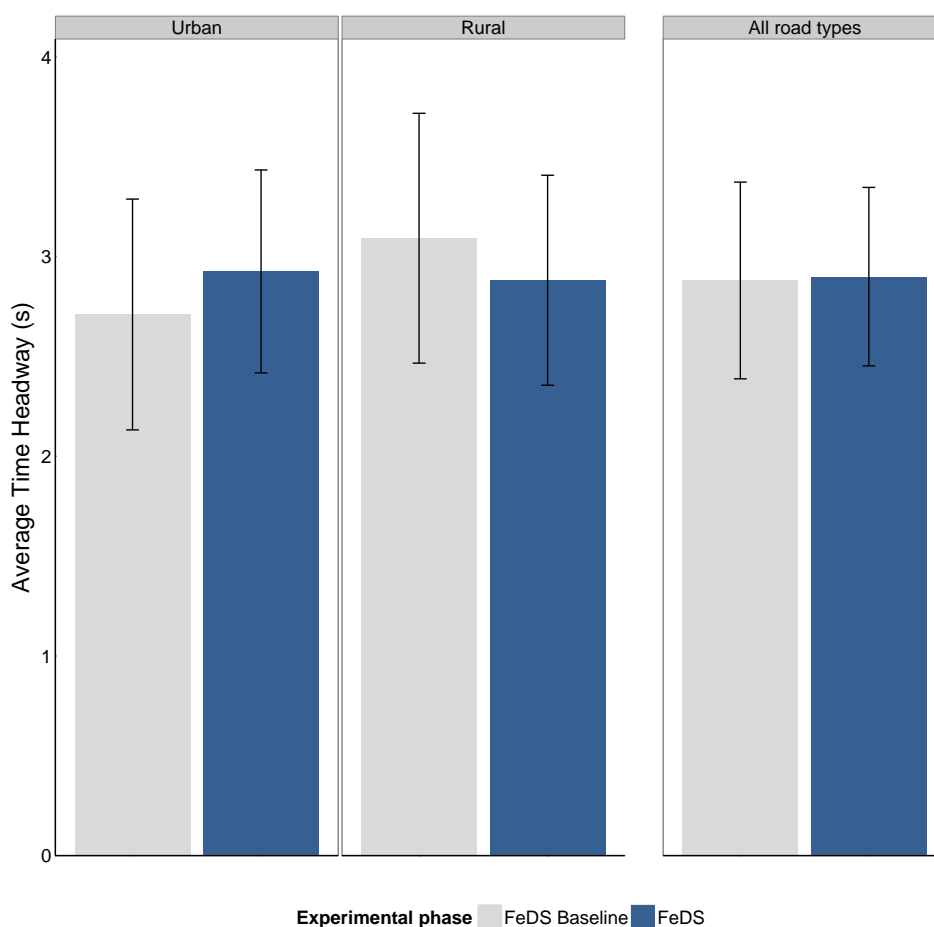


Figure 96: Model based average values of the average THW (s) for fixed effects.

Table 247: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	2.71	2.93	-0.22	0.902
Rural	3.09	2.88	0.21	0.920
All road types	2.88	2.90	-0.02	0.934

#### Preliminary conclusions:

No significant effects on THW for different road types and experimental phase were found.

## 7.11.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 248: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	3.1	3.1	1	409.3	0.8	0.380
road_type	5.5	5.5	1	391.1	1.4	0.241
Main_effect:road_type	0.009	0.009	1	407.0	0.002	0.961

Table 249: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	3.09	1.89	4.29	0.033
App	0.20	-0.25	0.64	0.390
Rural	-0.36	-1.18	0.46	0.387
App:Rural	0.02	-0.90	0.95	0.961
Random part	N			
Driver_id	39			
Vmc_id	2			
Number of observations	426			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.



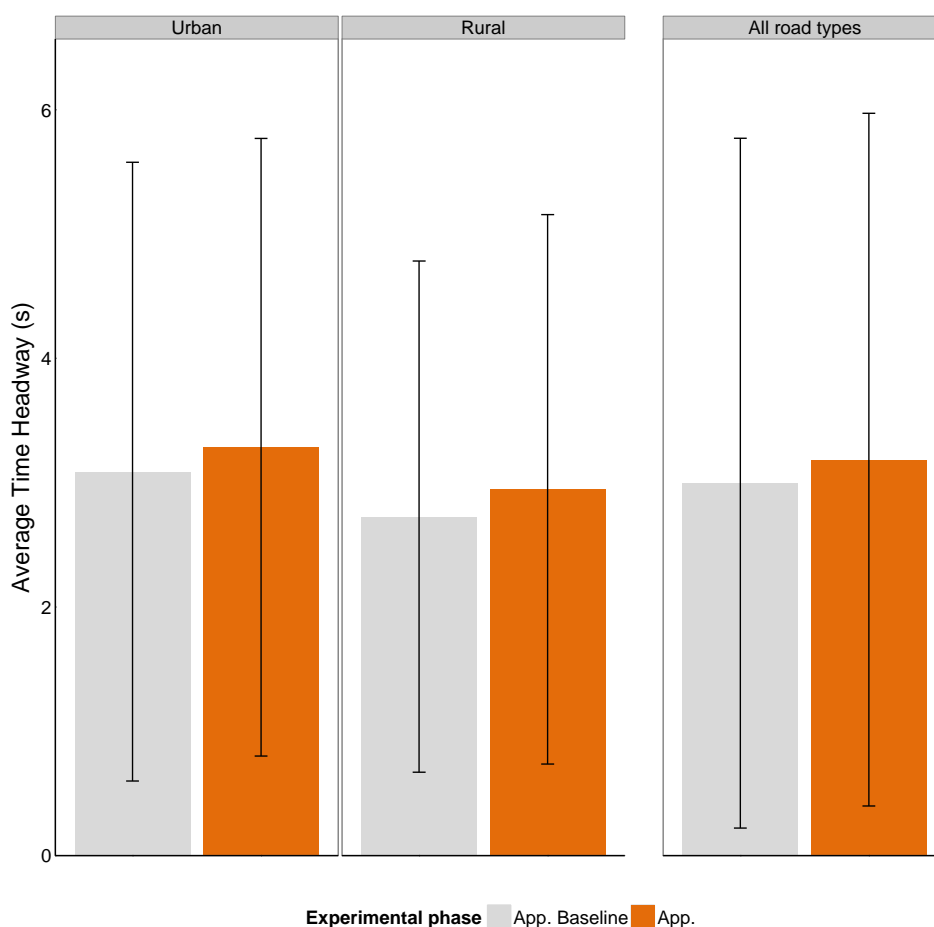


Figure 97: Model based average values of the average THW (s) for fixed effects.

Table 250: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	3.09	3.29	-0.20	0.819
Rural	2.73	2.95	-0.22	0.950
All road types	3.00	3.19	-0.19	0.344

#### Preliminary conclusions:

No significant effects on THW for different road types and experimental phase were found.

#### 7.11.1.5 Type E: Non-haptic vs Haptic

No data available for type E comparison.

### 7.11.2 Results summary

Table 251: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-0.21 (N.S.)	-0.22 (N.S.)	-0.22 (N.S.)	-0.2 (N.S.)	-	-
Rural	-0.01 (N.S.)	0.21 (N.S.)	0.21 (N.S.)	-0.22 (N.S.)	-	-
All road types	-0.14 (N.S.)	-0.02 (N.S.)	-0.02 (N.S.)	-0.19 (N.S.)	-	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-6.77 (N.S.)	-8.12 (N.S.)	-8.12 (N.S.)	-6.47 (N.S.)	-	-
Rural	-0.32 (N.S.)	6.8 (N.S.)	6.8 (N.S.)	-8.06 (N.S.)	-	-
All road types	-4.49 (N.S.)	-0.69 (N.S.)	-0.69 (N.S.)	-6.33 (N.S.)	-	-

### 7.11.3 Conclusions and implications

Around speed reducing measures, no significant effects for changes in average THW in treatment compared to baseline driving could be observed. When analysing the four different subsets of ecoDriver systems separately, also no significant differences in THW were found.

An increase of the average THW implies an increase of the average distance headway. This means that drivers extend the gap to the vehicles in front for a better anticipation of the traffic which can improve both safety and eco-friendly predictive driving. However, this effect cannot be shown for any of the tested systems within the range of speed reducing measures.

## 7.12 Hypothesis 21: Using an ecoDriver system, there will be shorter distances to vehicles before sharp curves

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, there will be shorter distances to vehicles before sharp curves*

11. Using an ecoDriver system, there will be shorter distances to vehicles before sharp curves. [Type A]
12. Using an embedded ecoDriver system, there will be shorter distances to vehicles before sharp curves. [Type B]
13. Using the full ecoDriver system (FeDS), there will be shorter distances to vehicles before sharp curves. [Type C]
14. Using the ecoDriver application, (App), there will be shorter distances to vehicles before sharp curves. [Type D]
15. Using a haptic ecoDriver, there will be shorter distances to vehicles before sharp curves. [Type E]

#### Performance indicator (PI):

Average time headway (THW)

(Average distance headway (DHW) is dependent on speed → average THW, see H17)

#### Data reduction method:

500m sections

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> <b>(Type A dataset)</b> <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> <b>(Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b> <b>(Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id

## Hypothesis analysis summary table

<b>Baseline App vs App (Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Vmc_id, Driver_id
<b>Non-haptic vs Haptic (Type E dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type*Main_effect
	Random effects	Driver_id

### Standard Filter:

- Exclude N/A's and obvious outliers.

### Filtering due to available amount of data:

- Only controlled data (no front sensor available in naturalistic studies)
- Type A-D: 2 road types (urban, rural)
- Type E: 1 road type (urban + rural)

### Extra Filtering:

- Filtering segments with avg\_speed < 10 and > 200 km/h
- Filtering segments with avg\_distance\_headway < 1 m
- Filtering segments with avg\_time\_headway > 10 s
- Only before safety critical location
- Excluding motorways

### 7.12.1 Controlled studies

#### 7.12.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 252: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	11.9	11.9	1	1913.8	4.6	<b>0.032</b>
road_type	171.5	171.5	1	1957.7	66.5	<b>&lt;0.001</b>
Main_effect:road_type	0.2	0.2	1	1919.5	0.1	0.769

Table 253: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	3.25	2.35	4.16	<b>&lt;0.001</b>
Treatment	0.15	-0.07	0.38	0.189
Rural	-0.72	-0.96	-0.48	<b>&lt;0.001</b>
Treatment:Rural	0.04	-0.25	0.34	0.769
Random part	N			
Driver_id	130			
Vmc_id	6			
Number of observations	1960			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

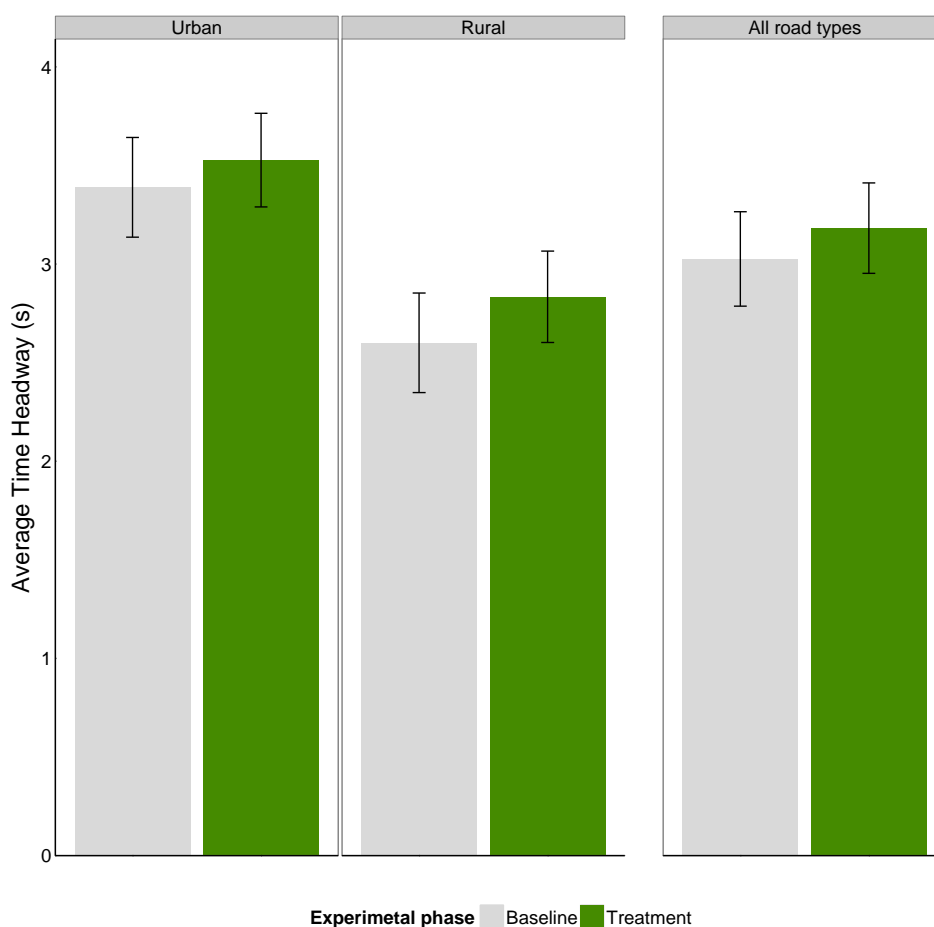


Figure 98: Model based average values of the average THW (s) for fixed effects.

Table 254: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	3.25	3.40	-0.15	0.553
Rural	2.54	2.73	-0.20	0.255
All road types	2.96	3.10	-0.14	0.081

#### Preliminary conclusions:

The main effect of experimental phase is significant with increased THW in the treatment condition. Furthermore, the THW differs significantly for different road types. However, the interaction between road type and phase is not significant, indicating that the effect of treatment on THW is consistent for all road types analysed. Overall, the mean THW increases within a range of 0.14 (all road types) up to 0.20 seconds (rural roads) in the treatment phase compared to the baseline.

### 7.12.1.2 Type B: Baseline embedded vs embedded

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 255: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	14.6	14.6	1	1113.3	8.6	<b>0.003</b>
road_type	6.2	6.2	1	1117.9	3.7	0.055
Main_effect:road_type	6.3	6.3	1	1089.4	3.7	0.055

Table 256: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	2.72	1.64	3.80	<b>0.003</b>
Embedded	0.45	0.17	0.72	<b>0.002</b>
Rural	-0.05	-0.37	0.28	0.787
Treatment:Rural	-0.34	-0.69	0.01	0.055
Random part	N			
Driver_id	91			
Vmc_id	5			
Number of observations	1120			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.



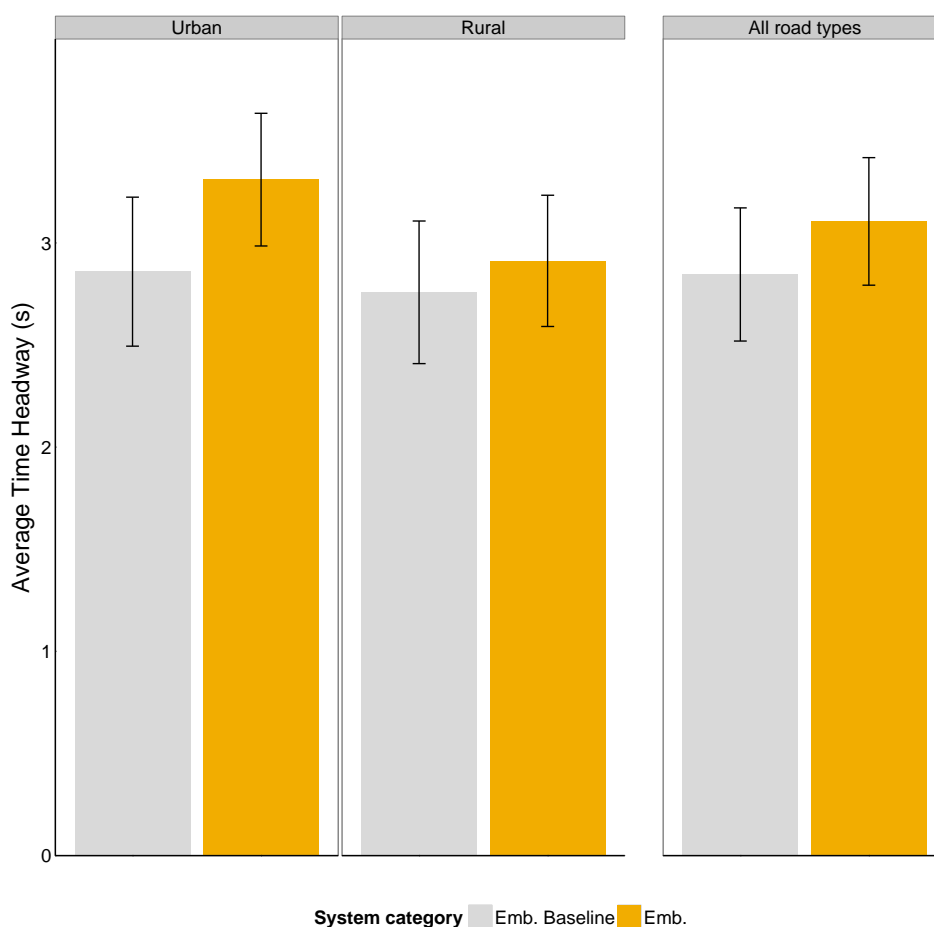


Figure 99: Model based average values of the average THW (s) for fixed effects.

Table 257: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	2.72	3.17	-0.45	<b>0.009</b>
Rural	2.68	2.78	-0.10	0.808
All road types	2.75	2.98	-0.23	<b>0.012</b>

#### Preliminary conclusions:

For the embedded systems, the main effect of experimental phase is significant with increased THW in the treatment condition. Overall, the mean THW increases within a range of 0.10 (rural roads) up to 0.45 seconds (urban roads) in the treatment phase compared to the Baseline.

## 7.12.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 258: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
<b>Main_effect</b>	10.8	10.8	1	970.1	7.5	<b>0.006</b>
<b>road_type</b>	1.6	1.6	1	804.5	1.1	0.296
<b>Main_effect:road_type</b>	7.0	7.0	1	958.5	4.9	<b>0.027</b>

Table 259: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	2.11	1.82	2.40	<b>&lt;0.001</b>
FeDS	0.47	0.17	0.77	<b>0.002</b>
Rural	0.09	-0.24	0.42	0.599
FeDS:Rural	-0.41	-0.77	-0.05	<b>0.027</b>
<b>Random part</b>	<b>N</b>			
Driver_id	59			
Vmc_id	3			
Number of observations	971			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

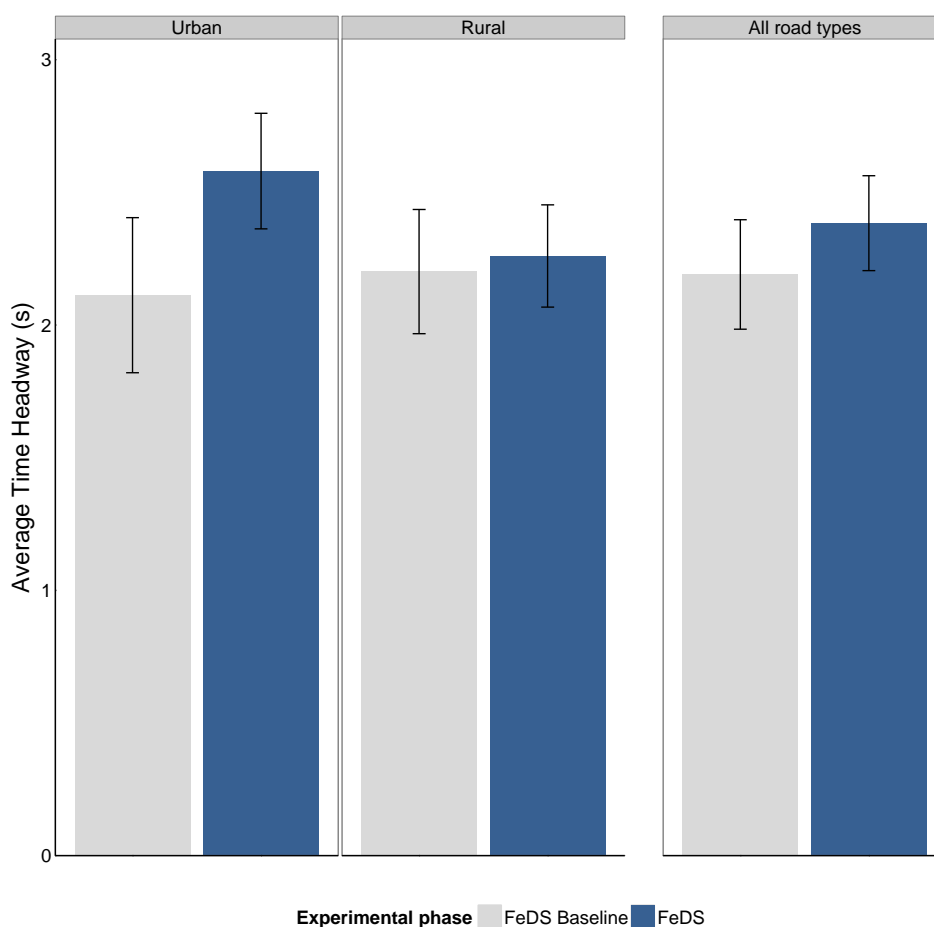


Figure 100: Model based average values of the average THW (s) for fixed effects.

Table 260: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	2.11	2.58	-0.47	<b>0.012</b>
Rural	2.20	2.26	-0.06	0.950
All road types	2.19	2.38	-0.19	<b>0.035</b>

#### Preliminary conclusions:

For the FeDS, the main effect of experimental phase is significant with increased THW in the treatment condition. Furthermore, the interaction between road type and phase is significant, post-hoc Tukey multiple comparison tests revealed significant effects of treatment on THW for urban roads and the all road types category. Overall, the mean THW increases within a range of 0.06 (rural roads) up to 0.47 seconds (urban roads) in the treatment phase compared to the Baseline.

## 7.12.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 261: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	2.5	2.5	1	726.2	0.7	0.405
road_type	181.9	181.9	1	833.1	50.2	<0.001
Main_effect:road_type	1.8	1.8	1	821.1	0.5	0.475

Table 262: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	3.55	2.56	4.54	0.015
App	0.02	-0.34	0.38	0.920
Rural	-1.04	-1.41	-0.68	<0.001
App:Rural	0.19	-0.33	0.71	0.475
Random part	N			
Driver_id	39			
Vmc_id	2			
Number of observations	840			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

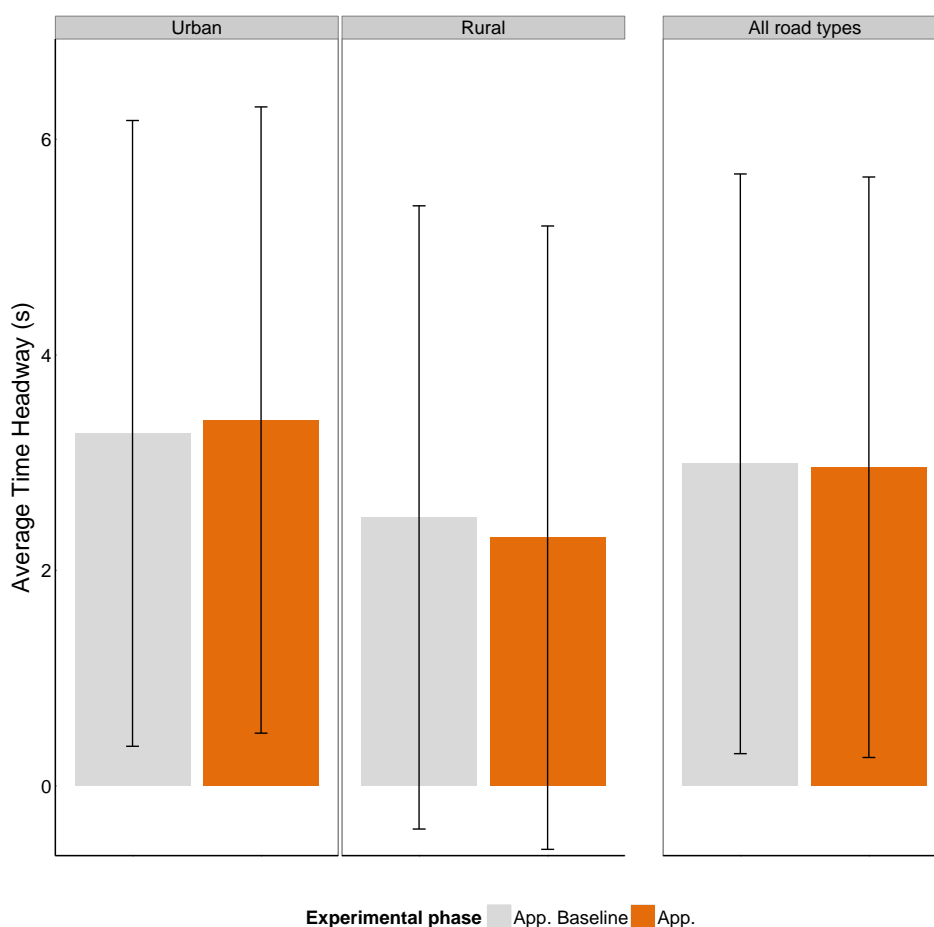


Figure 101: Model based average values of the average THW (s) for fixed effects.

Table 263: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	3.55	3.57	-0.02	1.000
Rural	2.51	2.72	-0.21	0.707
All road types	3.03	3.07	-0.04	0.782

#### Preliminary conclusions:

For the ecoDriver App, the main effect of experimental phase is not significant with increased THW in the treatment condition. However, the THW differs significantly for different road types.

## 7.12.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 264: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	2.8	2.8	1	64.2	0.7	0.417

Table 265: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	5.26	4.58	5.93	<0.001
Haptic	0.41	-0.58	1.41	0.417
Random part	N			
Driver_id	23			
Number of observations	66			

Reference of the model is the non-haptic baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

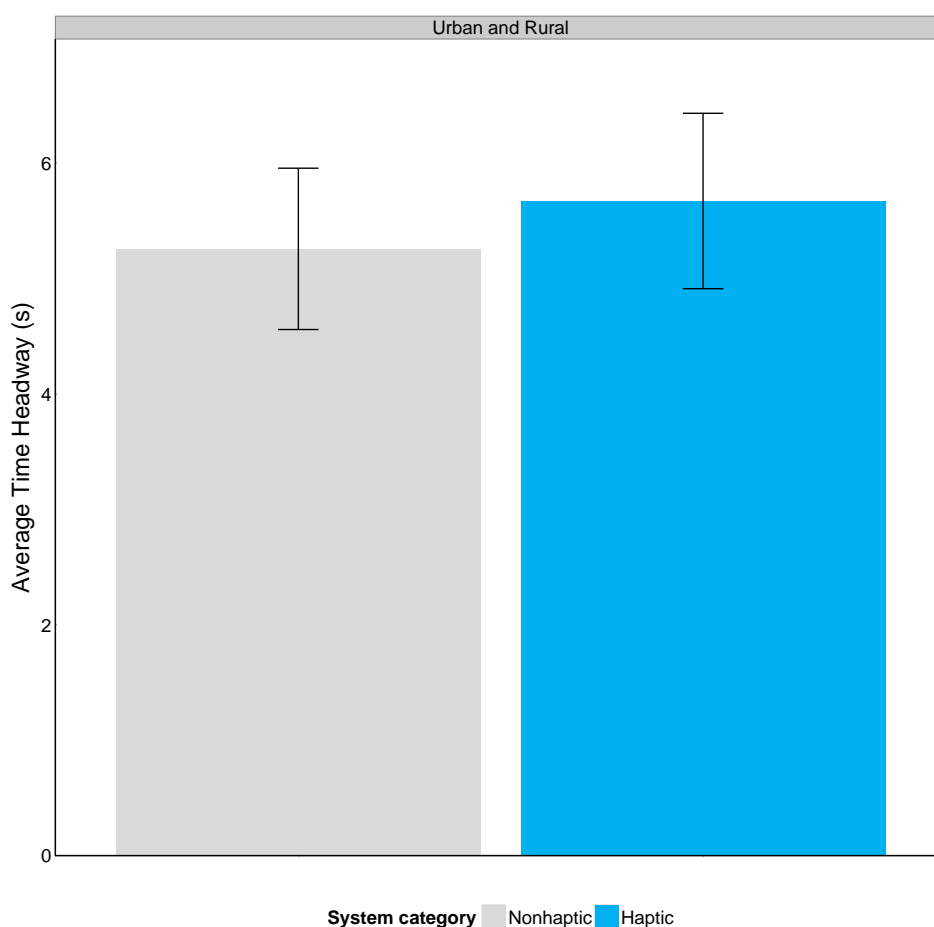


Figure 102: Model based average values of the average THW (s) for fixed effects.

Table 266: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
All road types (urban and rural)	5.26	5.67	-0.41	0.414

**Preliminary conclusions:**

Using a haptic pedal additional to an ecoDriver non-haptic system significantly decreases the average THW before intersections.

### 7.12.2 Results summary

Table 267: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-0.15 (N.S.)	-0.45	-0.47	-0.02 (N.S.)	-	-
Rural	-0.2 (N.S.)	-0.1 (N.S.)	-0.06 (N.S.)	-0.21 (N.S.)	-	-
All road types	-0.14 (N.S.)	-0.23	-0.19	-0.04 (N.S.)	-	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-4.62 (N.S.)	-16.54	-22.27	-0.56 (N.S.)	-	-
Rural	-7.87 (N.S.)	-3.73 (N.S.)	-2.73 (N.S.)	-8.37 (N.S.)	-	-
All road types	-4.73 (N.S.)	-8.36	-8.68	-1.32 (N.S.)	-	-

### 7.12.3 Conclusions and implications

Approaching sharp curves, the average THW increases in the treatment condition compared to baseline driving. When analysing the four different subsets of ecoDriver systems separately, significant differences between baseline and treatment condition could only be shown for embedded systems and the FeDS where the effect can be observed mainly on urban roads. No significant differences in THW were observed for the ecoDriver App and the haptic vs. non-haptic treatment conditions.

An increase of the average THW implies an increase of the average distance headway. This means that drivers extend the gap to the vehicles in front for a better anticipation of the traffic which can improve both safety and eco-friendly predictive driving. However, this effect can only be shown for two out of four different systems tested.



### 7.13 Hypothesis 22: Using an ecoDriver system, there will be shorter distances to vehicles before crests

#### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, there will be shorter distances to vehicles before crests*

16. Using an ecoDriver system, there will be shorter distances to vehicles before crests. [Type A]
17. Using an embedded ecoDriver system, there will be shorter distances to vehicles before crests. [Type B]
18. Using the full ecoDriver system (FeDS), there will be shorter distances to vehicles before crests. [Type C]
19. Using the ecoDriver application, (App), there will be shorter distances to vehicles before crests. [Type D]
20. Using a haptic ecoDriver, there will be shorter distances to vehicles before crests. [Type E]

#### Performance indicator (PI):

Average time headway (THW)

(Average distance headway (DHW) is dependent on speed → average THW, see H17)

#### Data reduction method:

500m sections

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> <b>(Type A dataset)</b> <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> <b>(Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b> <b>(Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id

## Hypothesis analysis summary table

<b>Baseline App vs App (Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Vmc_id, Driver_id
<b>Non-haptic vs Haptic (Type E dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type*Main_effect
	Random effects	Driver_id

### Standard Filter:

- Exclude N/A's and obvious outliers.

### Filtering due to available amount of data:

- Only controlled data (no front sensor available in naturalistic studies)
- Type A-C: 2 road types (urban, rural)
- Type D-E: 1 road type (rural)

### Extra Filtering:

- Filtering segments with avg\_speed < 10 and > 200 km/h
- Filtering segments with avg\_distance\_headway < 1 m
- Filtering segments with avg\_time\_headway > 10 s
- Only before safety critical location
- Excluding motorways

### 7.13.1 Controlled studies

#### 7.13.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 268: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.00003	0.00003	1	492.1	0.00001	0.997
road_type	4.8	4.8	1	494.7	2.3	0.130
Main_effect:road_type	0.05	0.05	1	491.7	0.02	0.878

Table 269: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	3.29	2.08	4.49	<b>0.001</b>
Treatment	-0.02	-0.41	0.37	0.918
Rural	-0.35	-0.91	0.22	0.228
Treatment:Rural	0.04	-0.50	0.58	0.878
Random part	N			
Driver_id	86			
Vmc_id	5			
Number of observations	496			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

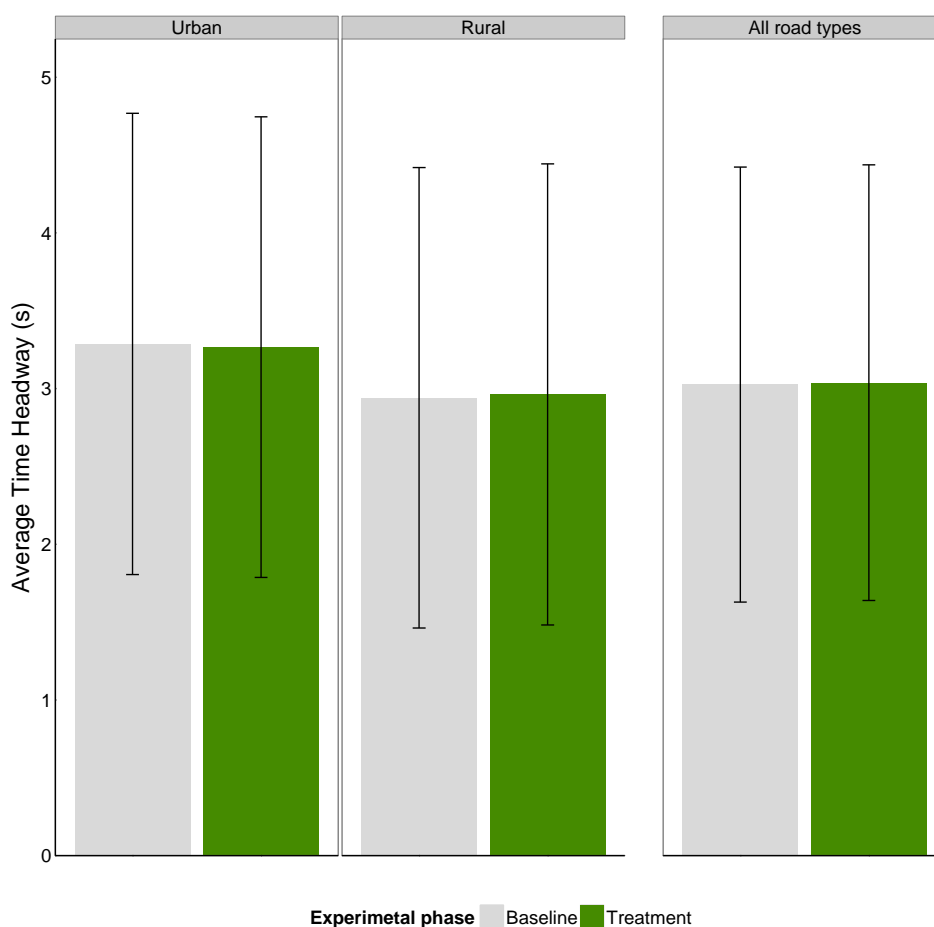


Figure 103: Model based average values of the average THW (s) for fixed effects.

Table 270: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	3.29	3.27	0.02	1.000
Rural	2.94	2.96	-0.02	0.999
All road types	3.03	3.04	-0.01	0.929

**Preliminary conclusions:**

No significant effects on THW for different road types and experimental phase were found.

## 7.13.1.2 Type B: Baseline embedded vs embedded

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 271: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.2	0.2	1	381.6	0.1	0.752
road_type	5.6	5.6	1	385.0	3.4	0.064
Main_effect:road_type	0.3	0.3	1	381.1	0.2	0.649

Table 272: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	2.94	1.70	4.18	<b>0.007</b>
Treatment	-0.02	-0.37	0.33	0.915
Rural	-0.42	-0.97	0.12	0.128
Treatment:Rural	0.13	-0.44	0.71	0.649
Random part	N			
Driver_id	58			
Vmc_id	4			
Number of observations	385			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

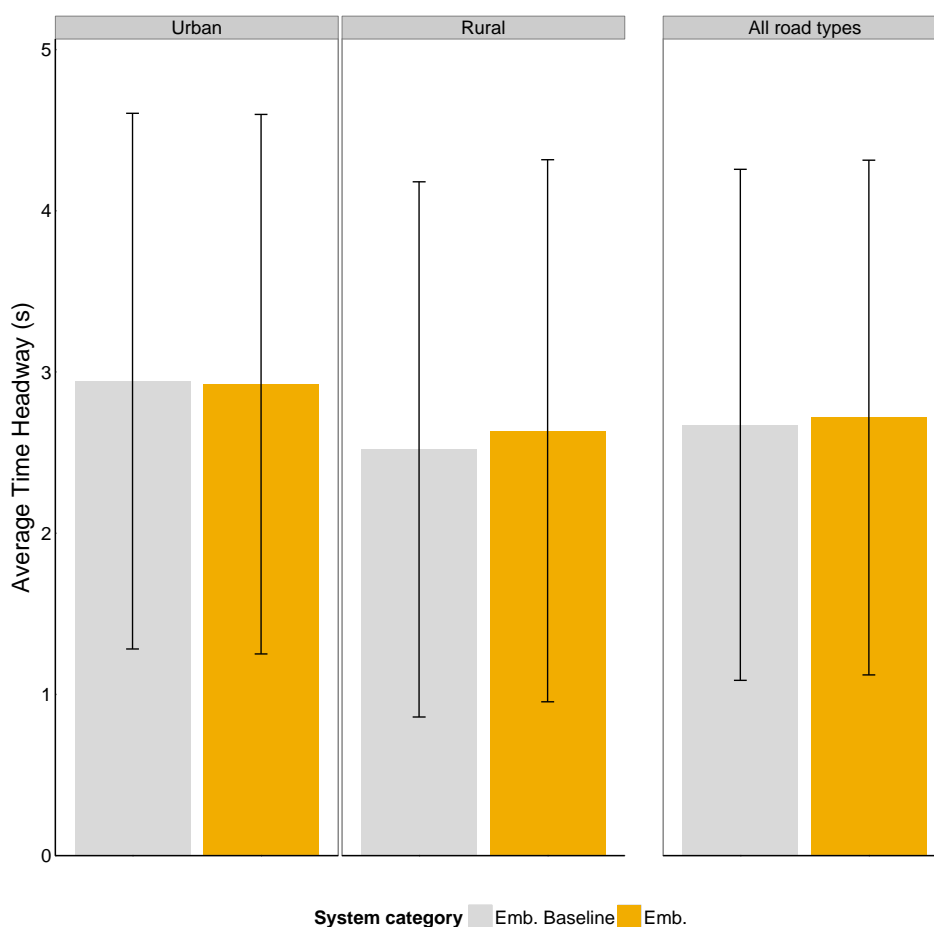


Figure 104: Model based average values of the average THW (s) for fixed effects.

Table 273: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	2.94	2.92	0.02	1.000
Rural	2.52	2.64	-0.12	0.963
All road types	2.67	2.72	-0.04	0.758

**Preliminary conclusions:**

No significant effects on THW for different road types and experimental phase were found.

## 7.13.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 274: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.7	0.7	1	324.4	0.5	0.478
road_type	7.1	7.1	1	286.0	5.3	<b>0.022</b>
Main_effect:road_type	0.9	0.9	1	349.1	0.7	0.405

Table 275: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	2.14	1.89	2.39	<b>&lt;0.001</b>
Treatment	-0.02	-0.33	0.29	0.910
Rural	-0.46	-0.94	0.02	0.063
Treatment:Rural	0.24	-0.33	0.81	0.405
Random part	N			
Driver_id	39			
Vmc_id	3			
Number of observations	352			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

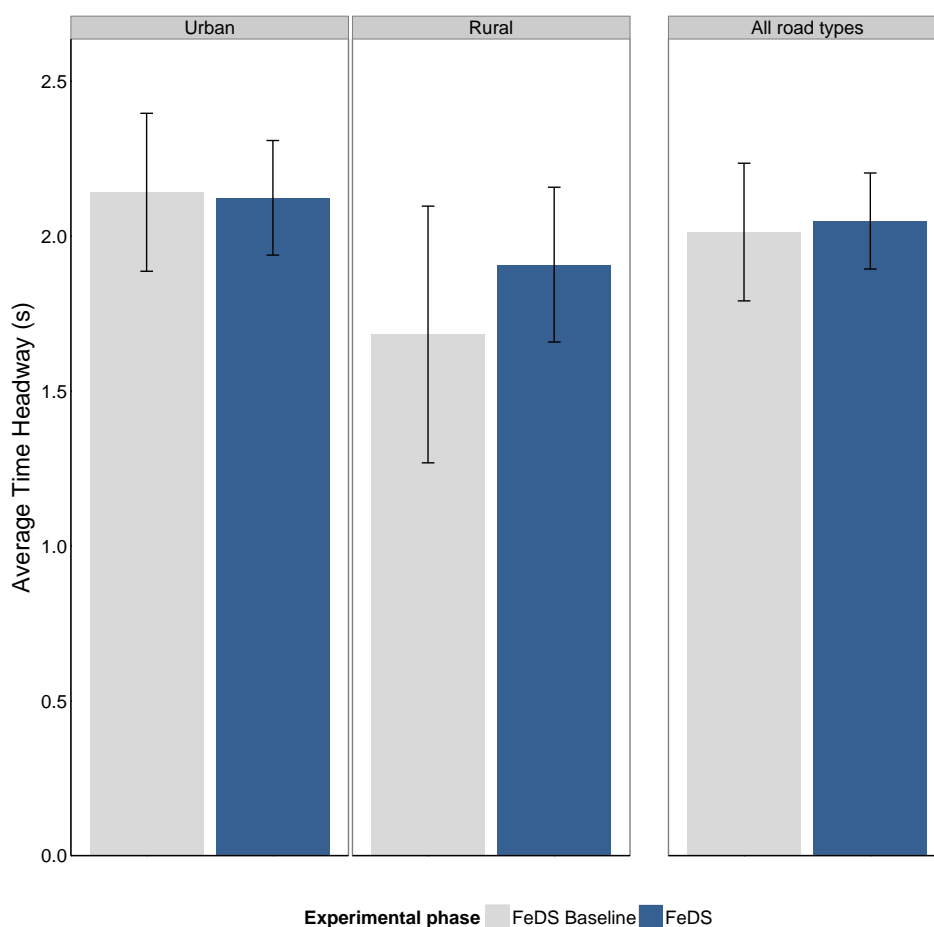


Figure 105: Model based average values of the average THW (s) for fixed effects.

Table 276: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	2.14	2.12	0.02	0.999
Rural	1.68	1.91	-0.23	0.789
All road types	2.01	2.05	-0.04	0.790

**Preliminary conclusions:**

For the ecoDriver App, the main effect of experimental phase is not significant with increased THW in the treatment condition. However, the THW differs significantly for different road types.



## 7.13.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 277: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.1	0.1	1	111.0	0.0	0.877

Table 278: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	4.36	3.88	4.84	<0.001
App	-0.06	-0.77	0.66	0.877
Random part	N			
Driver_id	28			
Vmc_id	1			
Number of observations	111			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

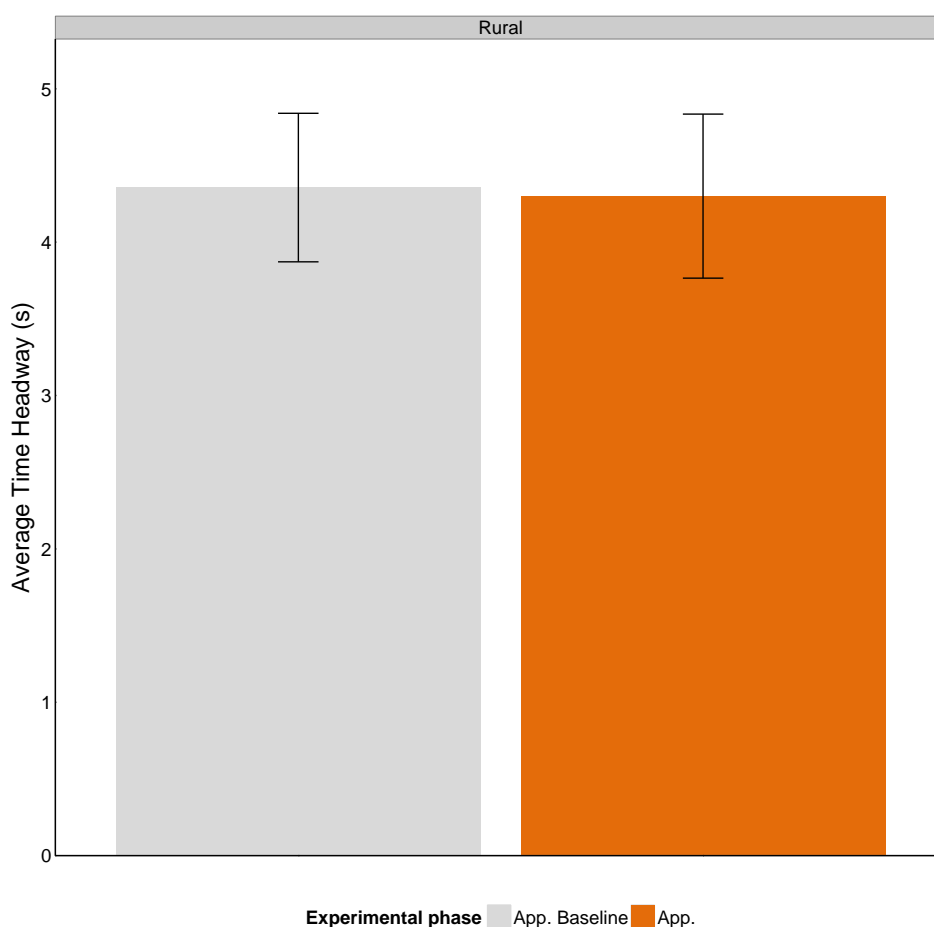


Figure 106: Model based average values of the average THW (s) for fixed effects.

Table 279: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates			Tukey multiple comparisons significance test
	Baseline	App	Difference (B-A)	
Rural	4.36	4.30	0.06	0.877

**Preliminary conclusions:**

For the App, the main effect of experimental phase is not significant with increased THW in the treatment condition.

## 7.13.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 280: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.7	0.7	1	24.0	0.2	0.680

Table 281: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	4.73	3.73	5.72	<0.001
Haptic	-0.37	-2.09	1.36	0.680
Random part	N			
Driver_id	18			
Number of observations	24			

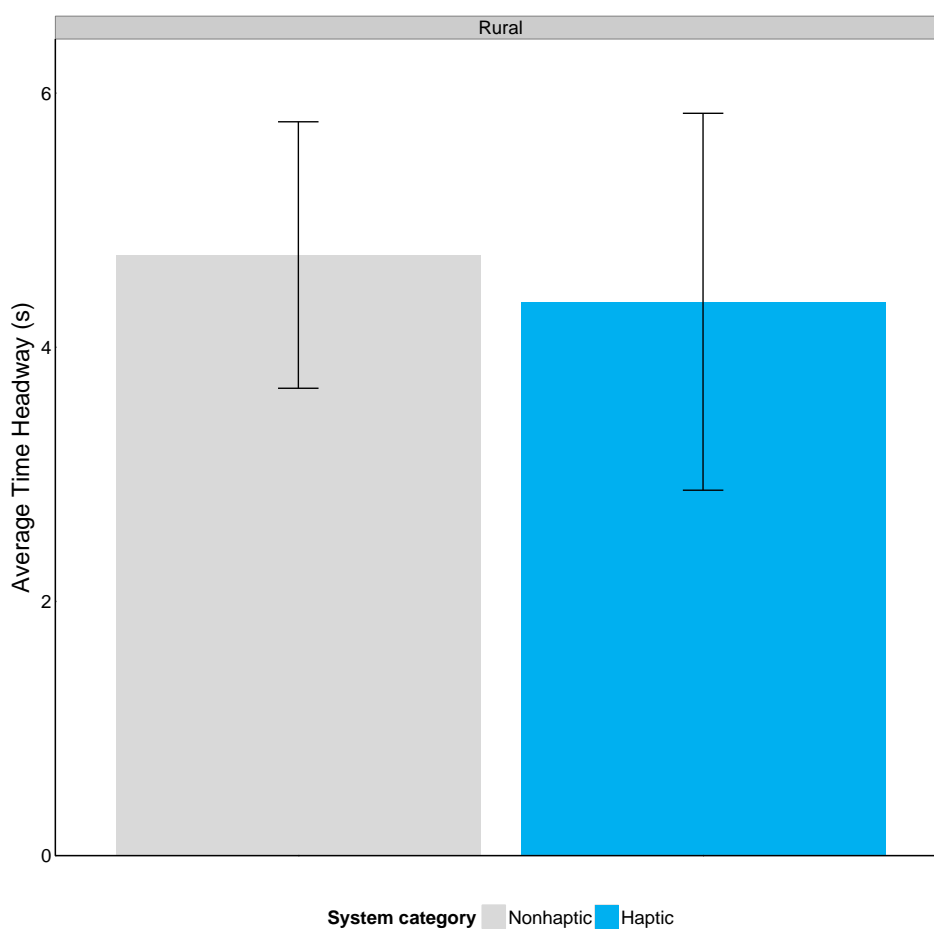


Figure 107: Model based average values of the average THW (s) for fixed effects.

Table 282: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Rural	4.73	4.36	0.37	0.677

**Preliminary conclusions:**

No significant effects on THW for different road types and experimental phase were found.

### 7.13.2 Results summary

Table 283: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	0.02 (N.S.)	0.02 (N.S.)	0.02 (N.S.)	-	-	-
Rural	-0.02 (N.S.)	-0.12 (N.S.)	-0.23 (N.S.)	-	-	-
All road types	-0.01 (N.S.)	-0.04 (N.S.)	-0.04 (N.S.)	0.06 (N.S.)	-	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	0.61 (N.S.)	0.68 (N.S.)	0.93 (N.S.)	-	-	-
Rural	-0.68 (N.S.)	-4.76 (N.S.)	-13.69 (N.S.)	-	-	-
All road types	-0.33 (N.S.)	-1.5 (N.S.)	-1.99 (N.S.)	1.38 (N.S.)	-	-

### 7.13.3 Conclusions and implications

Before crests, no significant effects for changes in average THW in treatment compared to baseline driving could be observed. When analysing the four different subsets of ecoDriver systems separately, also no significant differences in THW were found.

An increase of the average THW implies an increase of the average distance headway. This means that drivers extend the gap to the vehicles in front for a better anticipation of the traffic which can improve both safety and eco-friendly predictive driving. However, this effect cannot be shown for any of the tested systems within the range of crests.

## 7.14 Hypothesis 23: Using an ecoDriver system, there will be shorter distances to vehicles before speed limit changes

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, there will be shorter distances to vehicles before speed limit changes*

21. Using an ecoDriver system, there will be shorter distances to vehicles before speed limit changes. [Type A]
22. Using an embedded ecoDriver system, there will be shorter distances to vehicles before speed limit changes. [Type B]
23. Using the full ecoDriver system (FeDS), there will be shorter distances to vehicles before speed limit changes. [Type C]
24. Using the ecoDriver application, (App), there will be shorter distances to vehicles before speed limit changes. [Type D]
25. Using a haptic ecoDriver, there will be shorter distances to vehicles before speed limit changes

#### Performance indicator (PI):

Average time headway (THW)

(Average distance headway (DHW) is dependent on speed → average THW, see H17)

#### Data reduction method:

500m sections

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment (Type A dataset)</b>  <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded (Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS (Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id

## Hypothesis analysis summary table

<b>Baseline App vs App (Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Vmc_id, Driver_id
<b>Non-haptic vs Haptic (Type E dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type*Main_effect
	Random effects	Driver_id

### Standard Filter:

- Exclude N/A's and obvious outliers.

### Filtering due to available amount of data:

- Only controlled data (no front sensor available in naturalistic studies)
- Type A-C: 3 road types (urban, rural, motorway)
- Type D: 2 road types (urban, rural)
- Type E: 1 road type (urban + rural)

### Extra Filtering:

- Filtering segments with avg\_speed < 10 and > 200 km/h
- Filtering segments with avg\_distance\_headway < 1 m
- Filtering segments with avg\_time\_headway > 10 s
- Only situations before intersections (300 m)

### 7.14.1 Controlled studies

#### 7.14.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 284: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	32.4	32.4	1	7182.9	11.9	<0.001
road_type	397.5	198.7	2	6948.1	73.2	<0.001
Main_effect:road_type	7.7	3.8	2	7159.4	1.4	0.245

Table 285: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	3.34	2.47	4.22	<0.001
Treatment	0.24	0.11	0.37	<0.001
Rural	-0.44	-0.58	-0.31	<0.001
Motorway	-0.70	-1.00	-0.40	<0.001
Treatment:Rural	-0.13	-0.29	0.04	0.136
Treatment:Motorway	0.06	-0.28	0.41	0.730
Random part	N			
Driver_id	130			
Vmc_id	6			
Number of observations	7193			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.



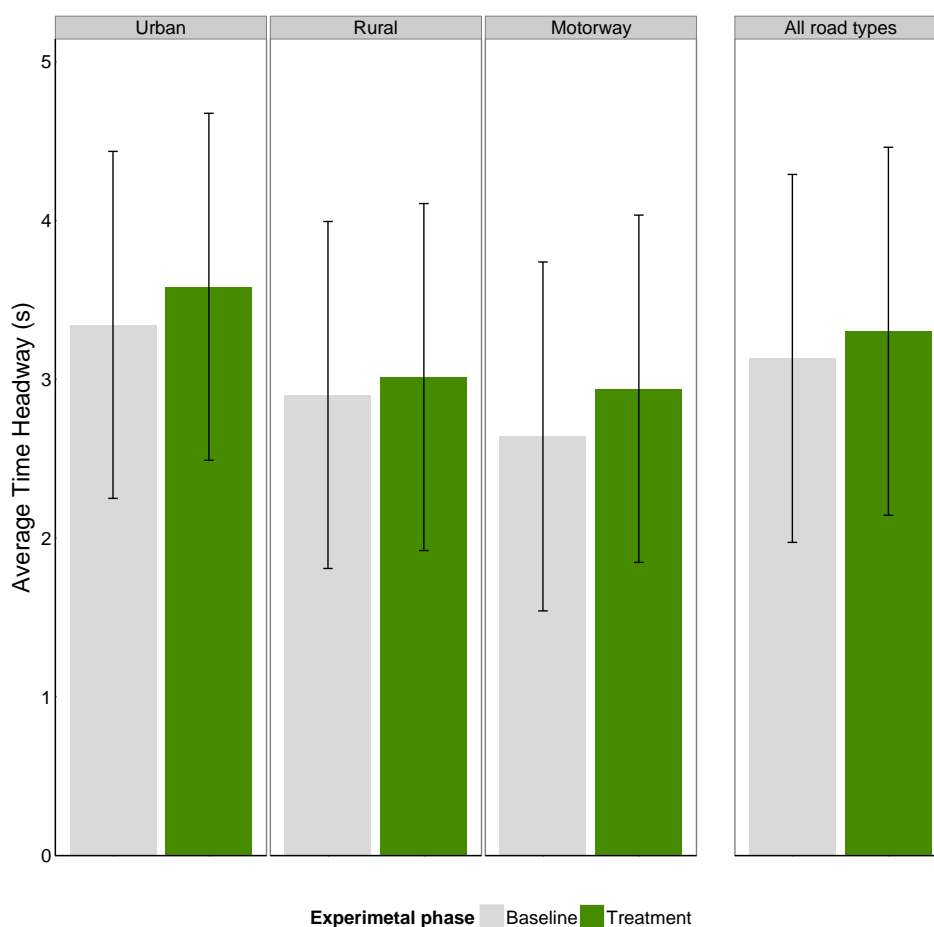


Figure 108: Model based average values of the average THW (s) for fixed effects.

Table 286: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	3.34	3.58	-0.24	<b>0.003</b>
Rural	2.90	3.01	-0.11	0.327
Motorway	2.64	2.94	-0.30	0.422
All road types	3.13	3.30	-0.17	<b>&lt;0.001</b>

#### Preliminary conclusions:

The main effect of experimental phase is significant with increased THW in the treatment condition. Furthermore, the THW differs significantly for different road types. However, the interaction between road type and phase is not significant, indicating that the effect of treatment on THW is consistent for all road types analysed. Overall, the mean THW increases within a range of 0.11 (rural roads) up to 0.30 seconds (motorways) in the treatment phase compared to the baseline.

### 7.14.1.2 Type B: Baseline embedded vs embedded

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 287: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	43.2	43.2	1	4784.4	22.2	<0.001
road_type	90.2	45.1	2	4741.1	23.2	<0.001
Main_effect:road_type	20.6	10.3	2	4752.8	5.3	0.005

Table 288: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	2.94	1.95	3.93	0.002
Embedded	0.41	0.27	0.54	<0.001
Rural	-0.02	-0.18	0.14	0.845
Motorway	-0.49	-0.76	-0.23	<0.001
Treatment:Rural	-0.30	-0.49	-0.12	0.001
Treatment:Motorway	-0.10	-0.41	0.20	0.512
Random part	N			
Driver_id	91			
Vmc_id	5			
Number of observations	4790			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

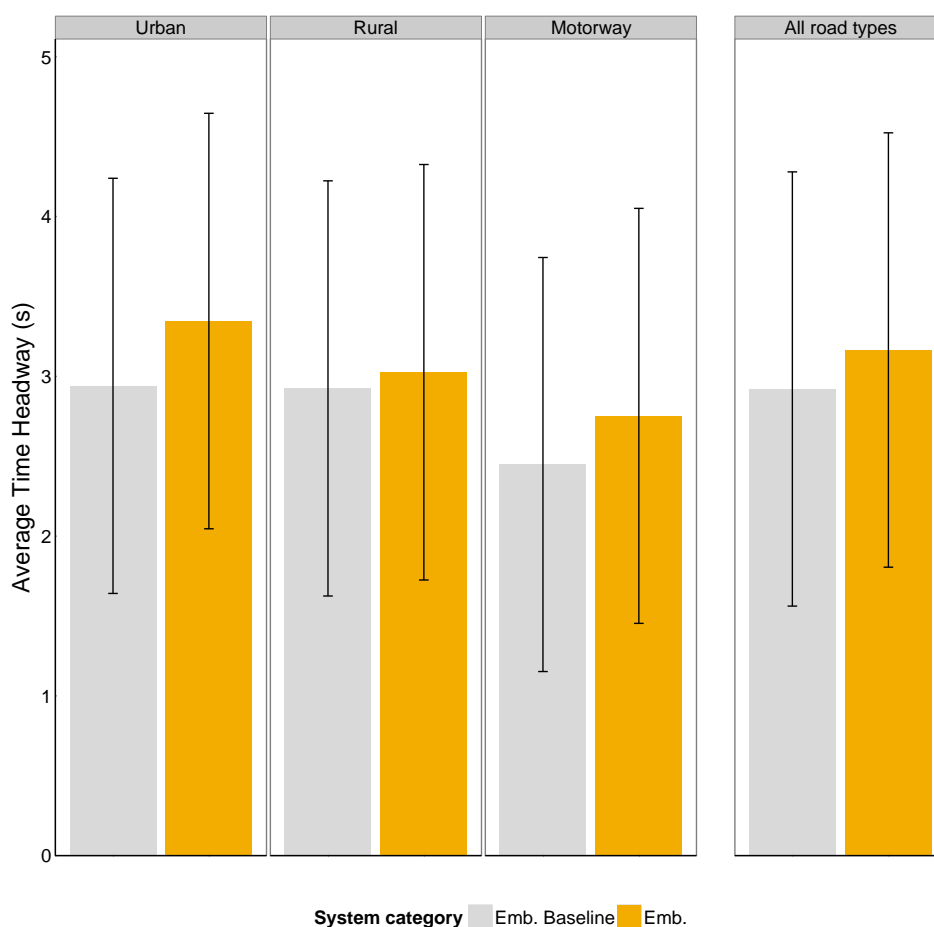


Figure 109: Model based average values of the average THW (s) for fixed effects.

Table 289: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	2.94	3.35	-0.41	<0.001
Rural	2.92	3.03	-0.10	0.597
Motorways	2.45	2.75	-0.30	0.233
All road types	2.92	3.17	-0.24	<0.001

#### Preliminary conclusions:

For the embedded systems, the main effect of experimental phase is significant with increased THW in the treatment condition. THW also differs significantly between different road types. Furthermore, the interaction between road type and phase is significant, post-hoc Tukey multiple comparison tests revealed significant effects of treatment on THW for urban areas and the all road types category. Overall, the mean THW increases within a range of 0.10 (rural roads) up to 0.41 seconds (urban roads) in the treatment phase compared to the Baseline.

## 7.14.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 290: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
<b>Main_effect</b>	40.1	40.1	1	4135.7	20.2	<b>&lt;0.001</b>
<b>road_type</b>	100.0	50.0	2	4060.3	25.2	<b>&lt;0.001</b>
<b>Main_effect:road_type</b>	21.2	10.6	2	4111.4	5.3	<b>0.005</b>

Table 291: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
<b>(Intercept)</b>	2.44	2.08	2.81	<b>&lt;0.001</b>
<b>FeDS</b>	0.41	0.26	0.57	<b>&lt;0.001</b>
<b>Rural</b>	-0.09	-0.27	0.09	0.328
<b>Motorway</b>	-0.53	-0.81	-0.26	<b>&lt;0.001</b>
<b>Treatment:Rural</b>	-0.33	-0.54	-0.13	<b>0.001</b>
<b>Treatment:Motorway</b>	-0.08	-0.39	0.24	0.644
<b>Random part</b>	<b>N</b>			
<b>Driver_id</b>	59			
<b>Vmc_id</b>	3			
<b>Number of observations</b>	4136			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

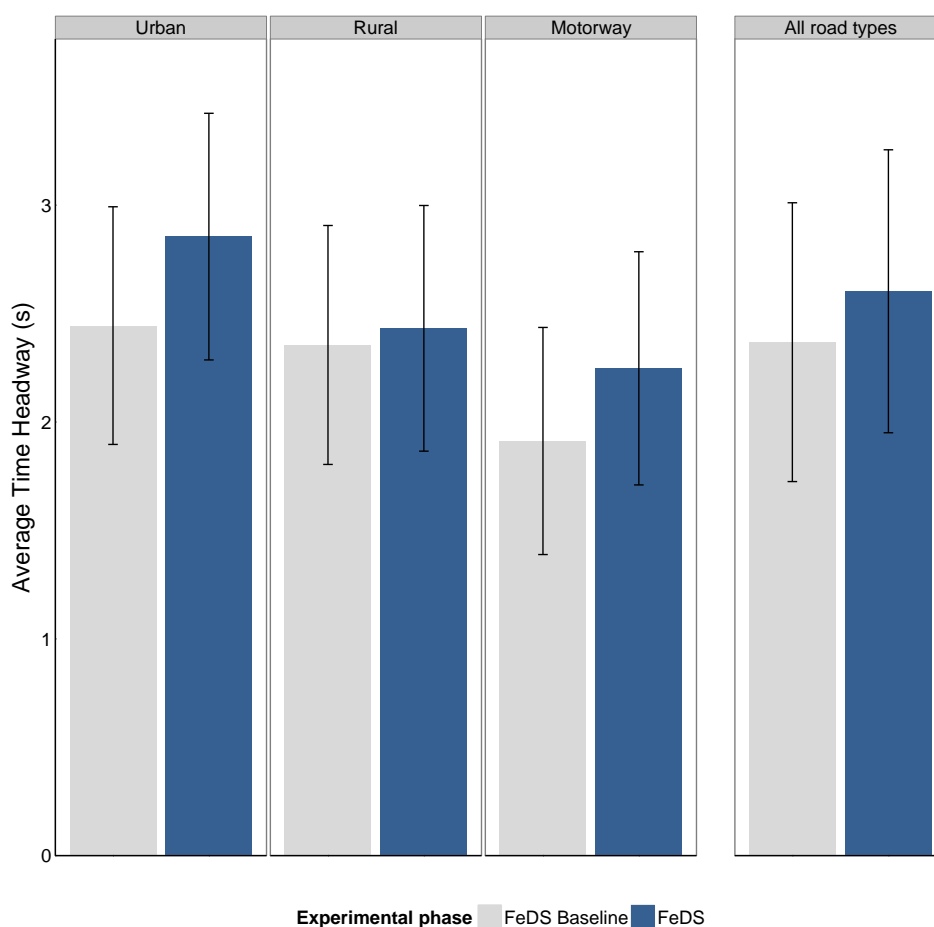


Figure 110: Model based average values of the average THW (s) for fixed effects.

Table 292: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	2.44	2.85	-0.41	<0.001
Rural	2.36	2.43	-0.08	0.876
Motorway	1.91	2.25	-0.34	0.176
All road types	2.37	2.60	-0.23	<0.001

**Preliminary conclusions:**

For the FeDS, the main effect of experimental phase is significant with increased THW in the treatment condition. THW also differs significantly between different road types. Furthermore, the interaction between road type and phase is significant, post-hoc Tukey multiple comparison tests revealed significant effects of treatment on THW for urban areas and the all road types category. Overall, the mean THW increases within a range of 0.10 (rural roads) up to 0.41 seconds (urban roads) in the treatment phase compared to the Baseline.

## 7.14.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 293: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	4.6	4.6	1	1891.7	1.1	0.295
road_type	498.3	498.3	1	2394.8	119.8	<0.001
Main_effect:road_type	6.2	6.2	1	2384.0	1.5	0.223

Table 294: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	3.58	2.17	5.00	0.036
App	0.20	-0.07	0.47	0.154
Rural	-0.85	-1.08	-0.61	<0.001
Treatment:Rural	-0.21	-0.55	0.13	0.223
Random part	N			
Driver_id	39			
Vmc_id	2			
Number of observations	840			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

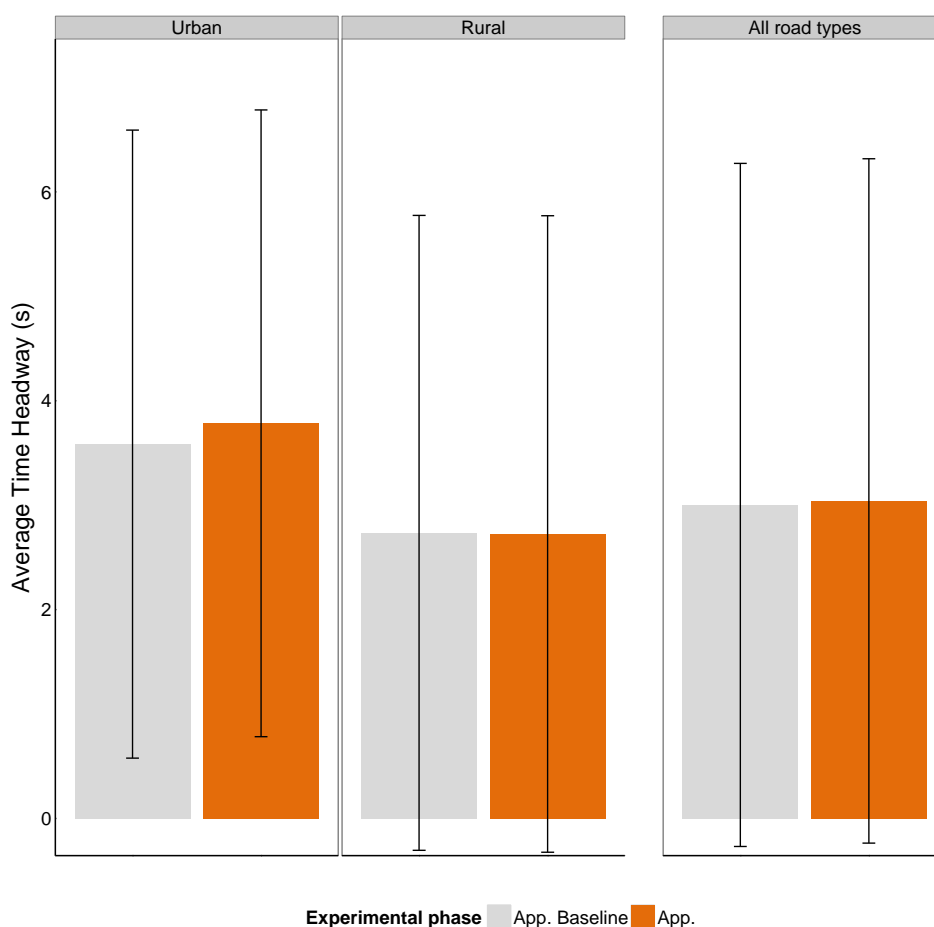


Figure 111: Model based average values of the average THW (s) for fixed effects.

Table 295: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	3.58	3.78	-0.20	0.480
Rural	2.74	2.72	0.01	1.000
All road types	3.00	3.04	-0.04	0.669

#### Preliminary conclusions:

For the ecoDriver App, only the main effect of road type is significant with larger THW for urban roads. No other effect was significant.

### 7.14.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 296: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	3.0	3.0	1	66.1	0.9	0.349

Table 297: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	5.13	4.46	5.80	<0.001
Haptic	0.43	-0.47	1.33	0.349
Random part	N			
Driver_id	24			
Number of observations	67			

Reference of the model is the non-haptic baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.



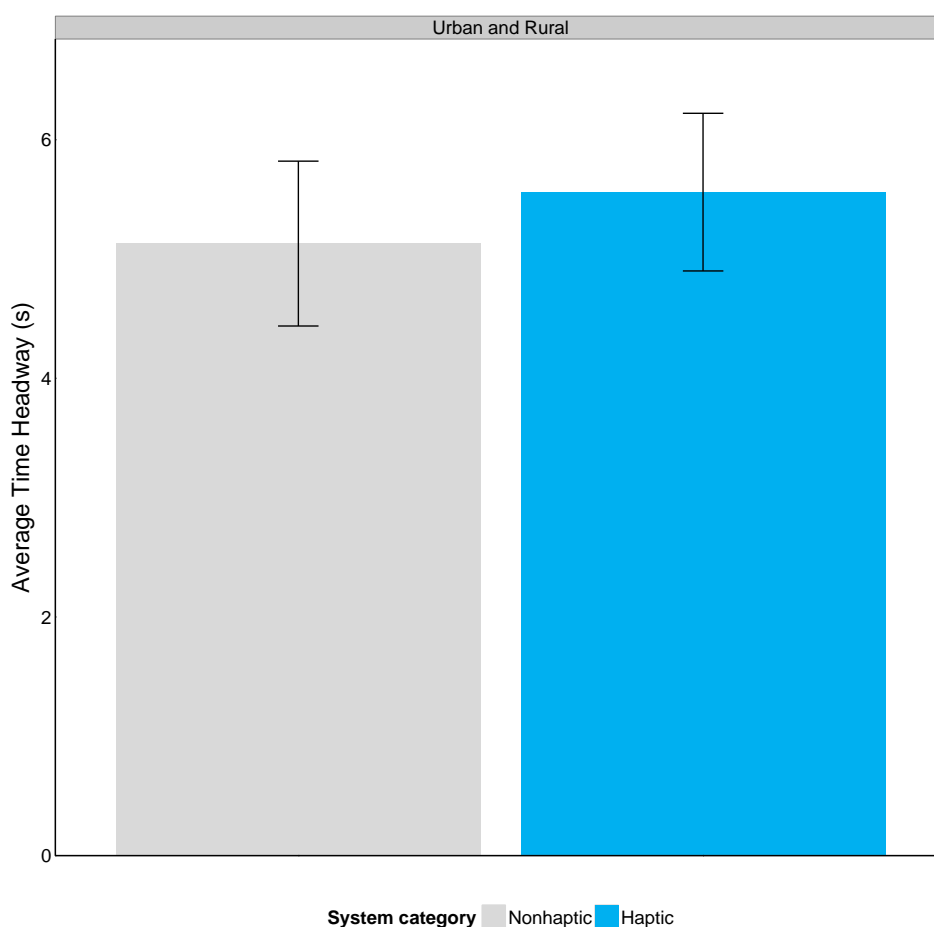


Figure 112: Model based average values of the average THW (s) for fixed effects.

Table 298: Average THW for the different levels of phase and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
All road types (urban and rural)	5.13	5.56	-0.43	0.346

#### Preliminary conclusions:

For the haptic systems, no significant effects on THW for different road types and experimental phase were found.

### 7.14.2 Results summary

Table 299: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-0.24	-0.41	-0.41	-0.2 (N.S.)	-	-
Rural	-0.11 (N.S.)	-0.1 (N.S.)	-0.08 (N.S.)	0.01 (N.S.)	-	-
Motorway	-0.3 (N.S.)	-0.3 (N.S.)	-0.34 (N.S.)	-	-	-
All road types	-0.17	-0.24	-0.23	-0.04 (N.S.)	-0.43 (N.S.)	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-7.19	-13.95	-16.8	-5.59 (N.S.)	-	-
Rural	-3.79 (N.S.)	-3.42 (N.S.)	-3.39 (N.S.)	0.36 (N.S.)	-	-
Motorway	-11.36 (N.S.)	-12.24 (N.S.)	-17.8 (N.S.)	-	-	-
All road types	-5.43	-8.22	-9.7	-1.33 (N.S.)	-8.38 (N.S.)	-

### 7.14.3 Conclusions and implications

Before speed limit changes, the average THW increases in the treatment condition compared to baseline driving which implies an increase of distance to front vehicles. This effect can be observed on all road types. When analysing the four different subsets of ecoDriver systems separately, significant differences between baseline and treatment condition could only be shown for embedded systems and the FeDS. For both, the analysis reveals that the effect is largest in urban areas. No significant differences in THW were observed for the ecoDriver App and the haptic vs. non-haptic treatment conditions.

An increase of the average THW implies an increase of the average distance headway. This means that drivers extend the gap to the vehicles in front for a better anticipation of the traffic which can improve both safety and eco-friendly predictive driving. However, this effect can only be shown for two out of four different systems tested. In contrast to other situations like intersections or the overall analysis (H17) of the data, the greatest effect before speed limit changes can be observed on urban roads (for the FeDS).

### 7.15 Hypothesis 24: Using an ecoDriver system, there will be more red or amber light violations

#### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecodriver system, there will be more red or amber light*

**Performance indicator (PI):**

# of Redlight\_violation

**Data reduction method:**

--

**Statistical models**

Wilcoxon test: Wilcoxon signed rank test is a non-parametric test used when participants are measured on two occasions. This test converts scores to ranks and compares then at two different times.

- **NOTE:**

Although the locations of the traffic lights are known and the car position can be calculated from the GPS-Position, the traffic light status is not available. So there are no objective measurements to evaluate if the car violates red or amber light.

The only sources are the observation protocols and it has not been taken down that there are more red or amber light violations comparing to baseline. That's why the hypothesis Nr. 18 can't be confirmed.

Hypothesis regarding red or amber light violations could not be analyzed because this condition of passing red or amber light violations was not registered with the observer protocol. It is necessary to have in mind that the observer protocol was used in controlled studies and therefore, the driver run the test with the researcher and it was more difficult driver could pass with amber or red traffic light.

## 7.16 Hypothesis 25: Using an ecoDriver system, there will be fewer overtakings

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, there will be fewer overtakings*

1. Using an ecoDriver system, there will be fewer overtakings. [Type A]
2. Using an embedded ecoDriver system, there will be fewer overtakings. [Type B]
3. Using the full ecoDriver system (FeDS), there will be fewer overtakings. [Type C]
4. Using the ecoDriver application, (App), there will be fewer overtakings. [Type D]
5. Using a haptic ecoDriver, there will be fewer overtakings. [Type E]

#### Performance indicator (PI):

# of overtakings

#### Data reduction method:

In this case, average of number of overtakings for first baseline and average of overtakings for experimental phases were calculated taking in consideration all the systems together (A), embedded comparisons (B), FeDS comparisons (C), ecoDriver App comparisons (D) and finally Haptic and Non Haptic comparisons.

#### Statistical models

Wilcoxon test: Wilcoxon signed rank test is a non-parametric test used when participants are measured on two occasions. This test converts scores to ranks and compares then at two different times.

#### Statistical analysis information

<b>Baseline vs Treatment (Type A dataset) For controlled data</b>	Paired comparisons	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
<b>Baseline embedded vs Embedded (Type B dataset) For controlled data</b>	Paired comparisons	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
<b>Baseline FeDS vs FeDS. (Type C dataset) For controlled data</b>	Paired comparisons	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
<b>Baseline ecoDriver App vs ecoDriver App (Type D dataset) For controlled data</b>	Paired comparisons	<ul style="list-style-type: none"> <li>Baseline ecoDriver App</li> <li>ecoDriver App</li> </ul>

## Hypothesis analysis summary table

<b>Haptic vs Non-haptic</b> <b>(Type E dataset)</b> <b>For controlled data</b>	Paired comparisons	<ul style="list-style-type: none"> <li>• Haptic</li> <li>• Non-haptic</li> </ul>
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### 7.16.1 Controlled studies

#### Baseline vs Treatment

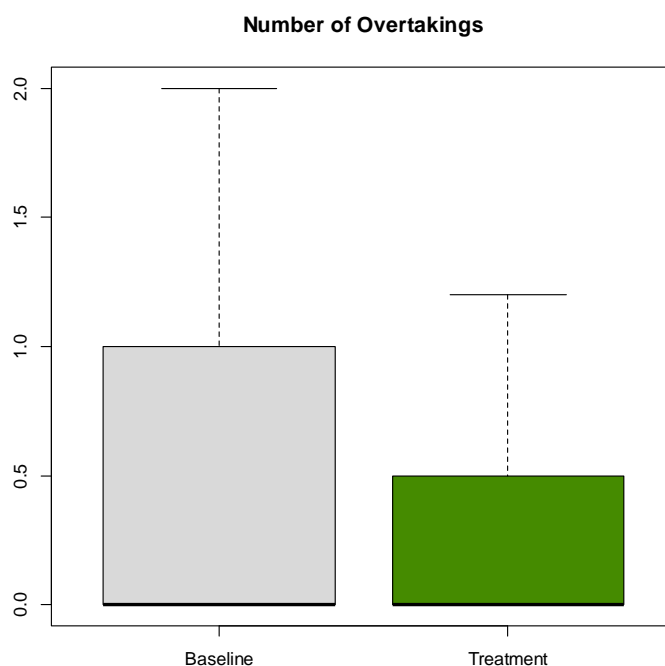


Figure 113: Boxplot for number of overtakings with to the experimental phase (Type A).

As it can be observed in the previous figure, there were not too much overtakings. In fact, most of the drivers performed none, one or two overtakings for most of the test (without considering outliers). Results for the Wilcoxon test statistics are provided in table below, calculating also the effect size if there is a statistically significant difference.

Table 300: Wilcoxon test statistics for type A comparison.

Median Baseline	Median Treatment	W	Z	p	r (Effect Size)
0.00	0.00	1414	-1.482	0.1388 (N.S.)	--

A Wilcoxon Signed Rank Test did not show a statistically significant difference between baseline and treatment conditions.

#### Preliminary conclusions:

Regarding first comparison Type A, there is not difference in the number of overtakings in baseline and treatment.

#### Baseline Embedded vs Embedded

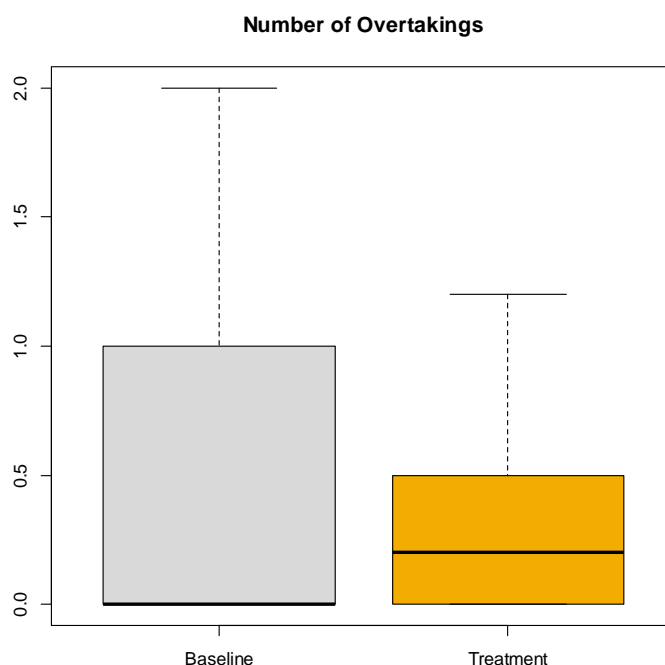


Figure 114: Boxplot for number of overtakings with to the experimental phase (Type B).

Regarding baseline embedded and embedded situations median is around 0 again for both situations. Results for the Wilcoxon test statistics are provided in table below, calculating also the effect size if there is a statistically significant difference.

Table 301: Wilcoxon test statistics for type B comparison.

Median Baseline Embedded	Median Embedded Treatment	W	Z	p	r (Effect Size)
0.00	0.20	839.5	-1.3412	0.1808 (N.S.)	--

Once again, a Wilcoxon Signed Rank test did not reveal differences when comparing baseline embedded and embedded.

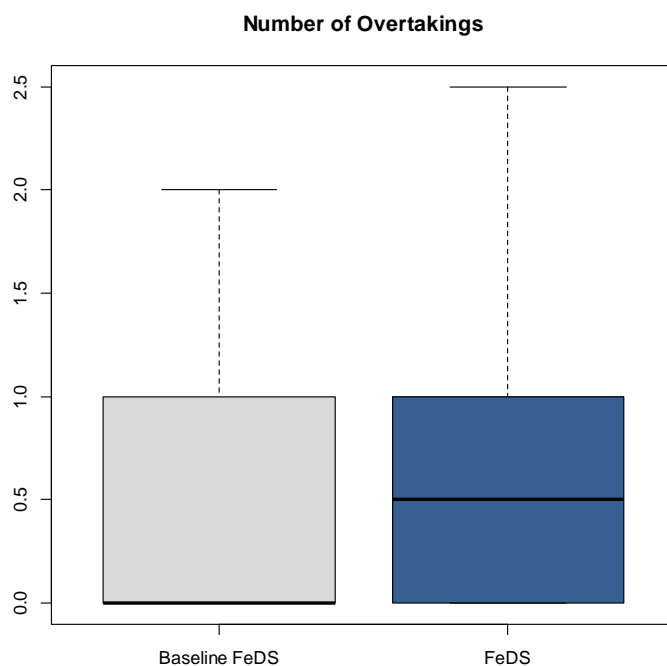
**Baseline FeDS vs FeDS**

Figure 115: Boxplot for number of overtakings with to the experimental phase (Type C).

Taking into consideration boxplots for baseline FeDS and FeDS median is 0 for baseline condition and 0.5 for FeDS.

Results for the Wilcoxon test statistics are provided in table below, calculating also the effect size if there is a statistically significant difference.

Table 302: Wilcoxon test statistics for type C comparison.

Median Baseline FeDS	Median FeDS Treatment	W	Z	p	r (Effect Size)
0.00	0.50	294.5	-0.034937	0.9736 (N.S.)	--

Once more, there is not statistically significant difference for this comparison.

**Preliminary conclusions:**

There are not statistically significant differences between FeDS baseline and FeDS treatment regarding number of overtakings.

## Baseline ecoDriver App vs ecoDriver App

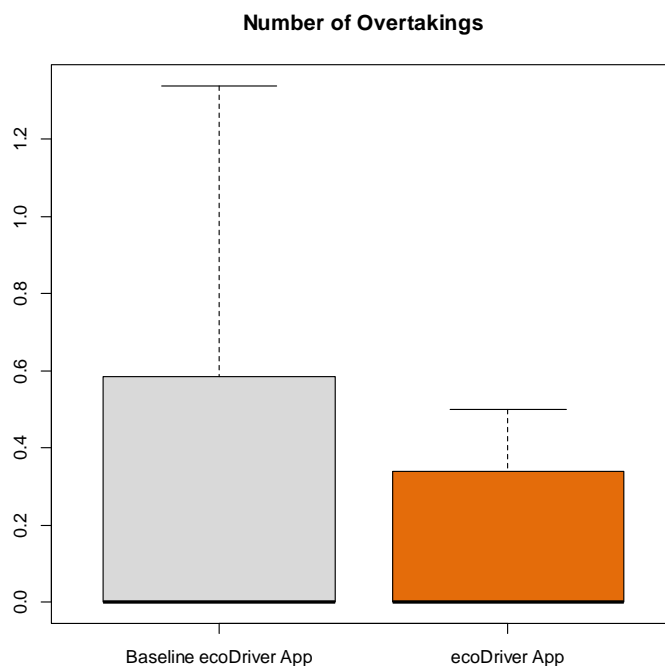


Figure 116: Boxplot for number of overtakings with to the experimental phase (Type C).

Having in mind what happened between baseline ecoDriver App and ecoDriver App situations; medians are similar (0) as it can be observed in the previous boxplots.

Results for the Wilcoxon test statistics are provided in table below, calculating also the effect size if there is a statistically significant difference.

Table 303: Wilcoxon test statistics for type D comparison.

Median Baseline ecoDriver App	Median ecoDriver App Treatment	W	Z	p	r (Effect Size)
0.00	0.00	72	-0.76387	0.4534 (N.S.)	--

Therefore, as it can be examine, it was similar the situation in this comparison regarding ecoDriver app.

**Preliminary conclusions:**

There are not statistically significant differences between ecoDriver App baseline and ecoDriver App treatment regarding number of overtakings.



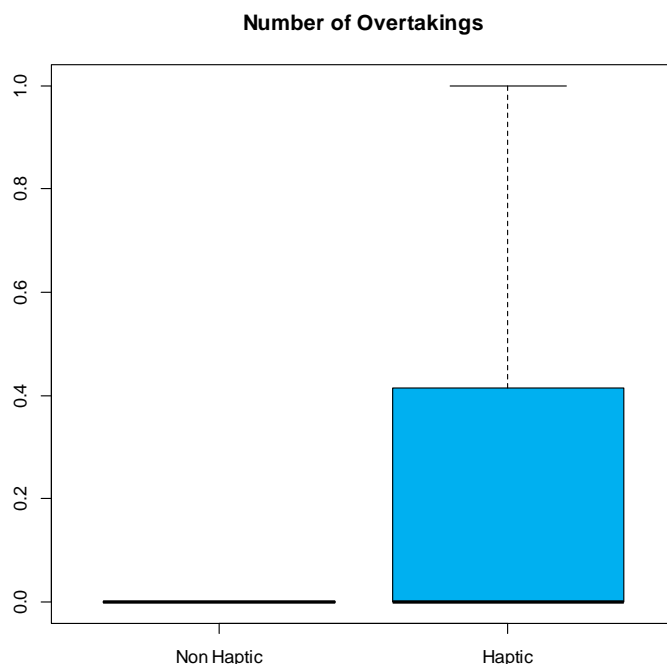
**Non-haptic vs haptic**

Figure 117: Boxplot for number of overtakings with to the experimental phase (Type E).

Previous figure points out that there was not overtaking in the not haptic situation, and this circumstance was similar to the haptic situation.

Results for the Wilcoxon test statistics are provided in table below, calculating also the effect size if there is a statistically significant difference.

Table 304: Wilcoxon test statistics for type E comparison.

Median Non Haptic	Median Haptic	W	Z	p	r (Effect Size)
0.00	0.00	49	0.90855	0.3755 (N.S.)	--

A Wilcoxon test revealed no significant difference for both, non-haptic and haptic situation.

**Preliminary conclusions:**

Once more, there are not statistically significant differences in reference of number of overtakings if we take into consideration haptic and non haptic conditions.

**7.16.2 Conclusions and implications**

For the second hypothesis, number of overtakings was used to compare if there were fewer overtakings when using advice and feedback from ecoDriver systems. In this case, average of overtakings for baseline situations and average of overtakings for experimental phases were calculated. As it can be

highlighted in the annex this hypothesis is not confirmed. There are not statistically significant differences between baselines and experimental conditions for the 5 situations performed (baseline vs treatment, embedded, FeDS, ecoDriver App and haptic situation). In fact, medians are next 0 in all the cases. This situation seems similar to the previous one, maybe when driver is being observed this driving is more precautionous and drivers are not risky to overtaking or violate a traffic light. New studies are necessary maybe using a inter-judge protocol with two observers in order to register deeply driver behaviour. Even it would be necessary to study the possibility of having cameras in naturalistic driving runs in order to know better the behaviour of drivers in an environment without observers.

**7.17 Hypothesis 26: Using an ecoDriver system, there will be less overspeeding.****Hypothesis analysis summary table**

Hypotheses formulations:

*Using an ecoDriver system, there will be less overspeeding*

1. Using an ecoDriver system, there will be less overspeeding. [Type A]
2. Using an embedded ecoDriver system, there will be less overspeeding. [Type B]
3. Using the full ecoDriver system (FeDS), there will be less overspeeding. [Type C]
4. Using the ecoDriver application, (App), there will be less overspeeding. [Type D]
5. Using a haptic ecoDriver, there will be less overspeeding. [Type E]

**Performance indicator (PI):**

# of overspeedings

**Data reduction method:**

In this case, average of number of overspeedings for first baseline and average of overspeedings for experimental phases were calculated taking in consideration all the systems together (A), embedded comparisons (B), FeDS comparisons (C), ecoDriver App comparisons (D) and finally Haptic and Non Haptic comparisons.

**Statistical models**

Wilcoxon test: Wilcoxon signed rank test is a non-parametric test used when participants are measured on two occasions. This test converts scores to ranks and compares then at two different times.

**Statistical analysis information**

<b>Baseline vs Treatment (Type A dataset) For controlled and naturalistic data</b>	Paired comparisons	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
<b>Baseline embedded vs Embedded (Type B dataset) For controlled data</b>	Paired comparisons	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
<b>Baseline FeDS vs FeDS. (Type C dataset) For controlled data</b>	Paired comparisons	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>

## Hypothesis analysis summary table

Baseline ecoDriver App vs ecoDriver App (Type D dataset) For controlled and naturalistic data	Paired comparisons	<ul style="list-style-type: none"> <li>Baseline ecoDriver App</li> <li>ecoDriver App</li> </ul>
Haptic vs Non-haptic (Type E dataset) For controlled data	Paired comparisons	<ul style="list-style-type: none"> <li>Haptic</li> <li>Non-haptic</li> </ul>

### 7.17.1 Controlled studies

#### Baseline vs Treatment

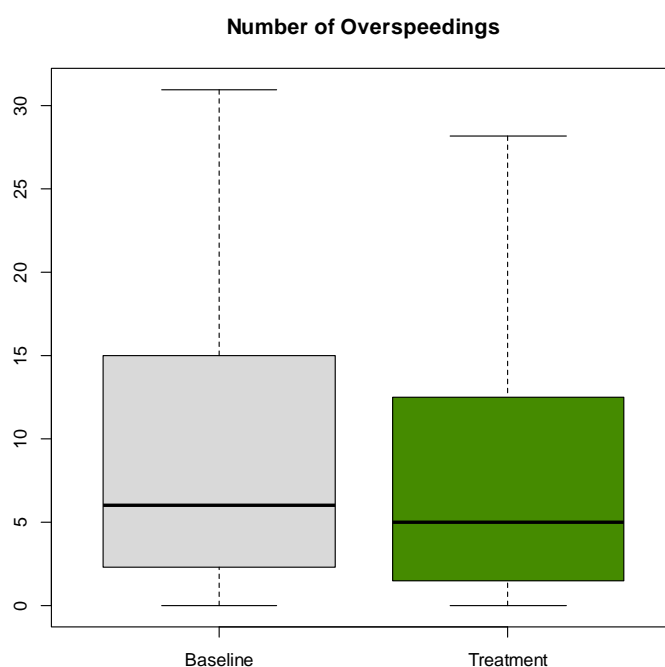


Figure 118: Boxplot for number of overspeedings with to the experimental phase (Type A).

In the Figure with boxplot for overspeeding it can be observed that median is higher in baseline (Md=6.00) than in treatment condition (5.00). Then, the number of overspeedings was fewer when using ecoDriver feedback.

Results for the Wilcoxon test statistics are provided in table below, calculating also the effect size if there is a statistically significant difference.

Table 305: Wilcoxon test statistics for type A comparison.

Median Baseline	MedianTreatment	W	Z	p	r (Effect Size)
6.00	5.00	5073	-5.0677	<.001	0.24

A Wilcoxon Signed Rank Test revealed a statistically significant reduction in number of overspeedings using ecoDriver,  $z=-5.0677$ ,  $p<.001$ , with a small effect size ( $r=.24$ ).

**Preliminary conclusions:**

Regarding first comparison Type A, the number of overspeedings is higher in baseline condition regarding treatment one with a small effect size.

**Baseline Embedded vs Embedded**

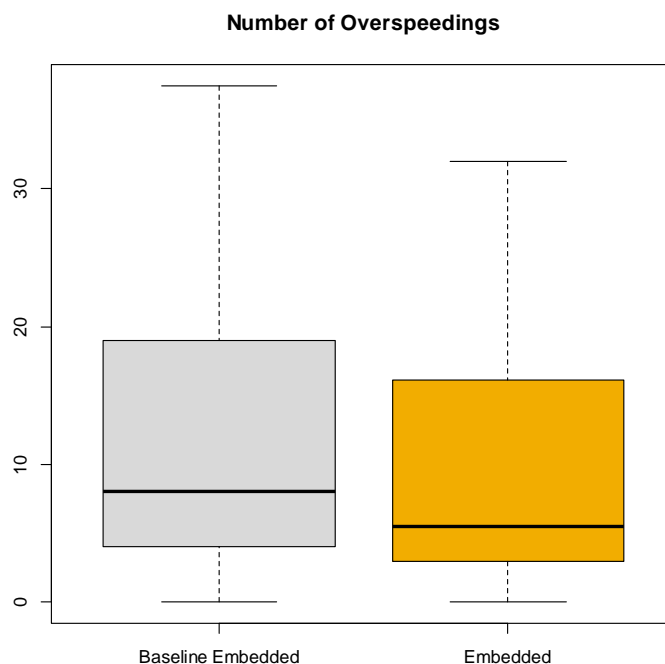


Figure 119: Boxplot for number of overspeedings with to the experimental phase (Type B).

For baseline embedded and embedded condition it is once again observed that median is higher for baseline situation (8.00) and embedded situation (5.50).

Results for the Wilcoxon test statistics are provided in table below, calculating also the effect size if there is a statistically significant difference.

Table 306: Wilcoxon test statistics for type B comparison.

Median Baseline Embedded	Median Embedded Treatment	W	Z	p	r (Effect Size)
8.00	5.50	3559	-5.0976	<.001	0.26

The results of a Wilcoxon test indicated that there was statistically significant difference in number of overspeedings regarding baseline embedded and embedded,  $z=-5.0967$ ,  $p<.001$ , with a small effect size ( $r=.26$ ).

**Preliminary conclusions:**

Number of overspeedings is higher in baseline condition regarding treatment one with a small effect size taking into consideration use of embedded conditions

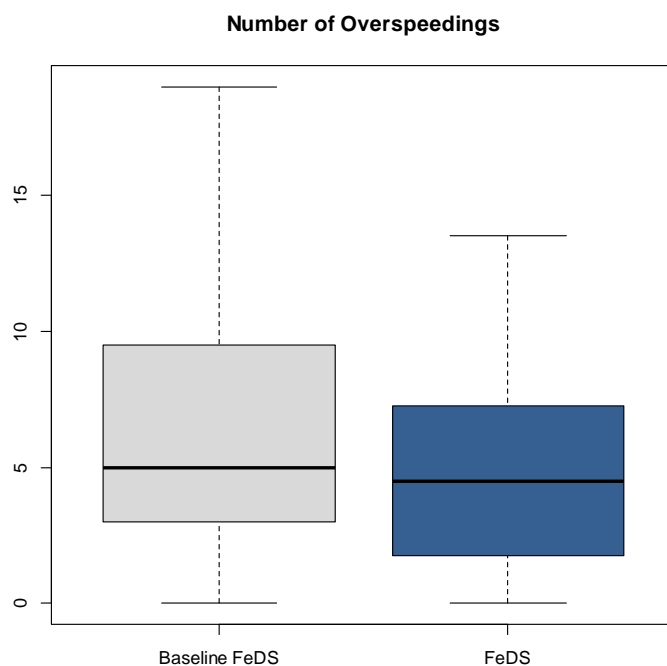
**Baseline FeDS vs FeDS**

Figure 120: Boxplot for number of overspeedings with to the experimental phase (Type C).

Considering the comparisons between baseline FeDS and FeDS, once again median is higher for baseline, although this time, the difference is short. The median for baseline FeDS is 5.00 and for FeDS is 4.50.

Results for the Wilcoxon test statistics are provided in table below, calculating also the effect size if there is a statistically significant difference.

Table 307: Wilcoxon test statistics for type C comparison.

Median Baseline FeDS	Median FeDS Treatment	W	Z	p	r (Effect Size)
5.00	4.50	809.5	-2.7056	<.005	0.21

The Wilcoxon test indicated a statistically significant reduction using FeDS regarding the baseline,  $z = -2.7056$ ,  $p < .005$ , with a small effect size ( $r = .21$ ).

**Preliminary conclusions:**

Although there is not too much differences in number of overtakings for FeDS baseline and treatment, this little difference is statistically significant with a small effect.

## Baseline ecoDriver App vs ecoDriver App

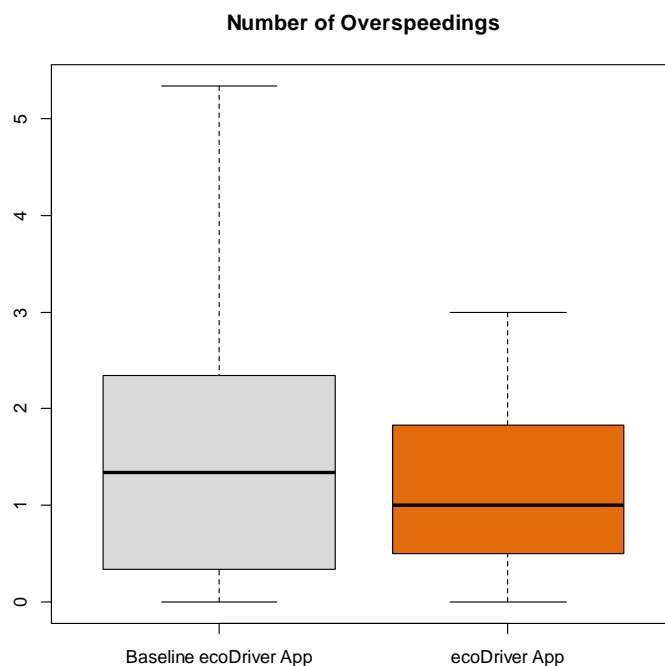


Figure 121: Boxplot for number of overspeedings with to the experimental phase (Type C).

The previous figure with boxplots for baseline ecoDriver App and ecoDriver App condition shows that there were not very many overspeedings in this situation. In fact, both medians are around 1.00.

Results for the Wilcoxon test statistics are provided in table below, calculating also the effect size if there is a statistically significant difference.

Table 308: Wilcoxon test statistics for type D comparison.

Median Baseline ecoDriver App	Median ecoDriver App Treatment	W	Z	p	r (Effect Size)
1.34	1.00	550.5	-0.67851	0.5049 (N.S.)	--

In this case, the Wilcoxon Test revealed no significant difference in number of overspeedings,  $z = -0.67851$ ,  $p = 0.5049$ .

**Preliminary conclusions:**

For ecoDriver App, baseline and treatment conditions are enough similar having not statically significant differences.

## Non-haptic vs haptic

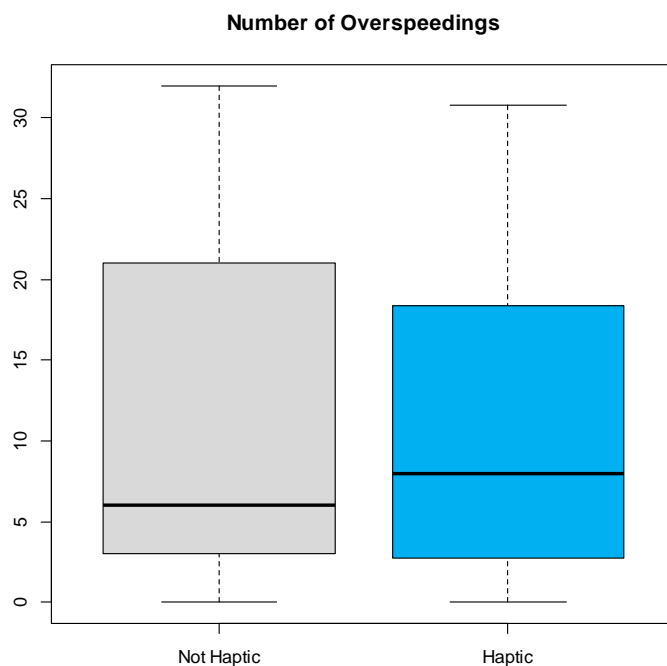


Figure 122: Boxplot for number of overspeedings with to the experimental phase (Type E).

Boxplots for non haptic and haptic condition are presented in the previous figure. In this case, median value is higher when drivers run with haptic pedal (Md=8.00) against driving without pedal (Md=6.00).

Results for the Wilcoxon test statistics are provided in table below, calculating also the effect size if there is a statistically significant difference.

Table 309: Wilcoxon test statistics for type E comparison.

Median Non Haptic	Median Haptic	W	Z	p	r (Effect Size)
6.00	8.00	207	-1.2266	0.2244 (N.S.)	--

The Wilcoxon test indicated no significant difference for difference between driving with haptic or driving without as it can be observed in previous table.

**Preliminary conclusions:**

Median for overspeeding is higher in haptic condition but in this case this difference regarding non haptic is not statistically significant.



### 7.17.2 Naturalistic studies

#### Baseline vs Treatment

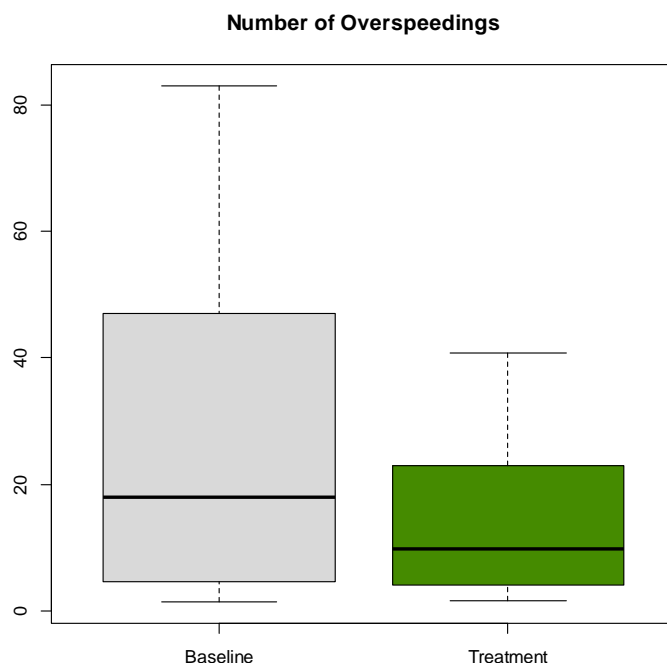


Figure 123: Boxplot for number of overspeedings with to the experimental phase (Type A).

In the Figure with boxplot for overspeeding it can be observed that median is higher in baseline (Md=18.00) than in treatment condition (9.825). Then, the number of overspeedings was fewer when using ecoDriver feedback.

Results for the Wilcoxon test statistics are provided in table below, calculating also the effect size if there is a statistically significant difference.

Table 310: Wilcoxon test statistics for type A comparison.

Median Baseline	MedianTreatment	W	Z	p	r (Effect Size)
18.00	9.825	133.5	-3.7168	<.001	0.41

A Wilcoxon Signed Rank Test revealed a statistically significant reduction in number of overspeedings using ecoDriver,  $z=-3.7168$ ,  $p<.001$ , with a medium effect size ( $r=.41$ ).

#### Preliminary conclusions:

It is clear regarding overspeeding in a naturalistic driving that the number of overspeedings is higher in baseline comparing with treatment. In this case, the effect size is medium.

## Baseline ecoDriver App vs ecoDriver App

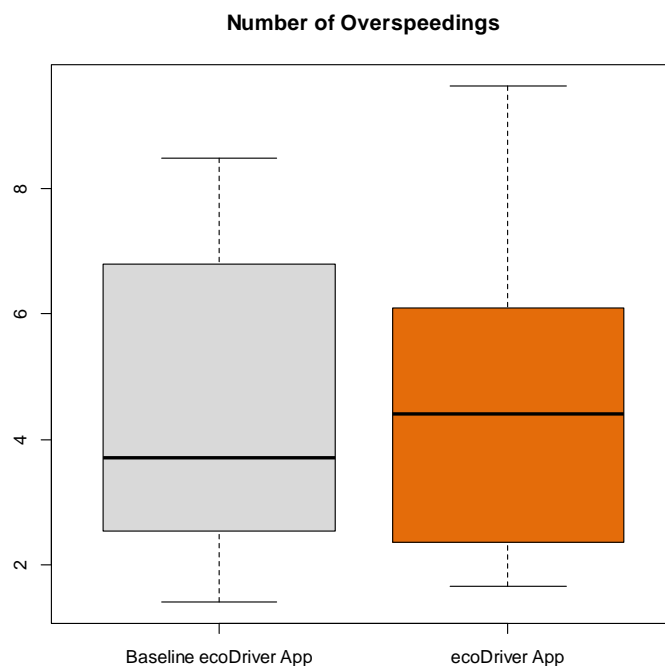


Figure 124: Boxplot for number of overspeedings with to the experimental phase (Type C).

The previous figure with boxplots for baseline ecoDriver App and ecoDriver App condition shows that there were not very much overspeedings in this naturalistic situation. In fact, both medians are around 4.00.

Results for the Wilcoxon test statistics are provided in table below, calculating also the effect size if there is a statistically significant difference.

Table 311: Wilcoxon test statistics for type D comparison.

Median Baseline ecoDriver App	Median ecoDriver App Treatment	W	Z	p	r (Effect Size)
3.70	4.40	74.5	-0.094689	0.9357 (N.S.)	--

In this case, the Wilcoxon Test revealed no significant difference in number of overspeedings,  $z = -0.094689$ ,  $p = 0.9357$ .

**Preliminary conclusions:**

Not statistically significant differences for overspeedings regarding ecoDriver App baseline and treatment.

### 7.17.3 Conclusions and implications

Having in mind that using only information from observer protocol was not enough it was decided to add a new hypothesis regarding overspeedings. Using information from datalogger and speed limit overspeedings were calculated. The new hypothesis pointed out was the next: “Compared to baseline, there will be less overspeedings when using ecoDriver system”. Overspeedings were calculated for controlled and naturalistic studies. In case of naturalistic studies only comparisons Type A and D could be performed. Results are showed in the annex of this document. In this case, it was confirmed that there were statistically significant less overspeedings when using ecoDriver system when comparing baseline with treatment, baseline embedded with embedded and baseline FeDS vs FeDS in controlled studies. Differences were not statistically significant for ecoDriver App and haptic situations (maybe because the number of drivers with information was not too much and it will be necessary future studies to know if there will better to use ecoDriver in both situations to reduce the number of overspeedings).

As it can be highlighted in the next boxplots, medians for number of overspeedings was higher for baseline situations, then it seems that having information with ecoDriver systems, in general, is a help to reduce the number of overspeedings.

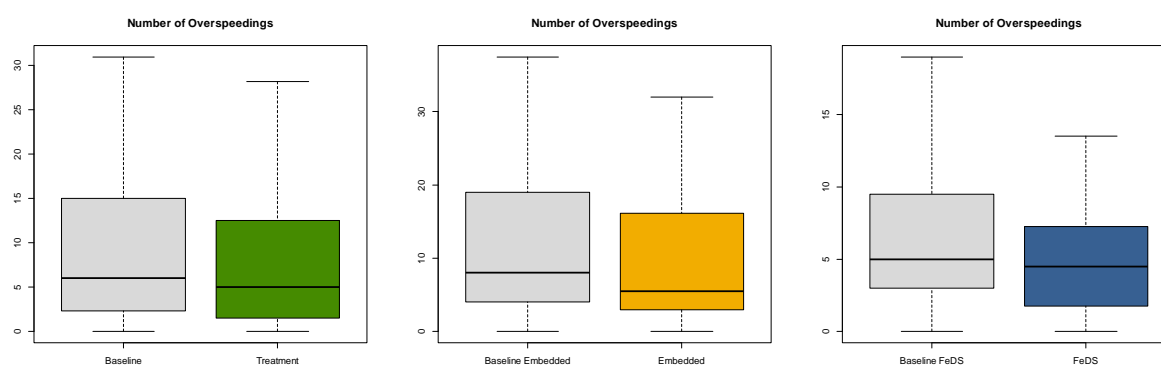


Figure 125: Boxplots for overspeedings regarding baseline vs treatment, embedded baseline vs embedded treatment and FeDS baseline vs FeDS treatment (Controlled studies).

Having in mind naturalistic studies, two analyses could be run regarding comparison between baseline and treatment (Type A) and comparison between ecoDriver app baseline and ecoDriver app. Only first comparison was statistically significant and, once more, number of overspeedings was higher in baseline condition vs treatment condition as it can be observed in the below. Moreover, the effect size for this comparison was medium ( $r=.41$ ).

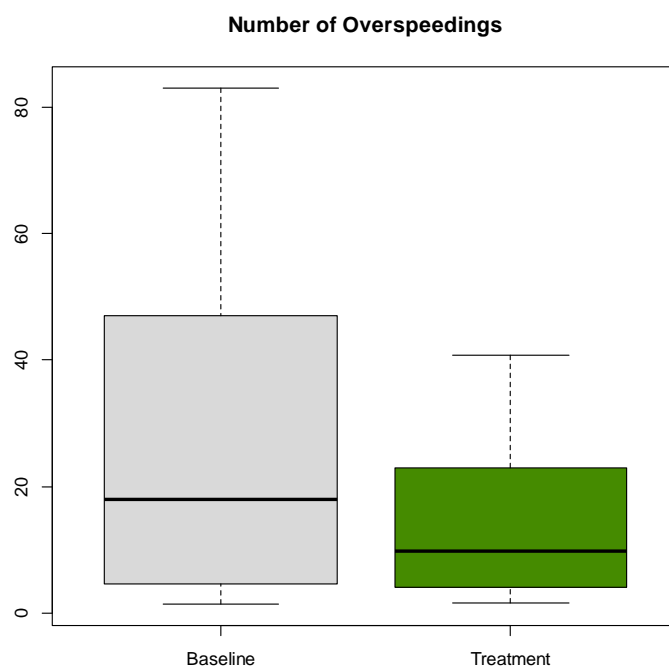


Figure 126: Boxplot for number of overspeedings with to the experimental phase (Type A) for naturalistic studies.

For second comparison, medians were around 4 overspeedings and although it was higher in ecoDriver app condition the difference were not statistically significant. Even it would be necessary to take into account that only data from 17 participants could be part of this analysis.

## 7.18 Hypothesis 27: Using an ecoDriver system, the average rpm when shifting up will be reduced

### Hypothesis analysis summary table

Hypotheses formulations:

*[Golden rule of ecodriving #1: Shift up as soon as possible: Shift up between 2.000 and 2.500 revolutions per minute]*

*Using an ecoDriver system, the average rpm when shifting up will be reduced.*

1. Using an ecoDriver system, the average rpm when shifting up will be reduced. [Type A]
2. Using an embedded ecoDriver system, the average rpm when shifting up will be reduced. [Type B]
3. Using the full ecoDriver system (FeDS), the average rpm when shifting up will be reduced. [Type C]
4. Using the ecoDriver application, (App), the average rpm when shifting up will be reduced. [Type D]
5. Using a haptic ecoDriver, the average rpm when shifting up will be reduced. [Type E]

#### Performance indicator (PI):

average rotations per minute when shifting up (avg\_rpm\_shifting\_up)

#### Data reduction method:

500m sections

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment (Type A dataset)</b> For both controlled and naturalistic data	Main effect	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded (Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS (Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline App vs App</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>

## Hypothesis analysis summary table

(Type D dataset)	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Vmc_id, Driver_id
Non-haptic vs Haptic (Type E dataset)	Main effect	<ul style="list-style-type: none"> <li>• Non-haptic</li> <li>• Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 7.18.1 Controlled studies

#### 7.18.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 312: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	27712546.7	27712546.7	1	22996.1	316.5	<0.001
road_type	1007607350.8	503803675.4	2	23029.9	5754.2	<0.001
Main_effect:road_type	41593197.9	20796599.0	2	22955.5	237.5	<0.001

Table 313: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1277.90	980.07	1575.74	<0.001
Treatment	9.35	-6.16	24.85	0.237
Rural	390.07	375.29	404.85	<0.001
Motorway	783.10	762.41	803.79	<0.001
Treatment:Rural	-200.22	-218.88	-181.57	<0.001
Treatment:Motorway	-75.01	-99.04	-50.99	<0.001
Random part	N			
Driver_id	122			
Vmc_id	5			
Number of observations	23356			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

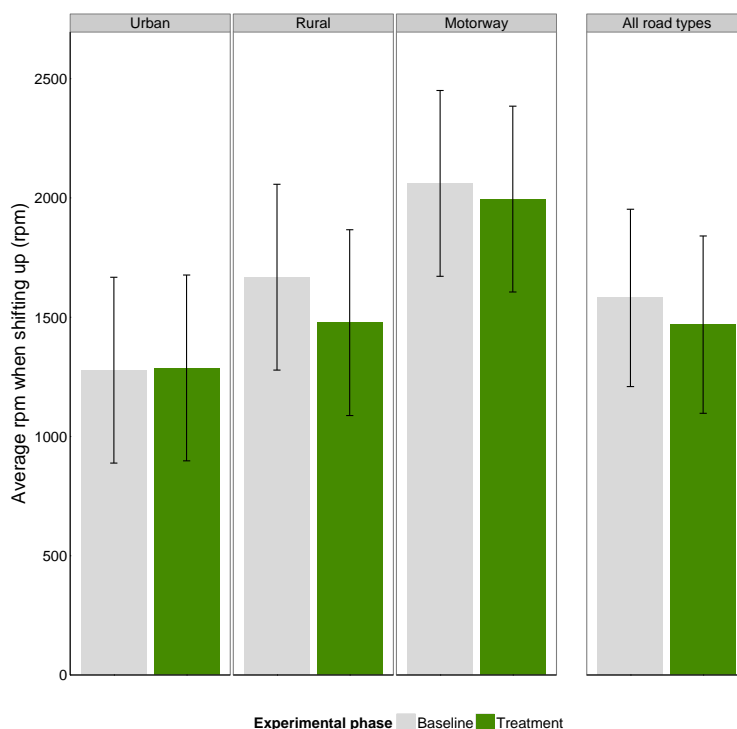


Figure 127: model based average values of avg\_rpm\_shift\_up for fixed effects.

Table 314 Average rpm when shifting gear up for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	1277.90	1287.25	-9.35	0.839
Rural	1667.98	1477.10	190.88	<0.001
Motorway	2061.00	1995.34	65.67	<0.001
All road types	1580.73	1468.65	112.08	<0.001

#### Preliminary conclusions:

A reduction of the Average rpm when shifting gear up correspond to a positive effect as stated in golden rule #1.

The treatment condition has a global significant effect in decreasing the average rpm when shifting gear up. This effect is stronger on rural roads (-191rpm), less salient on motorway (-65.7rpm) and not significant on urban roads.

The ecoDriver systems positive impact on average rpm when shifting gear up is significant when driving on rural and motorway compared to urban.

## 7.18.1.2 Type B: Baseline embedded vs embedded

Table 315: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	30350485.1	30350485.1	1	18996.6	487.2	<0.001
road_type	724687196.3	362343598.2	2	19011.5	5816.1	<0.001
Main_effect:road_type	5584256.3	2792128.2	2	18969.5	44.8	<0.001

Table 316: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
1325.43	1107.57	1543.30	<0.001	1325.43
-74.62	-90.43	-58.82	<0.001	-74.62
117.13	101.15	133.10	<0.001	117.13
589.24	570.14	608.35	<0.001	589.24
-69.15	-88.16	-50.15	<0.001	-69.15
9.08	-12.99	31.16	0.420	9.08
Random part		N		
Driver_id		82		
Vmc_id		4		
Number of observations		18924		

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.



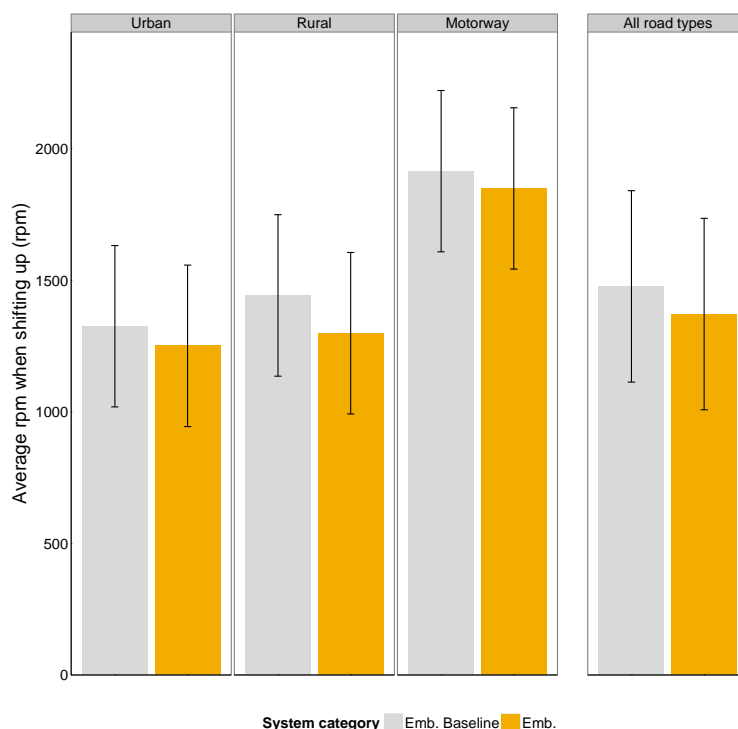


Figure 128: model based average values of avg\_rpm\_shift\_up for fixed effects.

Table 317 Average rpm when shifting gear up for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	1325.4	1250.8	74.6	<0.001
Rural	1442.6	1298.8	143.8	<0.001
Motorway	1914.7	1849.1	65.5	<0.001
All road types	1477.0	1371.5	105.4	<0.001

#### Preliminary conclusions:

Compared to their baseline, the embedded systems provide significant reduction of the average rpm when shifting gear up in all road conditions. As already stated, the effect is larger (-144rpm) for rural roads.

### 7.18.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 318: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
<b>Main_effect</b>	41203539.8	41203539.8	1	15274.4	705.2	<0.001
<b>road_type</b>	700700555.1	350350277.5	2	15292.5	5996.0	<0.001
<b>Main_effect:road_type</b>	11310775.7	5655387.8	2	15256.0	96.8	<0.001

Table 319: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
<b>(Intercept)</b>	1454.53	1345.68	1563.38	<0.001
<b>FeDS</b>	-97.12	-114.20	-80.03	<0.001
<b>Rural</b>	155.07	137.32	172.82	<0.001
<b>Motorway</b>	588.43	568.82	608.04	<0.001
<b>FeDS:Rural</b>	-99.67	-120.64	-78.71	<0.001
<b>FeDS:Motorway</b>	29.28	6.63	51.93	0.011
<b>Random part</b>	<b>N</b>			
<b>Driver_id</b>	58			
<b>Vmc_id</b>	3			
<b>Number of observations</b>	15316			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

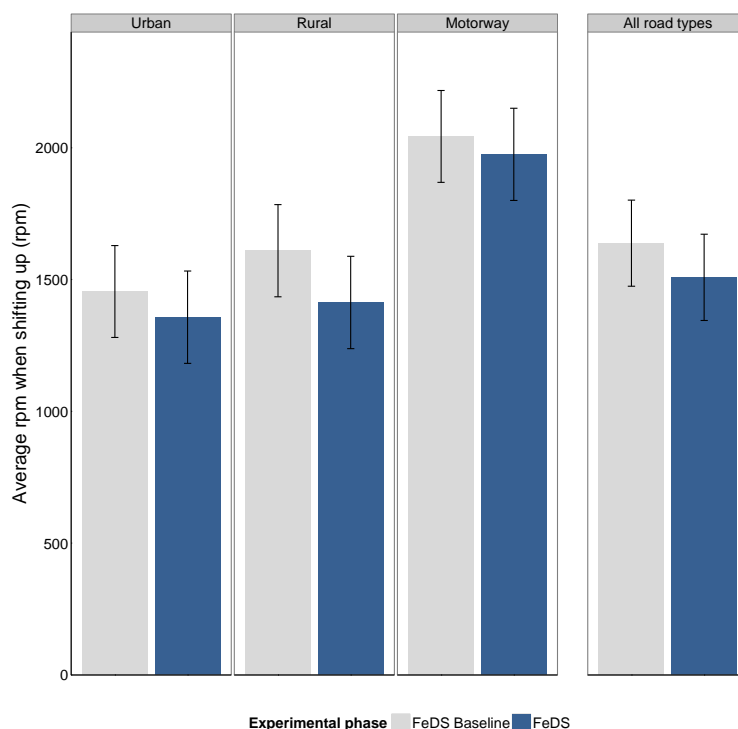


Figure 129: model based average values of avg\_rpm\_shift\_up for fixed effects.

Table 320: Average rpm when shifting gear up for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	1454.53	1357.41	97.12	<0.001
Rural	1609.60	1412.81	196.79	<0.001
Motorway	2042.96	1975.12	67.83	<0.001
All road types	1637.85	1508.42	129.43	<0.001

#### Preliminary conclusions:

Compared to its own baseline, the FeDS system present the same picture as the larger category of embedded system (FeDS is an embedded system).

The main effect is significant, with a reduction of the average rpm when shifting gear up, up to 196.8 rpm in rural conditions.

## 7.18.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 321: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	13779722.1	13779722.1	1	4432.5	115.3	<0.001
road_type	604037517.7	604037517.7	1	4395.3	5054.7	<0.001
Main_effect:road_type	935282.1	935282.1	1	4394.9	7.8	0.005

Table 322: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1221.83	741.43	1702.23	0.038
App	-89.71	-123.65	-55.77	<0.001
Rural	802.08	774.40	829.76	<0.001
App:Rural	-60.71	-103.24	-18.18	0.005
Random part	N			
Driver_id	40			
Vmc_id	5			
Number of observations	4432			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

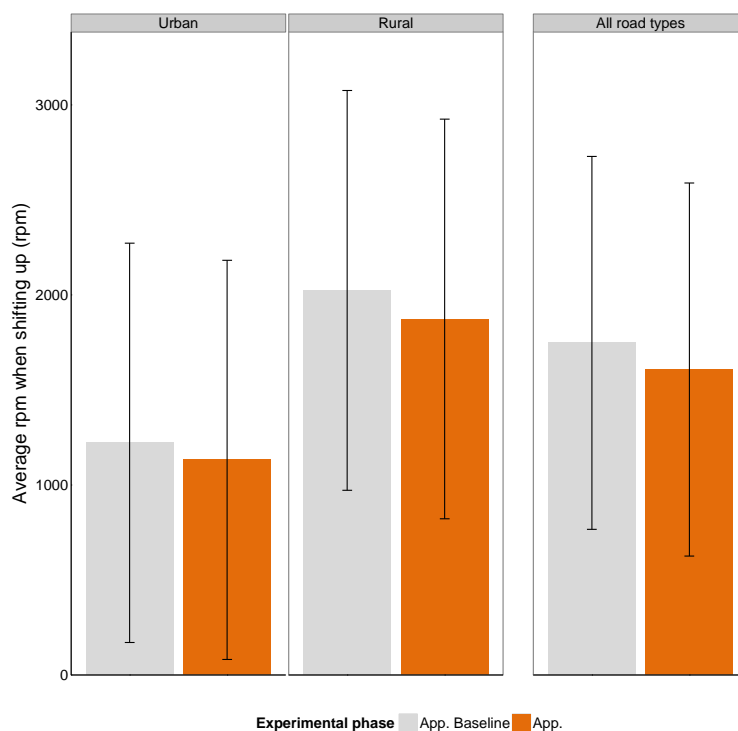


Figure 130: model based average values of avg\_rpm\_shift\_up for fixed effects.

Table 323: Average rpm when shifting gear up for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	1221.83	1132.12	89.71	<0.001
Rural	2023.91	1873.49	150.42	<0.001
Motorway	NA	NA	NA	NA
All road types	1747.85	1607.53	140.32	<0.001

#### Preliminary conclusions:

The ecoDriver app is significantly reducing globally the average rpm when shifting gear up. This reduction is significant for both urban and rural roads (no data for motorway with the app), with a greater impact on rural roads (-150rpm).

### 7.18.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 324: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	268809.4	268809.4	1	2357.4	3.4	0.065
road_type	27311.2	27311.2	1	2355.7	0.3	0.556
Main_effect:road_type	60592.6	60592.6	1	2357.3	0.8	0.380

Table 325: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	980.87	945.75	1015.99	<0.001
Haptic	-36.91	-83.38	9.56	0.120
Rural	-3.91	-41.58	33.76	0.839
Haptic:Rural	23.77	-29.33	76.87	0.380
Random part	N			
Driver_id	24			
Number of observations	2394			

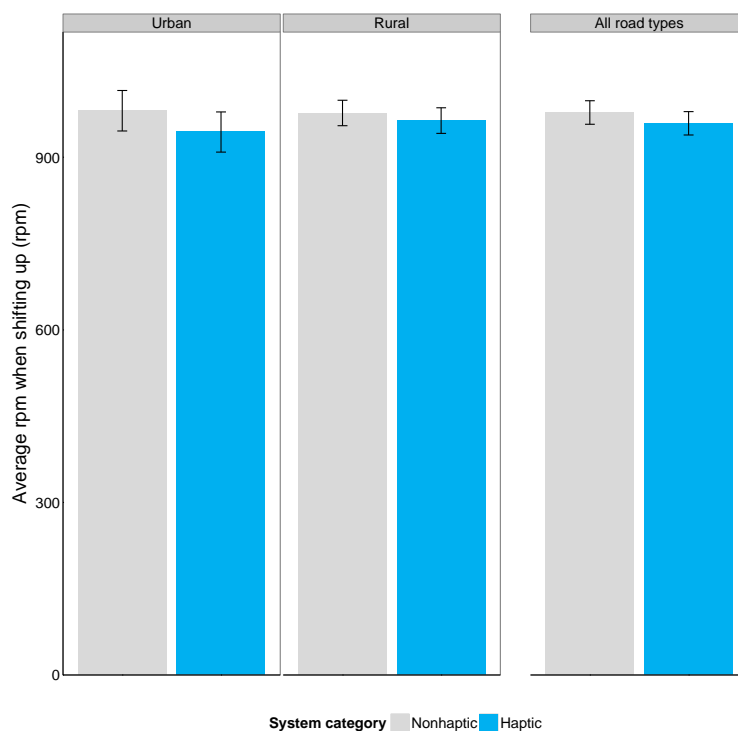


Figure 131: model based average values of avg\_rpm\_shift\_up for fixed effects.

Table 326: Average rpm when shifting gear up for the different systems and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	980.87	943.96	36.91	0.394
Rural	976.97	963.82	13.15	0.741
Motorway	NA	NA	NA	NA
All road types	977.87	959.13	18.74	0.102

**Preliminary conclusions:**

Using an haptic pedal additional to an ecoDriver non-haptic system does not significantly decrease the average rpm when shifting gear up. There is no additional improvement for this PI with an haptic pedal.

## 7.18.2 Naturalistic studies

### 7.18.2.1 TypeA : Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 327: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	27813881.9	27813881.9	1	12820.4	138.9	<0.001
road_type	2027496819.7	1013748409.8	2	12818.5	5060.8	<0.001
Main_effect:road_type	10156467.4	5078233.7	2	12815.0	25.4	<0.001

Table 328: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1628.55	1121.82	2135.28	0.055
Treatment	-62.65	-88.05	-37.24	<0.001
Rural	571.33	543.73	598.93	<0.001
Motorway	1074.24	1043.98	1104.50	<0.001
Treatment:Rural	-119.73	-156.46	-83.00	<0.001
Treatment:Motorway	3.42	-36.37	43.22	0.866
Random part	N			
Driver_id	12			
Vmc_id	2			
Number of observations	12748			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.



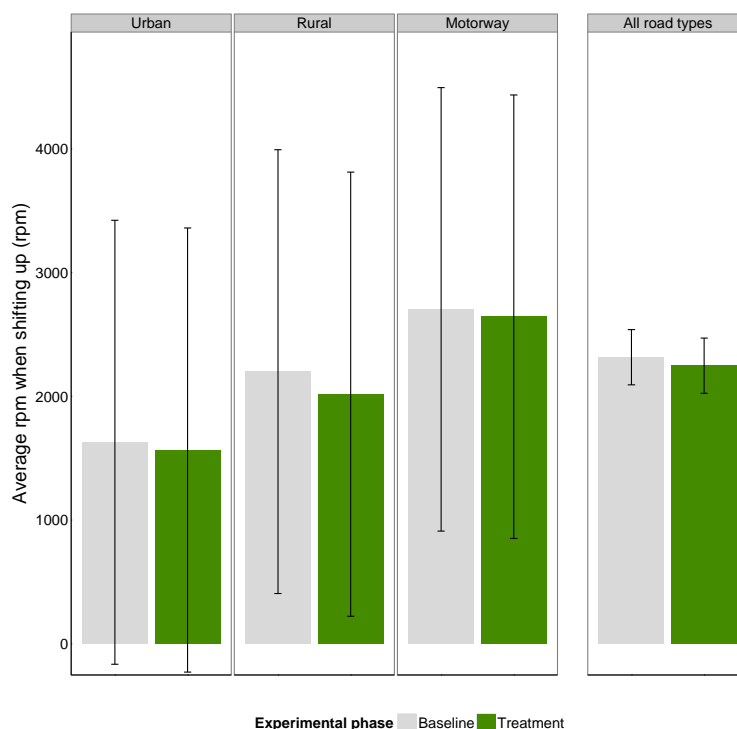


Figure 132: model based average values of avg\_rpm\_shift\_up for fixed effects.

Table 329: Average rpm when shifting gear up for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	1628.55	1565.91	62.65	<0.001
Rural	2199.88	2017.51	182.38	<0.001
Motorway	2702.80	2643.57	59.22	0.003
All road types	2316.38	2247.49	68.89	<0.001

**Preliminary conclusions:**

The observed effects of ecoDriver systems on controlled roads are similar for the naturalistic data set. The greater reduction of Average rpm when shifting gear up is observed on rural roads (-182rpm), while reduction is smaller on urban conditions (-63rpm) and on motorways (-60rpm). Effects for naturalistic data are in line with the controlled ones. These not-embedded systems (ecoDriver app & TomTom system) seems to perform well in helping the driver to change gear earlier.

### 7.18.3 Results summary

Table 330: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App)
Urban	-9.35 (N.S.)	74.6	97.12	89.71	36.91 (N.S.)	62.65
Rural	190.88	143.8	196.79	150.42	13.15 (N.S.)	182.38
Motorway	65.67	65.5	67.83	-	-	59.22
All road types	112.08	105.4	129.43	140.32	18.74 (N.S.)	68.89

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App)
Urban	-0.73 (N.S.)	5.63	6.68	7.34	3.76 (N.S.)	3.85
Rural	11.44	9.97	12.23	7.43	1.35 (N.S.)	8.29
Motorway	3.19	3.42	3.32	-	-	2.19
All road types	7.09	7.14	7.9	8.03	1.92 (N.S.)	2.97

### 7.18.4 Conclusions and implications

The first golden rule of ecodriving is asking the driver to *Shift up as soon as possible*. The average rpm when shifting up is reflecting the application of this rule. A reduction of this PI is expected if ecoDriver systems succeed in generating a green driving behaviour as defined by professionals.

- Type A: The treatment condition has a global significant effect in increasing the average rpm when shifting gear up. This effect is stronger on rural roads, less salient on motorway and on urban roads. The ecoDriver systems positive impact on average rpm when shifting gear up is significant when driving on all road types.
- Type B: Compared to their baseline, the embedded systems provide significant reduction of the average rpm when shifting gear up in all road conditions. As already stated, the effect is larger for rural roads.
- Type C: Compared to its own baseline, the FeDS system present the same picture as the larger category of embedded system (FeDS is an embedded system). The main effect is significant, with a reduction of the average rpm when shifting gear up, up to 144 rpm in rural conditions.
- Type D: The ecoDriver app is significantly reducing globally the average rpm when shifting gear up. This reduction is significant for both urban and rural roads (no data for motorway with the app), with a greater impact on rural roads (-150rpm).
- Type E: Using a haptic pedal additional to an ecoDriver non-haptic system does not significantly decrease the average rpm when shifting gear up. There is no additional improvement for this PI with a haptic pedal.
- Naturalistic type A: The observed effects of ecoDriver systems on controlled roads are similar for the naturalistic data set. The greater reduction of Average rpm when shifting gear up is observed on urban areas (-182rpm), while reduction is smaller on rural conditions and for motorways. Effects for naturalistic data are in line with the controlled ones These not-

embedded systems (ecoDriver app & TomTom system) seems to perform well in helping the driver to change gear earlier.

## 7.19 Hypothesis 28: Using an ecoDriver system, the weighted average engine rpm will be decreased

### Hypothesis analysis summary table

Hypotheses formulations:

*[Golden rule of ecodriving #2: Maintain a steady speed: Use the highest gear possible and drive with low engine RPM.]*

*Using an ecoDriver system, the weighted average engine rpm will be decreased.*

1. Using an ecoDriver system, the weighted average engine rpm will be decreased. [Type A]
2. Using an embedded ecoDriver system, the weighted average engine rpm will be decreased. [Type B]
3. Using the full ecoDriver system (FeDS), the weighted average engine rpm will be decreased. [Type C]
4. Using the ecoDriver application, (App), the weighted average engine rpm will be decreased. [Type D]
5. Using a haptic ecoDriver, the weighted average engine rpm will be decreased. [Type E]

#### Performance indicator (PI):

weighted average engine rpm (index\_gear\_rpm)

#### Data reduction method:

500m sections

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment (Type A dataset)</b> For both controlled and naturalistic data	Main effect	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded (Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS (Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline App vs App</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>

## Hypothesis analysis summary table

(Type D dataset)	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Vmc_id, Driver_id
Non-haptic vs Haptic (Type E dataset)	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 7.19.1 Controlled studies

#### 7.19.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterwhaite approximation for the degrees of freedom.

Table 331: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	26110.8	26110.8	1	24814.3	392.0	<0.001
road_type	647290.8	323645.4	2	24772.3	4858.9	<0.001
Main_effect:road_type	20729.6	10364.8	2	24753.5	155.6	<0.001

Table 332: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	26.21	14.90	37.52	0.004
Treatment	-0.65	-1.05	-0.25	0.002
Rural	7.47	7.08	7.86	<0.001
Motorway	19.09	18.53	19.65	<0.001
Treatment:Rural	-4.21	-4.70	-3.72	<0.001
Treatment:Motorway	-1.23	-1.87	-0.58	<0.001
Random part	N			
Driver_id	130			
Vmc_id	6			
Number of observations	24855			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

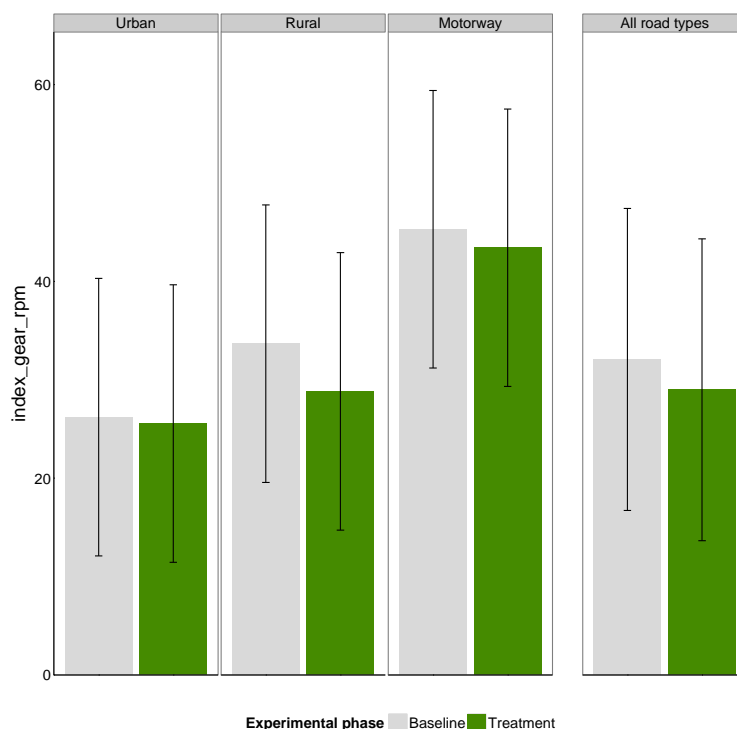


Figure 133: model based average values of index\_gear\_rpm for fixed effects.

Table 333: Weighted average engine rpm for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	26.21	25.55	0.65	0.018
Rural	33.67	28.81	4.86	<0.001
Motorway	45.30	43.42	1.88	<0.001
All road types	32.07	28.98	3.09	<0.001

#### Preliminary conclusions:

The weighted average engine rpm is a PI without unit.

The treatment condition decreases significantly the weighted average engine rpm compared to baseline. The weighted average engine rpm is significantly lower on urban roads than on rural or motorways, denoting globally lower rpm associated to low gears.

On average the systems are significantly more effective on rural roads.

## 7.19.1.2 Type B: Baseline embedded vs embedded

Table 334: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	29702.0	29702.0	1	20387.5	482.6	<0.001
road_type	534597.6	267298.8	2	20360.1	4343.1	<0.001
Main_effect:road_type	4191.8	2095.9	2	20350.5	34.1	<0.001

Table 335: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	27.63	14.65	40.62	0.008
Embedded	-2.52	-2.98	-2.06	<0.001
Rural	1.91	1.44	2.38	<0.001
Motorway	15.03	14.45	15.61	<0.001
Embedded:Rural	-1.60	-2.16	-1.04	<0.001
Embedded:Motorway	0.64	-0.03	1.30	0.061
Random part	N			
Driver_id	90			
Vmc_id	5			
Number of observations	20423			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

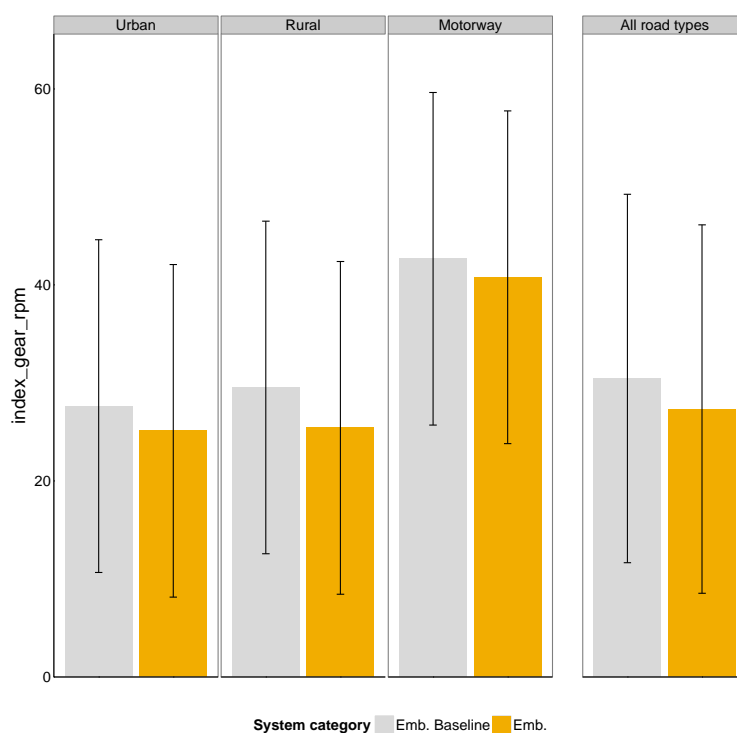


Figure 134: model based average values of index\_gear\_rpm for fixed effects.

Table 336: Weighted average engine rpm for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	27.63	25.12	2.52	<0.001
Rural	29.54	25.42	4.12	<0.001
Motorway	42.66	40.78	1.88	<0.001
All road types	30.46	27.34	3.12	<0.001

#### Preliminary conclusions:

Embedded systems also present significant positive effects (reduction of the PI, showing lower rpm) on all road types.

The effect is slightly more pronounced on rural roads. Embedded systems show better performances on urban roads compared to the average of all systems.



### 7.19.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 337: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	39662.1	39662.1	1	15302.5	752.1	<0.001
road_type	516133.2	258066.6	2	15310.0	4893.5	<0.001
Main_effect:road_type	9085.3	4542.6	2	15280.6	86.1	<0.001

Table 338: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	37.29	29.99	44.60	0.002
FeDS	-3.50	-4.01	-2.99	<0.001
Rural	3.33	2.80	3.87	<0.001
Motorway	15.18	14.59	15.77	<0.001
FeDS:Rural	-2.27	-2.90	-1.64	<0.001
FeDS:Motorway	1.55	0.87	2.24	<0.001
Random part	N			
Driver_id	58			
Vmc_id	3			
Number of observations	15327			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

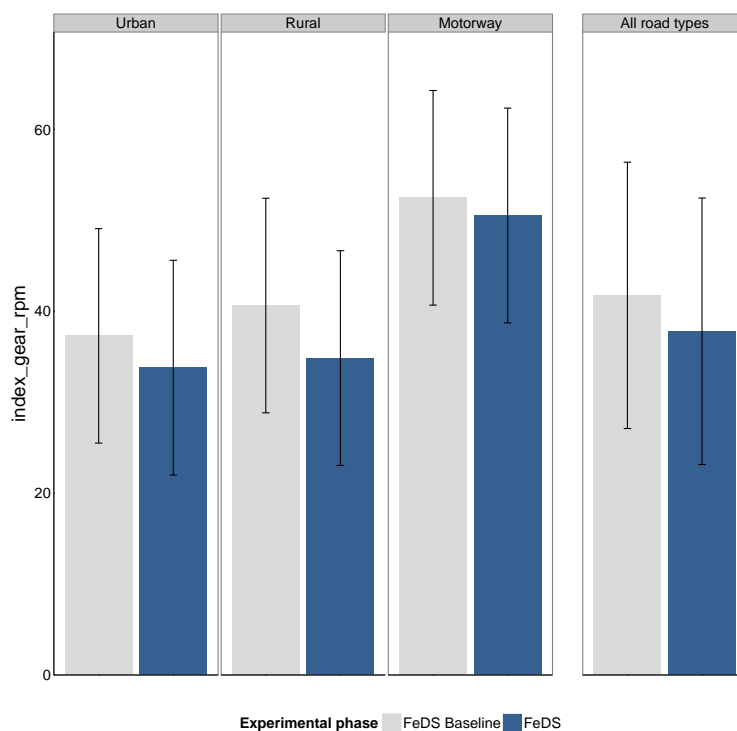


Figure 135: model based average values of index\_gear\_rpm for fixed effects.

Table 339: Weighted average engine rpm for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	37.29	33.79	3.50	<0.001
Rural	40.63	34.85	5.77	<0.001
Motorway	52.47	50.53	1.95	<0.001
All road types	41.75	37.80	3.95	<0.001

#### Preliminary conclusions:

The FeDS system show performances similar to the embedded systems in general. The global impact is significant, and it is also significant on every road types.

## 7.19.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 340: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	6517.6	6517.6	1	4431.7	133.0	<0.001
road_type	284619.4	284619.4	1	4390.2	5810.0	<0.001
Main_effect:road_type	64.1	64.1	1	4388.4	1.3	0.253

Table 341: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	30.66	29.75	31.57	<0.001
App	-2.36	-3.05	-1.67	<0.001
Rural	17.00	16.44	17.56	<0.001
App:Rural	-0.50	-1.36	0.36	0.253
Random part	N			
Driver_id	40			
Vmc_id	5			
Number of observations	4432			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

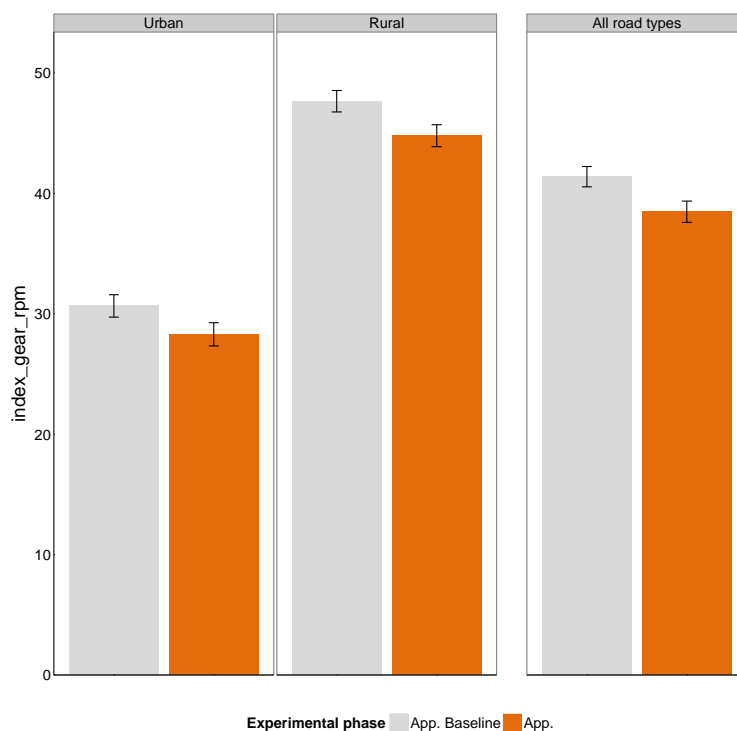


Figure 136: model based average values of index\_gear\_rpm for fixed effects.

Table 342: Weighted average engine rpm for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	30.66	28.30	2.36	<0.001
Rural	47.66	44.80	2.86	<0.001
Motorway	NA	NA	NA	NA
All road types	41.39	38.48	2.91	<0.001

#### Preliminary conclusions:

The ecoDriver App is not evaluated on motorways. The impact of the App on urban and rural road types is of similar size and significant (reduction around 2.5).

### 7.19.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 343: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.2	0.2	1	2373.0	0.0	0.971
road_type	1427.8	1427.8	1	2371.6	11.6	<0.001
Main_effect:road_type	23.1	23.1	1	2372.9	0.2	0.665

Table 344: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	25.25	23.82	26.67	<0.001
Haptic	0.25	-1.59	2.09	0.789
Rural	-1.59	-3.08	-0.10	0.037
Haptic:Rural	-0.46	-2.57	1.64	0.665
Random part	N			
Driver_id	24			
Number of observations	2394			

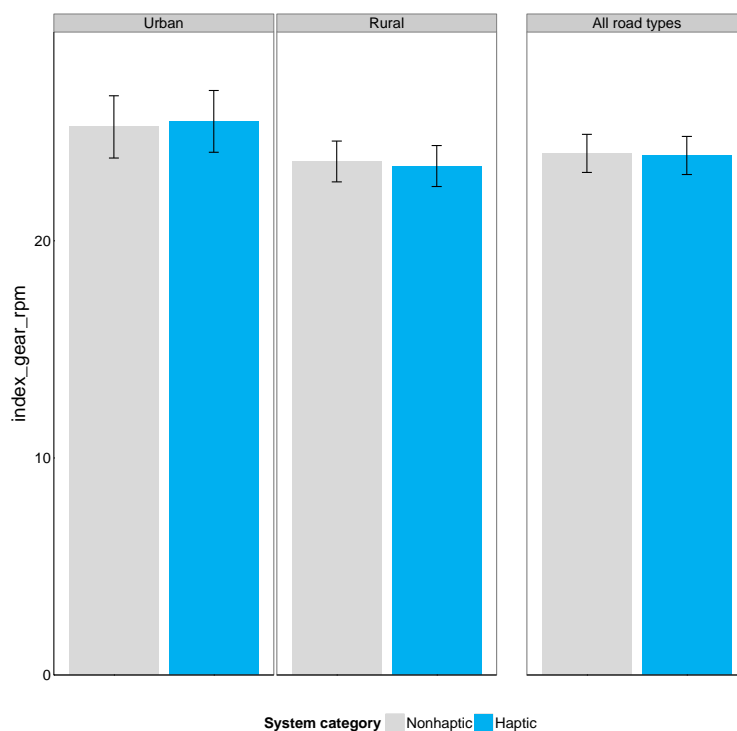


Figure 137: model based average values of index\_gear\_rpm for fixed effects.

Table 345: Weighted average engine rpm for the different systems and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	25.25	25.50	-0.25	0.993
Rural	23.66	23.44	0.21	0.976
Motorway	NA	NA	NA	NA
All road types	24.02	23.93	0.10	0.832

**Preliminary conclusions:**

The haptic versions of the systems are not providing any additional positive effects compared to not haptic ecoDriver systems.

## 7.19.2 Naturalistic studies

### 7.19.2.1 TypeA : Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 346: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	29470.8	29470.8	1	20332.0	106.8	<0.001
road_type	351271.2	175635.6	2	20331.6	636.4	<0.001
Main_effect:road_type	7379.9	3689.9	2	20329.8	13.4	<0.001

Table 347: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	35.91	18.17	53.66	0.074
Treatment	-2.56	-3.38	-1.74	<0.001
Rural	8.18	7.34	9.02	<0.001
Motorway	10.11	9.29	10.93	<0.001
Treatment:Rural	-1.45	-2.61	-0.30	0.014
Treatment:Motorway	1.53	0.42	2.64	0.007
Random part	N			
Driver_id	14			
Vmc_id	2			
Number of observations	20343			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

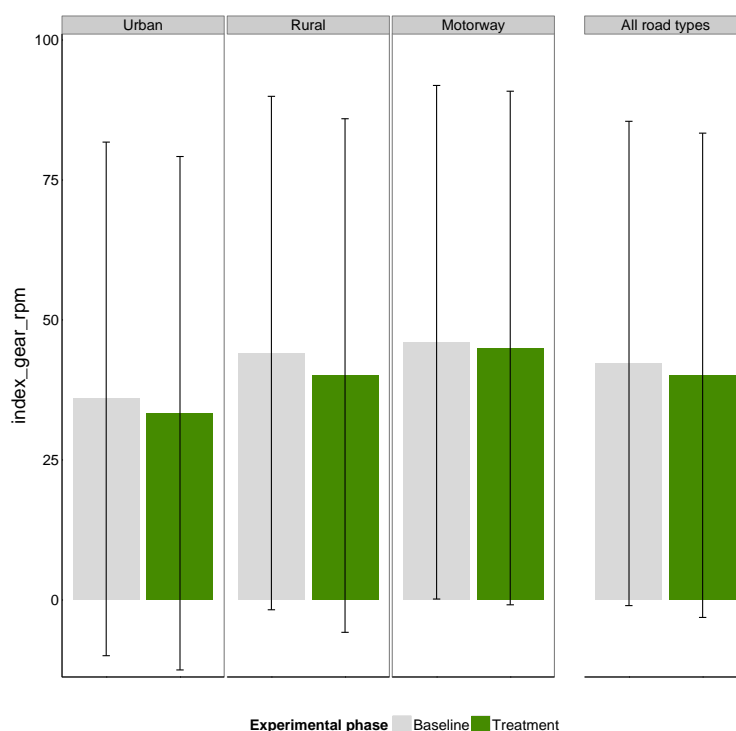


Figure 138: model based average values of index\_gear\_rpm for fixed effects.

Table 348: Weighted average engine rpm for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	35.91	33.35	2.56	<0.001
Rural	44.09	40.08	4.02	<0.001
Motorway	46.02	44.99	1.03	0.087
All road types	42.24	40.13	2.11	<0.001

#### Preliminary conclusions:

The naturalistic present more variability than others controlled datasets. Despite this, we observe significant impact of the systems. The impact is significant for both urban and rural roads, with a greater effect for urban. The impact of the systems is not significant on motorways.



### 7.19.3 Results summary

Table 349: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App)
Urban	0.65	2.52	3.5	2.36	-0.25 (N.S.)	2.56
Rural	4.86	4.12	5.77	2.86	0.21 (N.S.)	4.02
Motorway	1.88	1.88	1.95	-	-	1.03 (N.S.)
All road types	3.09	3.12	3.95	2.91	0.1 (N.S.)	2.11

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App)
Urban	2.48	9.12	9.39	7.7	-0.99 (N.S.)	7.13
Rural	14.43	13.95	14.2	6	0.89 (N.S.)	9.12
Motorway	4.15	4.41	3.72	-	-	2.24 (N.S.)
All road types	9.64	10.24	9.46	7.03	0.42 (N.S.)	5

### 7.19.4 Conclusions and implications

The second golden rule of ecodriving is asking the driver to *maintain a steady speed by the mean of using the highest gear possible and drive with low engine RPM*. This behaviour is captured using a specific PI corresponding to a weighted average of the engine rpm for each gear. The lower is this PI, the lower is the average rpm and the best eco-friendly the driving is. The weighted average engine rpm is a PI without unit.

- Type A: The treatment condition decreases significantly the weighted average engine rpm compared to baseline. The weighted average engine rpm is significantly lower on urban roads than on rural or motorways, denoting globally lower rpm associated to low gears. On average the systems are significantly more effective on rural roads.
- Type B: Embedded systems also present significant positive effects (reduction of the PI, showing lower rpm) on all road types. The effect is slightly more pronounced on rural roads. Embedded systems show better performances on urban roads compared to the average of all systems.
- Type C: The FeDS system shows performances similar to the embedded systems in general. The global impact is significant, and it is also significant on every road types.
- Type D: The ecoDriver App is not evaluated on motorways. The impact of the App on urban and rural road types is of similar size and significant (reduction around 2.5).
- Type E: The haptic versions of the systems are not providing any additional positive effects compared to not haptic ecoDriver systems.
- Naturalistic type A: The naturalistic present more variability than others controlled datasets. Despite this, we observe significant impact of the systems. The impact is significant for both urban and rural roads, with a greater effect for urban. The impact of the systems is not significant on motorways.

## 7.20 Hypothesis 29: Using an ecoDriver system, the variability of speed profiles will be reduced

### Hypothesis analysis summary table

Hypotheses formulations:

*[Golden rule of ecodriving #3: Anticipate traffic flow: Look ahead as far as possible and anticipate the surrounding traffic.]*

*Using an ecoDriver system, the variability of speed profiles (PKE) will be reduced*

1. Using an ecoDriver system, the variability of speed profiles (PKE) will be reduced. [Type A]
2. Using an embedded ecoDriver system, the variability of speed profiles (PKE) will be reduced. [Type B]
3. Using the full ecoDriver system (FeDS), the variability of speed profiles (PKE) will be reduced. [Type C]
4. Using the ecoDriver application, (App), the variability of speed profiles (PKE) will be reduced. [Type D]
5. Using a haptic ecoDriver, the variability of speed profiles (PKE) will be reduced. [Type E]

#### Performance indicator (PI):

Positive kinetic energy (positive\_kinetic\_energy). To fit statistical models hypotheses, sqrt\_positive\_kinetic\_energy is analysed instead.

#### Data reduction method:

500m sections

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.  
Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> (Type A dataset) For both controlled and naturalistic data	Main effect	<ul style="list-style-type: none"> <li>• Baseline</li> <li>• Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> (Type B dataset)	Main effect	<ul style="list-style-type: none"> <li>• Baseline_embedded</li> <li>• Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b> (Type C dataset)	Main effect	<ul style="list-style-type: none"> <li>• Baseline_FeDS</li> <li>• FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id

## Hypothesis analysis summary table

Baseline App vs App (Type D dataset)	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Vmc_id, Driver_id

### 7.20.1 Controlled studies

#### 7.20.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 350: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	1.6	1.6	1	37216.0	56.2	<0.001
road_type	68.7	34.3	2	35898.7	1203.4	<0.001
Main_effect:road_type	1.2	0.6	2	37146.0	21.8	<0.001

Table 351: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.64	0.59	0.69	<0.001
Treatment	-0.04	-0.04	-0.03	<0.001
Rural	-0.06	-0.07	-0.05	<0.001
Motorway	-0.18	-0.19	-0.17	<0.001
Treatment:Rural	0.02	0.01	0.03	<0.001
Treatment:Motorway	0.04	0.02	0.05	<0.001
Random part	N			
Driver_id	143			
Vmc_id	7			
Number of observations	37225			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

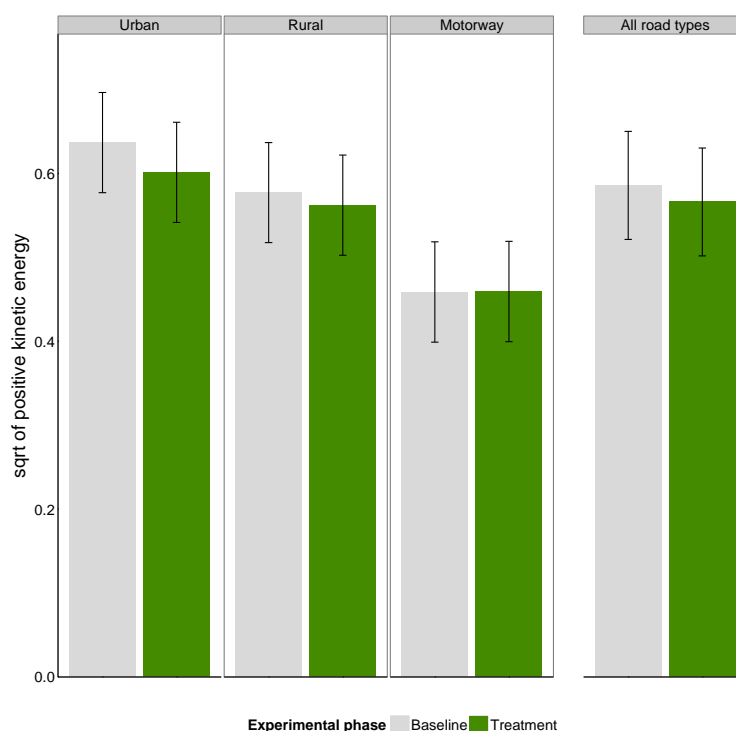


Figure 139: model based average values of sqrt\_positive\_kinetic\_energy for fixed effects.

Table 352: Square root of Positive kinetic energy for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	0.64	0.60	0.04	<0.001
Rural	0.58	0.56	0.01	<0.001
Motorway	0.46	0.46	0.00	1.000
All road types	0.59	0.57	0.02	<0.001

#### Preliminary conclusions:

The positive kinetic energy (PKE) (or its square root) is an indicator which is highly correlated with fuel consumption, and represent the variability of the speed profiles.

The ecoDriver systems are globally reducing the PKE which is the sign of smoother speed profiles. This reduction is higher on urban areas than on urban. There is no significant change for motorway conditions.

### 7.20.1.2 Type B: Baseline embedded vs embedded

Table 353: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	1.7	1.7	1	32786.4	58.5	<0.001
road_type	57.7	28.8	2	31652.1	1000.6	<0.001
Main_effect:road_type	0.8	0.4	2	32738.9	13.6	<0.001

Table 354: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.62	0.57	0.68	<0.001
Embedded	-0.02	-0.03	-0.02	<0.001
Rural	-0.02	-0.03	-0.01	<0.001
Motorway	-0.16	-0.17	-0.15	<0.001
Embedded:Rural	-0.01	-0.01	0.00	0.271
Embedded:Motorway	0.02	0.01	0.04	<0.001
Random part	N			
Driver_id	103			
Vmc_id	6			
Number of observations	32793			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

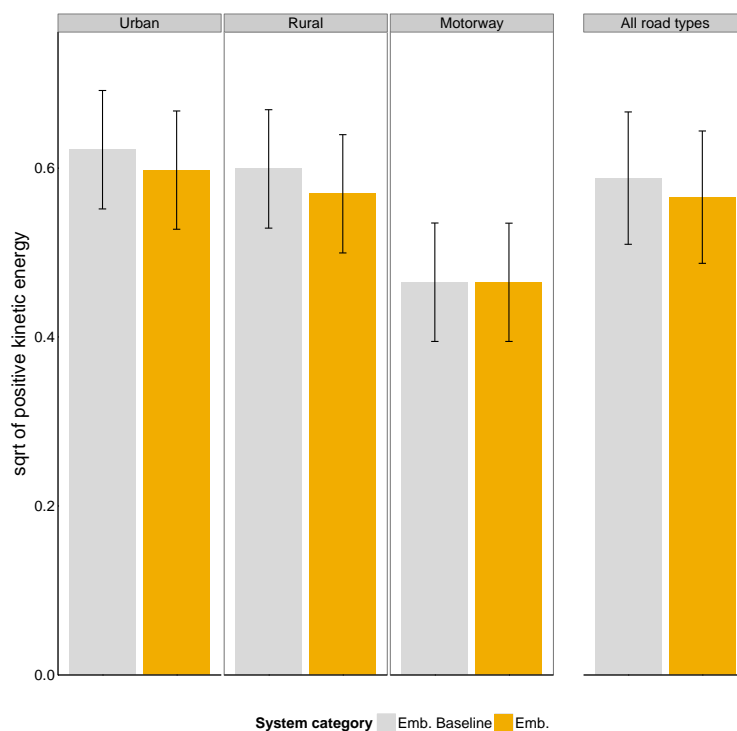


Figure 140: model based average values of sqrt\_positive\_kinetic\_energy for fixed effects.

Table 355: Positive kinetic energy for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	0.62	0.60	0.02	<0.001
Rural	0.60	0.57	0.03	<0.001
Motorway	0.46	0.46	0.00	1.000
All road types	0.59	0.57	0.02	<0.001

#### Preliminary conclusions:

Embedded systems present the same picture than the overall baseline vs treatment comparison. There is a global significant decrease, due to urban and rural conditions, while there is no effect on motorways.

### 7.20.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 356: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.4	0.4	1	16538.3	18.3	<0.001
road_type	58.2	29.1	2	16322.3	1226.3	<0.001
Main_effect:road_type	0.2	0.1	2	16504.7	3.6	0.028

Table 357: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.63	0.59	0.66	<0.001
FeDS	-0.02	-0.03	-0.01	<0.001
Rural	-0.06	-0.07	-0.05	<0.001
Motorway	-0.19	-0.20	-0.18	<0.001
FeDS:Rural	0.00	-0.01	0.01	0.803
FeDS:Motorway	0.02	0.00	0.03	0.021
Random part	N			
Driver_id	59			
Vmc_id	3			
Number of observations	16548			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

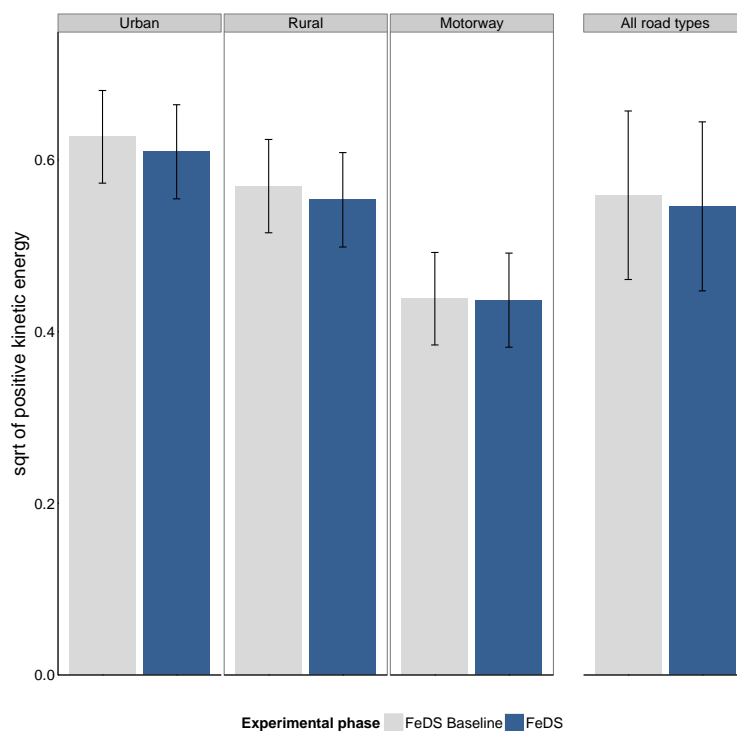


Figure 141: model based average values of sqrt\_positive\_kinetic\_energy for fixed effects.

Table 358: Square root of Positive kinetic energy for the different levels of the main effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	0.63	0.61	0.02	0.008
Rural	0.57	0.55	0.02	0.001
Motorway	0.44	0.44	0.00	0.999
All road types	0.56	0.55	0.01	<0.001

#### Preliminary conclusions:

The FeDS system, which is part of the embedded systems, present the same pattern. The decrease in PKE is a bit smaller than for the average of the embedded systems, but still significant. There is no impact on motorways.



## 7.20.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 359: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.0	0.0	1	4362.5	1.9	0.163
road_type	22.3	22.3	1	4400.6	947.8	<0.001
Main_effect:road_type	0.0	0.0	1	4400.0	1.8	0.184

Table 360: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.69	0.65	0.73	<0.001
App	-0.01	-0.03	0.00	0.084
Rural	-0.15	-0.17	-0.14	<0.001
App:Rural	0.01	-0.01	0.03	0.184
Random part	N			
Driver_id	40			
Vmc_id	2			
Number of observations	4432			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

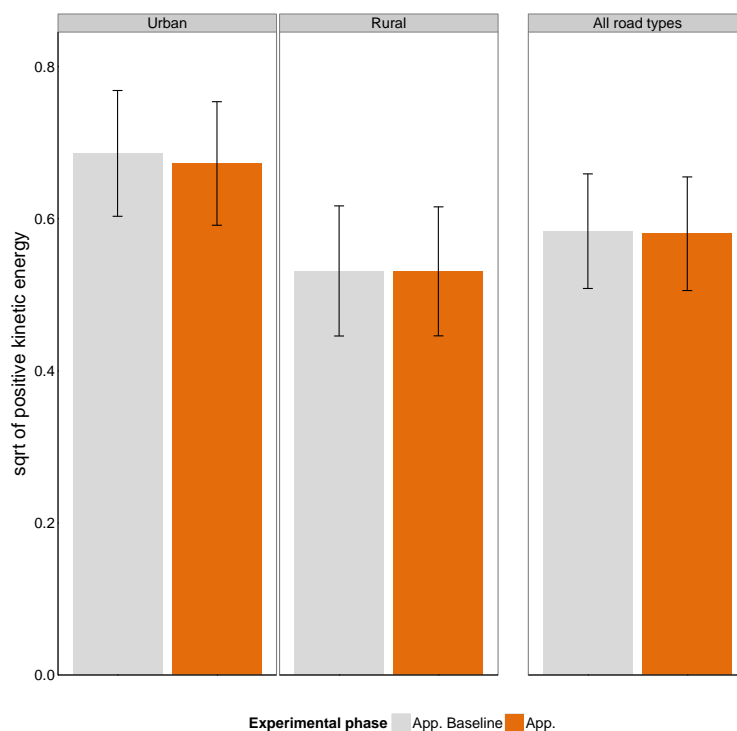


Figure 142: model based average values of sqrt\_positive\_kinetic\_energy for fixed effects.

Table 361: Positive kinetic energy for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	0.69	0.67	0.01	0.305
Rural	0.53	0.53	0.00	1.000
Motorway	NA	NA	NA	NA
All road types	0.58	0.58	0.00	0.524

#### Preliminary conclusions:

The ecoDriver App does not present significant differences in PKE from baseline. This is likely due to the absence of advice about instant green speed in the App.

### 7.20.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 362: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.0	0.0	1	5465.5	2.0	0.162
road_type	0.2	0.2	1	5463.0	8.2	0.004
Main_effect:road_type	0.0	0.0	1	5451.4	0.8	0.367

Table 363: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.66	0.63	0.70	<0.001
Haptic	0.00	-0.02	0.01	0.728
Rural	-0.01	-0.02	0.01	0.225
Haptic:Rural	-0.01	-0.02	0.01	0.367
Random part	N			
Driver_id	36			
Vmc_id	2			
Number of observations	5487			

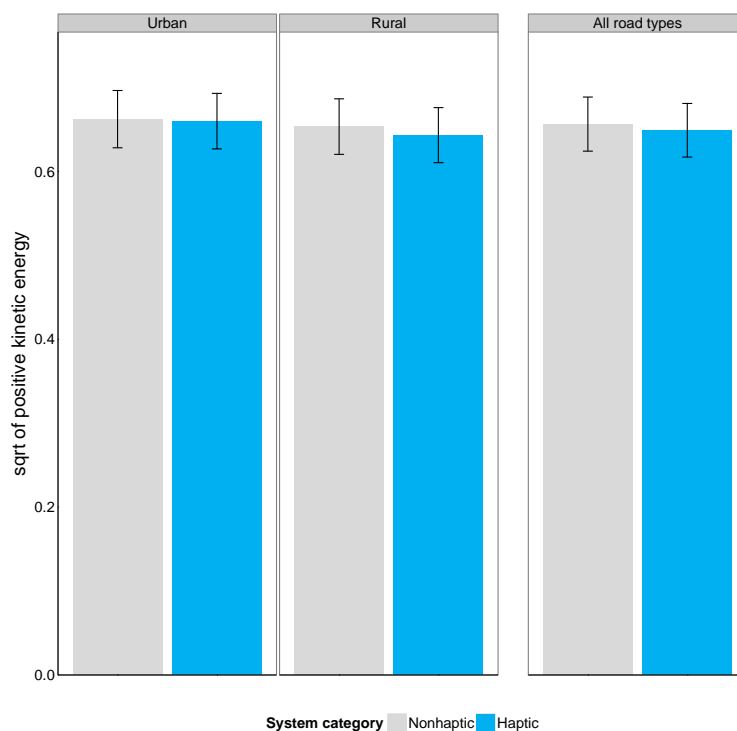


Figure 143: model based average values of sqrt\_positive\_kinetic\_energy for fixed effects.

Table 364: Positive kinetic energy for the different systems and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	0.66	0.66	0.00	0.985
Rural	0.65	0.64	0.01	0.225
Motorway	NA	NA	NA	NA
All road types	0.66	0.65	0.01	0.092

**Preliminary conclusions:**

The haptic version of the systems does not present significant differences in PKE with the non-haptic systems.

## 7.20.2 Naturalistic studies

### 7.20.2.1 TypeA : Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 365: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.1	0.1	1	27624.8	4.5	0.034
road_type	35.2	17.6	2	27623.8	742.1	<0.001
Main_effect:road_type	0.0	0.0	2	27629.9	0.5	0.616

Table 366: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.64	0.61	0.67	<0.001
Treatment	-0.01	-0.01	0.00	0.052
Rural	-0.07	-0.08	-0.06	<0.001
Motorway	-0.10	-0.10	-0.09	<0.001
Treatment:Rural	0.00	-0.01	0.01	0.419
Treatment:Motorway	0.00	0.00	0.01	0.362
Random part	N			
Driver_id	20			
Vmc_id	2			
Number of observations	27639			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

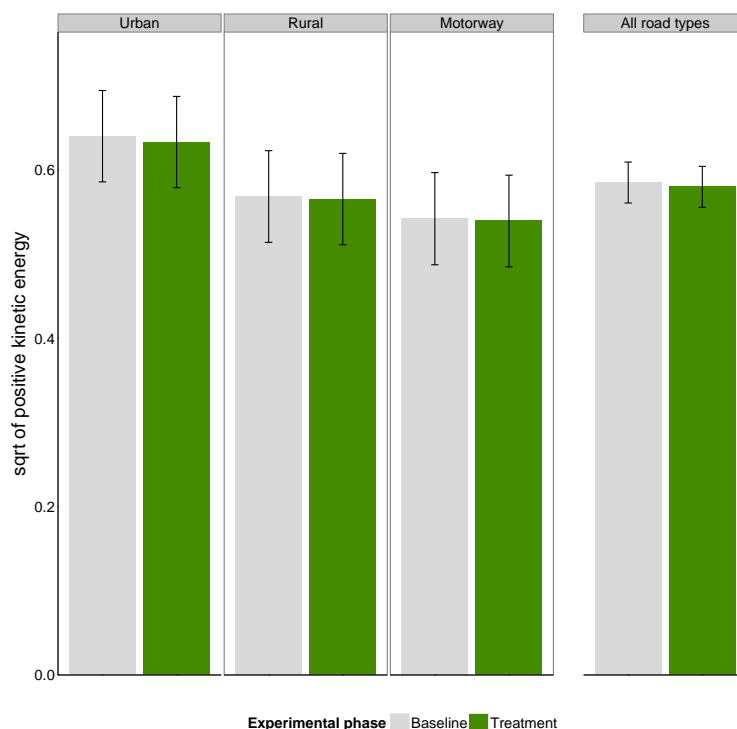


Figure 144: model based average values of sqrt\_positive\_kinetic\_energy for fixed effects.

Table 367: Positive kinetic energy for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	0.64	0.63	0.01	0.373
Rural	0.57	0.57	0.00	0.946
Motorway	0.54	0.54	0.00	0.951
All road types	0.59	0.58	0.01	0.010

#### Preliminary conclusions:

For the naturalistic data set, the global picture is quite different. The global effect of systems is not significant for any road type.

### 7.20.3 Results summary

Table 368: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App)
Urban	0.04	0.02	0.02	0.01 (N.S.)	0 (N.S.)	0.01 (N.S.)
Rural	0.01	0.03	0.02	0 (N.S.)	0.01 (N.S.)	0 (N.S.)
Motorway	0 (N.S.)	0 (N.S.)	0 (N.S.)	-	-	0 (N.S.)
All road types	0.02	0.02	0.01	0 (N.S.)	0.01 (N.S.)	0.01

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App)
Urban	6.25	3.23	3.17	1.45 (N.S.)	0 (N.S.)	1.56 (N.S.)
Rural	1.72	5	3.51	0 (N.S.)	1.54 (N.S.)	0 (N.S.)
Motorway	0 (N.S.)	0 (N.S.)	0 (N.S.)	-	-	0 (N.S.)
All road types	3.39	3.39	1.79	0 (N.S.)	1.52 (N.S.)	1.69

### 7.20.4 Conclusions and implications

The third rule of ecodriving is asking to *anticipate traffic flow by looking ahead as far as possible and anticipate the surrounding traffic*. As anticipating while driving induces smoother speed profiles, we chose to monitor the changes due to the application of this rule by the positive kinetic energy (PKE). The lower is the PKE, the smoother is the speed profile. This PI is highly correlated with fuel consumption.

- Type A: The ecoDriver systems are globally reducing the PKE which is the sign of smoother speed profiles. This reduction is higher on urban areas than on urban. There is no significant change for motorway conditions.
- Type B: Embedded systems present the same picture than the overall baseline vs treatment comparison. There is a global significant decrease, due to urban and rural conditions, while there is no effect on motorways.
- Type C: The FeDS system, which is part of the embedded systems, present the same pattern. The decrease in PKE is a bit smaller than for the average of the embedded systems, but still significant. There is no impact on motorways.
- Type D: The ecoDriver App does not present significant differences in PKE from baseline. This is likely due to the absence of advice about instant green speed in the App.
- Type E: The haptic version of the systems does not present significant differences in PKE with the non-haptic systems.
- Naturalistic type A: For the naturalistic data set, the global picture is quite different. The global effect of systems is significant for each road type, but not in the same direction. The effect is negative (increase of the PKE) on every road types.

## 7.21 Hypothesis 30: Using an ecoDriver system, the driving time with engine brake will increase

### Hypothesis analysis summary table

Hypotheses formulations:

*[Golden rule of ecodriving #4: When you have to slow down or to stop, decelerate smoothly by releasing the accelerator in time, leaving the car in gear.]*

*Using an ecoDriver system, the driving time with engine brake will increase*

1. Using an ecoDriver system, the driving time with engine brake will increase. [Type A]
2. Using an embedded ecoDriver system, the driving time with engine brake will increase. [Type B]
3. Using the full ecoDriver system (FeDS), the driving time with engine brake will increase. [Type C]
4. Using the ecoDriver application, (App), the driving time with engine brake will increase. [Type D]
5. Using a haptic ecoDriver, the driving time with engine brake will increase. [Type E]

#### Performance indicator (PI):

Percentage of driving time with engine brake (time\_engine\_brake\_ratio).

To fit statistical models hypotheses, sqrt\_time\_engine\_brake\_ratio is analysed instead.

#### Data reduction method:

500m sections

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> <b>(Type A dataset)</b> <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> <b>(Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b> <b>(Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline App vs App</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>



## Hypothesis analysis summary table

(Type D dataset)	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Vmc_id, Driver_id
Non-haptic vs Haptic (Type E dataset)	Main effect	<ul style="list-style-type: none"> <li>• Non-haptic</li> <li>• Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 7.21.1 Controlled studies

#### 7.21.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 369: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	9.6	9.6	1	19467.0	2.1	0.152
road_type	822.5	411.3	2	16310.1	88.1	<0.001
Main_effect:road_type	152.3	76.1	2	19479.9	16.3	<0.001

Table 370: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	5.19	4.86	5.52	<0.001
Treatment	-0.15	-0.26	-0.04	0.008
Rural	-0.32	-0.43	-0.21	<0.001
Motorway	-0.95	-1.14	-0.75	<0.001
Treatment:Rural	0.40	0.26	0.54	<0.001
Treatment:Motorway	0.23	0.00	0.46	0.046
Random part	N			
Driver_id	123			
Vmc_id	5			
Number of observations	19542			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

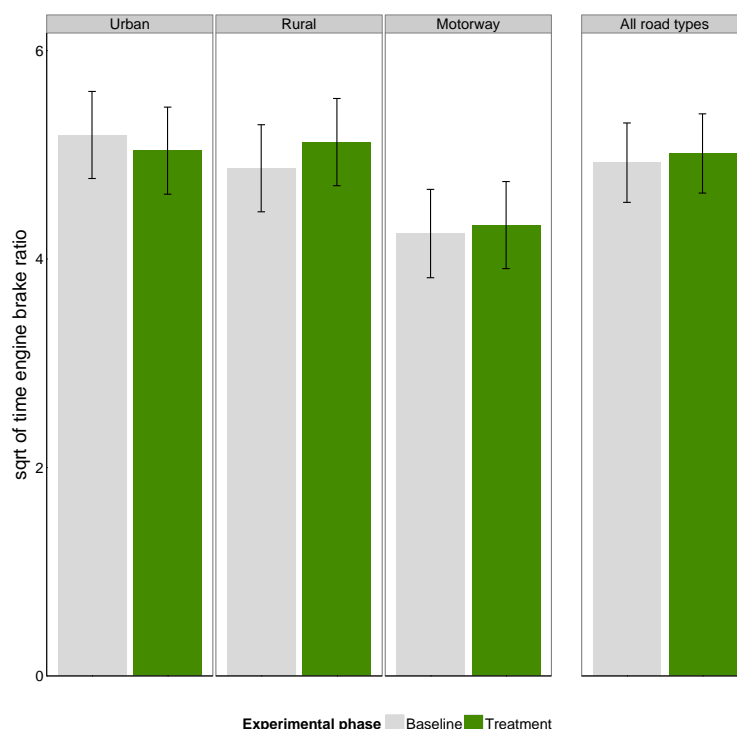


Figure 145: model based average values of sqrt\_time\_engine\_brake\_ratio for fixed effects.

Table 371: Square root of the percentage of driving time with engine brake for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	5.19	5.04	0.15	0.077
Rural	4.87	5.12	-0.25	<0.001
Motorway	4.24	4.33	-0.08	0.965
All road types	4.92	5.01	-0.09	0.009

#### Preliminary conclusions:

This PI reflect the usage of the engine brake: The greater it is, the more ecodriving compliant are the systems. The global significance of the main effect is due only to rural roads, which show a significant increase in percentage of driving time with engine brake. Both urban and motorways does not present any significant effect.

#### 7.21.1.2 Type B: Baseline embedded vs embedded

Table 372: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	13.4	13.4	1	15486.6	2.7	0.101
road_type	1363.8	681.9	2	11742.8	136.6	<0.001
Main_effect:road_type	0.9	0.5	2	15851.0	0.1	0.911

Table 373: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	4.99	4.66	5.32	<0.001
Embedded	0.05	-0.09	0.19	0.482
Rural	0.43	0.29	0.57	<0.001
Motorway	-0.53	-0.74	-0.32	<0.001
Embedded:Rural	0.03	-0.14	0.20	0.721
Embedded:Motorway	0.05	-0.20	0.29	0.705
Random part	N			
Driver_id	83			
Vmc_id	4			
Number of observations	15874			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

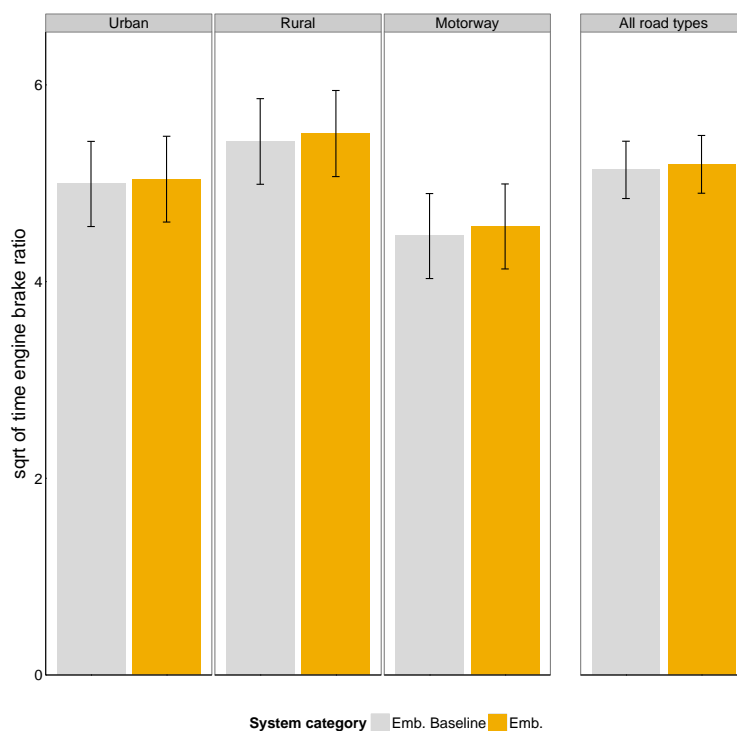


Figure 146: model based average values of sqrt\_time\_engine\_brake\_ratio for fixed effects.

Table 374: Square root of the percentage of driving time with engine brake for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	4.99	5.04	-0.05	0.980
Rural	5.42	5.50	-0.08	0.604
Motorway	4.46	4.56	-0.10	0.937
All road types	5.14	5.19	-0.06	0.155

#### Preliminary conclusions:

Compared to their baselines, the embedded systems category provide significant and positive changes only for rural roads.

### 7.21.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 375: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	56.1	56.1	1	12153.5	13.7	<0.001
road_type	1145.1	572.5	2	9224.3	140.2	<0.001
Main_effect:road_type	19.2	9.6	2	12243.1	2.4	0.095

Table 376: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	5.12	4.93	5.30	<0.001
FeDS	0.11	-0.02	0.25	0.106
Rural	0.37	0.22	0.52	<0.001
Motorway	-0.45	-0.65	-0.25	<0.001
FeDS:Rural	0.17	-0.01	0.34	0.062
FeDS:Motorway	-0.01	-0.24	0.22	0.916
Random part	N			
Driver_id	59			
Vmc_id	3			
Number of observations	12266			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

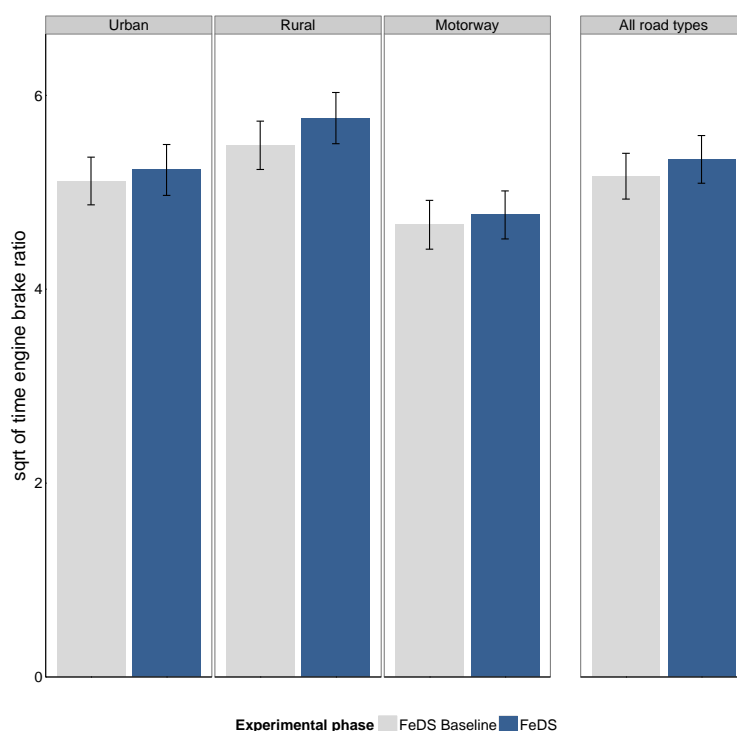


Figure 147: model based average values of sqrt\_time\_engine\_brake\_ratio for fixed effects.

Table 377: Square root of the percentage of driving time with engine brake for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	5.12	5.23	-0.11	0.575
Rural	5.48	5.76	-0.28	<0.001
Motorway	4.66	4.77	-0.10	0.891
All road types	5.17	5.34	-0.17	<0.001

#### Preliminary conclusions:

As a part of the embedded systems, the FeDS provide the same picture: A significant and positive effect on rural roads, and no effect on other road types.

## 7.21.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 378: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	22.4	22.4	1	3645.6	9.0	0.003
road_type	2194.3	2194.3	1	3649.3	886.2	<0.001
Main_effect:road_type	3.2	3.2	1	3637.9	1.3	0.259

Table 379: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	5.10	4.81	5.39	0.001
App	0.10	-0.05	0.26	0.188
Rural	-1.65	-1.78	-1.51	<0.001
App:Rural	0.12	-0.09	0.33	0.259
Random part	N			
Driver_id	40			
Speed_limit	2			
Number of observations	3668			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

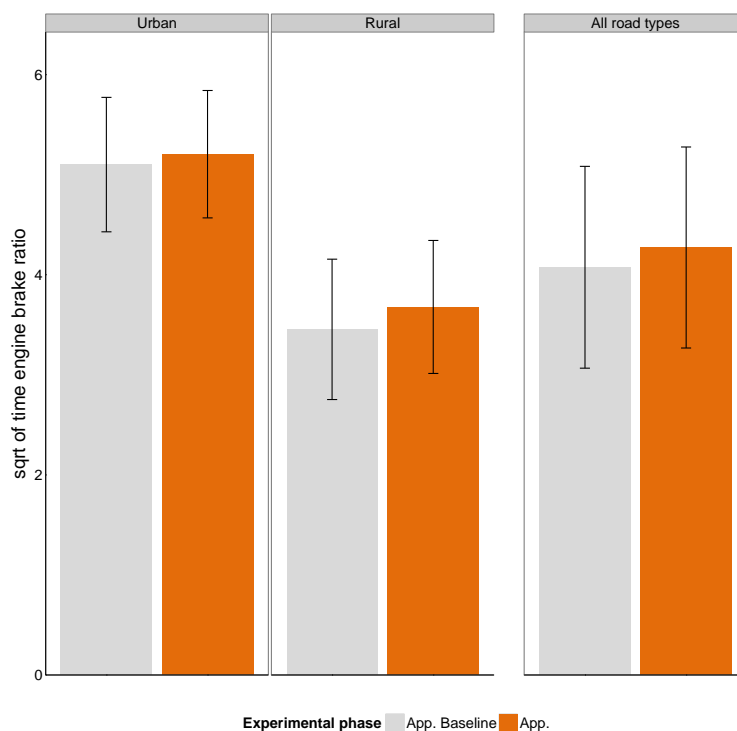


Figure 148: model based average values of sqrt\_time\_engine\_brake\_ratio for fixed effects.

Table 380: Square root of the percentage of driving time with engine brake for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	5.10	5.21	-0.10	0.552
Rural	3.45	3.68	-0.22	0.012
Motorway	NA	NA	NA	NA
All road types	4.08	4.27	-0.20	0.001

#### Preliminary conclusions:

The ecoDriver App (no data on motorways) is also presenting a positive and significant change for rural roads. There is no effect on urban roads.



## 7.21.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 381: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	18.3	18.3	1	2377.1	2.2	0.135
road_type	56.6	56.6	1	2374.1	6.9	0.009
Main_effect:road_type	2.3	2.3	1	2377.0	0.3	0.595

Table 382: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	4.55	4.21	4.89	<0.001
Haptic	-0.13	-0.61	0.34	0.582
Rural	0.44	0.05	0.82	0.026
Haptic:Rural	-0.15	-0.69	0.39	0.595
Random part	N			
Driver_id	24			
Number of observations	2394			

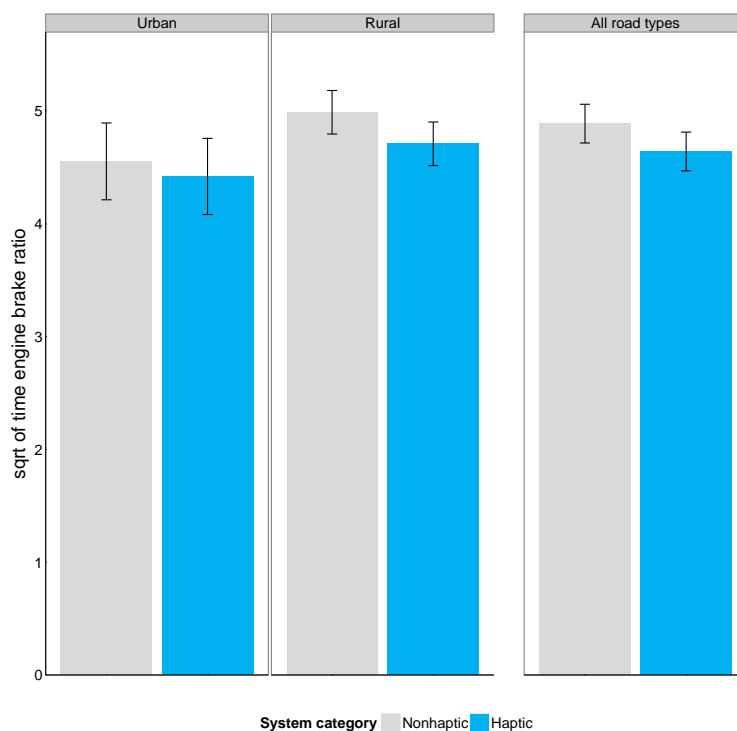


Figure 149: model based average values of sqrt\_time\_engine\_brake\_ratio for fixed effects.

Table 383: Square root of the percentage of driving time with engine brake for the different systems and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	4.55	4.42	0.13	0.945
Rural	4.99	4.71	0.28	0.150
Motorway	NA	NA	NA	NA
All road types	4.89	4.64	0.25	0.035

**Preliminary conclusions:**

The main effect is not globally significant, and so, no significant change is observed across road types when changing from an ecoDriver non-haptic system, to an ecoDriver haptic one.

## 7.21.2 Naturalistic studies

### 7.21.2.1 Type A : Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 384: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	4.3	4.3	1	11239.8	0.8	0.381
road_type	521.8	260.9	2	11238.2	47.1	<0.001
Main_effect:road_type	78.0	39.0	2	11232.2	7.0	<0.001

Table 385: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	5.66	4.91	6.40	<0.001
Treatment	-0.04	-0.17	0.09	0.538
Rural	-0.56	-0.72	-0.41	<0.001
Motorway	0.27	0.10	0.43	0.001
Treatment:Rural	0.23	0.02	0.44	0.030
Treatment:Motorway	-0.24	-0.46	-0.02	0.031
Random part	N			
Driver_id	11			
Vmc_id	2			
Number of observations	11241			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

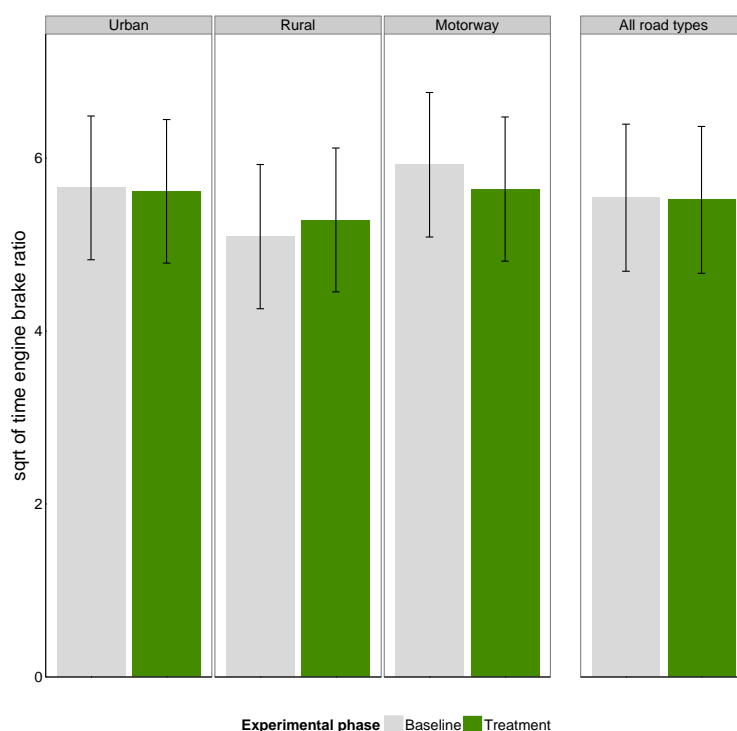


Figure 150: model based average values of sqrt\_time\_engine\_brake\_ratio for fixed effects.

Table 386: Percentage of driving time with engine brake for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	5.66	5.62	0.04	0.990
Rural	5.09	5.28	-0.19	0.239
Motorway	5.92	5.64	0.28	0.026
All road types	5.54	5.52	0.03	0.589

#### Preliminary conclusions:

On average, the main effect is slightly significant, but when looking into the details, there is no real effect on any road types. A small negative effect (reduction of percentage of driving time with engine brake) is observed on motorways without sufficient significance. The changes are mainly due to road conditions.

### 7.21.3 Results summary

Table 387: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App)
Urban	0.15 (N.S.)	-0.05 (N.S.)	-0.11 (N.S.)	-0.1 (N.S.)	0.13 (N.S.)	0.04 (N.S.)
Rural	-0.25	-0.08 (N.S.)	-0.28	-0.22	0.28 (N.S.)	-0.19 (N.S.)
Motorway	-0.08 (N.S.)	-0.1 (N.S.)	-0.1 (N.S.)	-	-	0.28
All road types	-0.09	-0.06 (N.S.)	-0.17	-0.2	0.25	0.03 (N.S.)

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App)
Urban	2.89 (N.S.)	-1 (N.S.)	-2.15 (N.S.)	-1.96 (N.S.)	2.86 (N.S.)	0.71 (N.S.)
Rural	-5.13	-1.48 (N.S.)	-5.11	-6.38	5.61 (N.S.)	-3.73 (N.S.)
Motorway	-1.89 (N.S.)	-2.24 (N.S.)	-2.15 (N.S.)	-	-	4.73
All road types	-1.83	-1.17 (N.S.)	-3.29	-4.9	5.11	0.54 (N.S.)

### 7.21.4 Conclusions and implications

The fourth golden rule is asking to *decelerate smoothly by releasing the accelerator in time, leaving the car in gear*. This behaviour is captured by the percentage of driving time with engine brake. This PI needs to increase for a more ecodriently way to drive.

- Type A: The global significance of the main effect is due only to rural roads, which show a significant increase in percentage of driving time with engine brake. Both urban and motorways does not present any significant effect.
- Type B: Compared to their baselines, the embedded systems category provide significant and positive changes only for rural roads.
- Type C: As a part of the embedded systems, the FeDS provide the same picture: A significant and positive effect on rural roads, and no effect on other road types.
- Type D: The ecoDriver App (no data on motorways) is also presenting a positive and significant change for rural roads. There is no effect on urban roads.
- Type E: The main effect is not globally significant, and so, no significant change is observed across road types when changing from an ecoDriver non-haptic system, to an ecoDriver haptic one.
- Naturalistic type A: On average, the main effect is slightly significant, but when looking into the details, there is no real effect on any road types. A small negative effect (reduction of percentage of driving time with engine brake) is observed on motorways without sufficient significance. The changes are mainly due to road conditions.

## 7.22 Hypothesis 31: Using an ecoDriver system, the 95th percentile positive acceleration will be lowered

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, the 95th percentile positive acceleration will be lowered*

1. Using an ecoDriver system, the 95th percentile positive acceleration will be lowered. [Type A]
2. Using an embedded ecoDriver system, the 95th percentile positive acceleration will be lowered. [Type B]
3. Using the full ecoDriver system (FeDS), the 95th percentile positive acceleration will be lowered. [Type C]
4. Using the ecoDriver application, (App), the 95th percentile positive acceleration will be lowered. [Type D]
5. Using a haptic ecoDriver, the 95th percentile positive acceleration will be lowered. [Type E]

#### Performance indicator (PI):

95th percentile positive acceleration (percentile\_acc\_95)

#### Data reduction method:

500m sections

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.  
Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> <b>(Type A dataset)</b> <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline</li> <li>• Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> <b>(Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_embedded</li> <li>• Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b> <b>(Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_FeDS</li> <li>• FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline App vs App</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_App</li> <li>• App</li> </ul>

## Hypothesis analysis summary table

(Type D dataset)	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
Non-haptic vs Haptic (Type E dataset)	Main effect	<ul style="list-style-type: none"> <li>• Non-haptic</li> <li>• Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 7.22.1 Controlled studies

#### 7.22.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 388: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	13.7	13.7	1	36838.0	78.6	<0.001
road_type	1208.8	604.4	2	36793.3	3464.4	<0.001
Main_effect:road_type	20.4	10.2	2	36769.1	58.5	<0.001

Table 389: Model summary for type A comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.95	0.85	1.05	<0.001
Treatment	-0.13	-0.14	-0.11	<0.001
Rural	-0.39	-0.41	-0.37	<0.001
Motorway	-0.70	-0.73	-0.68	<0.001
Treatment:Rural	0.10	0.08	0.12	<0.001
Treatment:Motorway	0.13	0.10	0.16	<0.001
Random part	N			
Driver_id	143			
Vmc_id	7			
Number of observations	37225			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

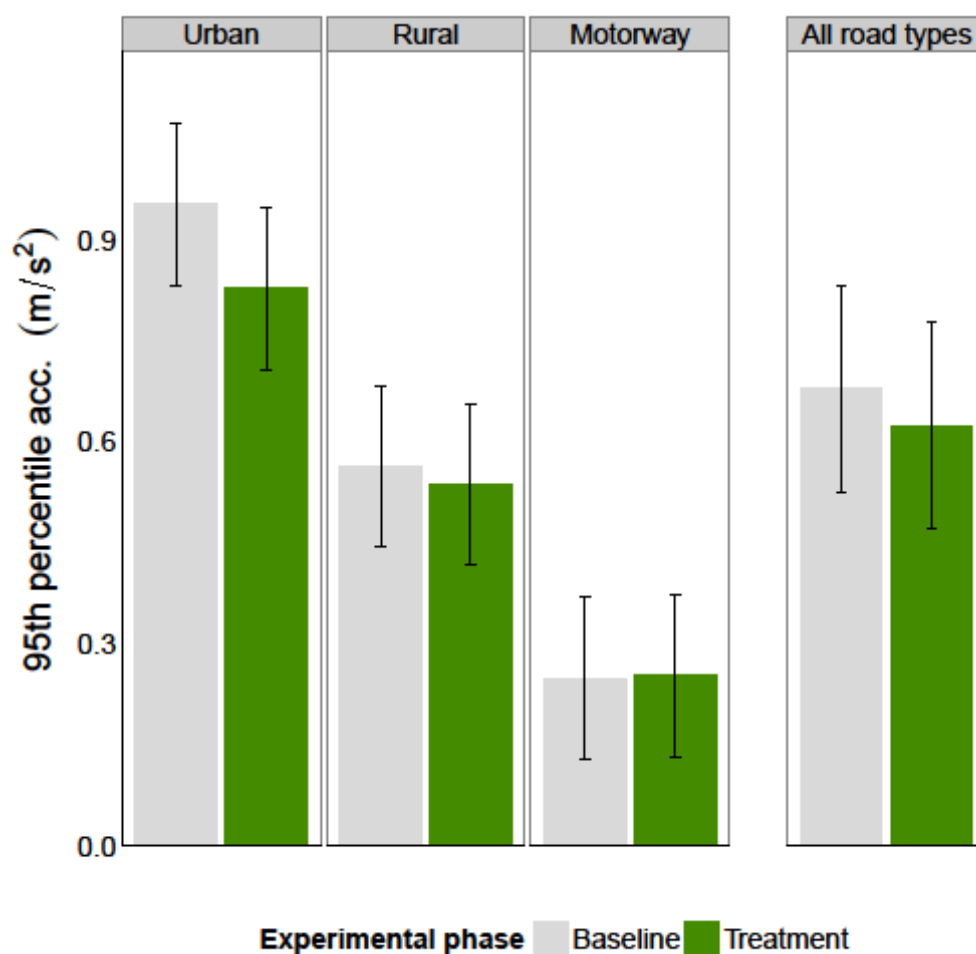


Figure 151: model based average values of 95th percentile positive acceleration for fixed effects.

Table 390: 95th percentile positive acceleration for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates			Tukey multiple comparisons significance test
	Baseline	Treatment	Difference (B-T)	
Urban	0.95	0.83	0.13	<0.001
Rural	0.56	0.54	0.03	0.003
Motorway	0.25	0.25	0.00	1.000
All roads	0.68	0.62	0.05	<0.001

#### Preliminary conclusions:

In Urban and Rural setting, the EcoDriver system significantly reduces 95<sup>th</sup> percentile acceleration. When driving on motorways, acceleration and deceleration is of a smaller magnitude due to vehicle dynamics and traffic conditions, and acceleration is likely more dependent on other vehicles in traffic rather than volitional deceleration.



## 7.22.1.2 Type B: Baseline embedded vs embedded

Table 391: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	13.1	13.1	1	32467.6	77.8	<0.001
road_type	781.9	390.9	2	32221.1	2314.2	<0.001
Main_effect:road_type	5.9	2.9	2	32415.0	17.4	<0.001

Table 392: Model summary for type B comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.83	0.71	0.95	<0.001
Embedded	-0.07	-0.09	-0.05	<0.001
Rural	-0.23	-0.25	-0.21	<0.001
Motorway	-0.60	-0.63	-0.57	<0.001
Embedded:Rural	-0.01	-0.03	0.01	0.437
Embedded:Motorway	0.07	0.04	0.10	<0.001
Random part	N			
Driver_id	103			
Vmc_id	6			
Number of observations	32793			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

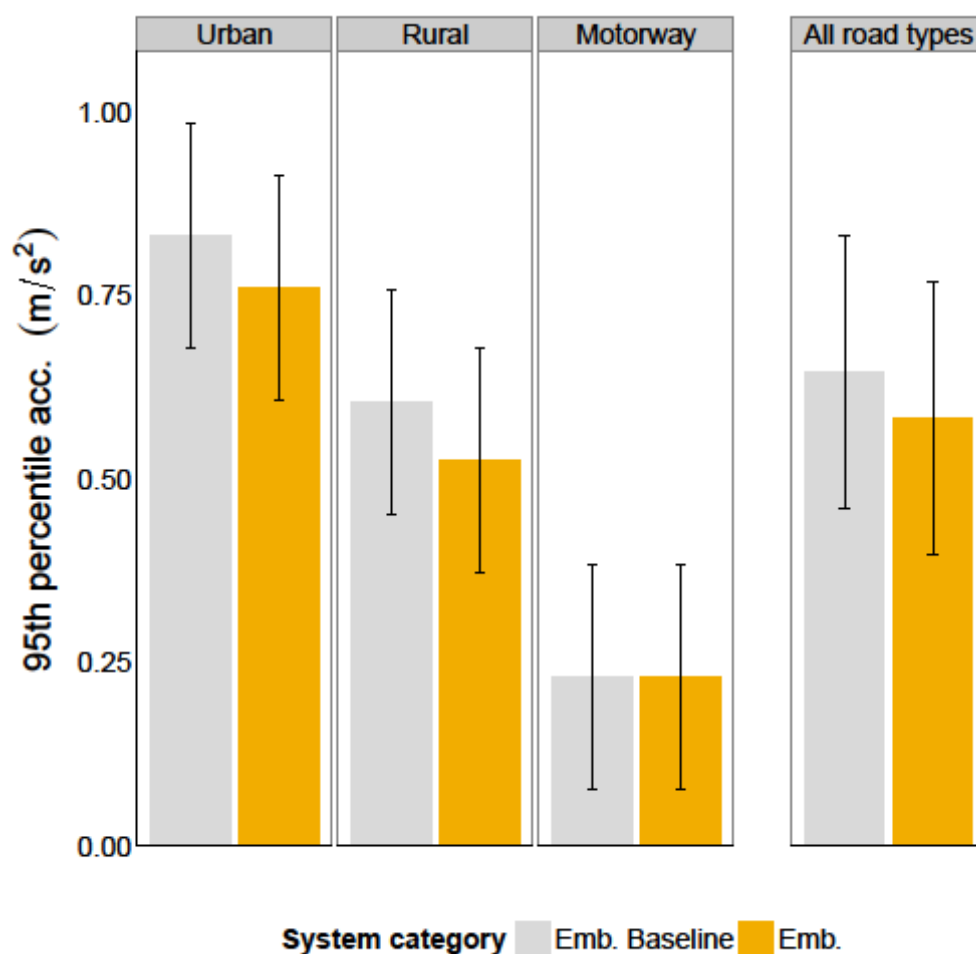


Figure 152: model based average values of 95th percentile positive acceleration for fixed effects.

Table 393: 95th percentile positive acceleration for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	0.83	0.76	0.07	<0.001
Rural	0.61	0.53	0.08	<0.001
Motorway	0.23	0.23	0.00	1.000
All roads	0.65	0.58	0.06	<0.001

**Preliminary conclusions:**

The embedded EcoDriver systems significantly reduce 95<sup>th</sup> percentile acceleration on urban and rural roads.

## 7.22.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 394: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	4.1	4.1	1	16363.6	25.7	<0.001
road_type	714.9	357.4	2	16343.5	2242.2	<0.001
Main_effect:road_type	1.0	0.5	2	16339.9	3.1	0.044

Table 395: Model summary for type C comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.90	0.77	1.03	<0.001
FeDS	-0.05	-0.07	-0.02	<0.001
Rural	-0.32	-0.35	-0.29	<0.001
Motorway	-0.70	-0.73	-0.66	<0.001
FeDS:Rural	0.00	-0.04	0.03	0.891
FeDS:Motorway	0.03	0.00	0.07	0.051
Random part	N			
Driver_id	59			
Vmc_id	3			
Number of observations	16548			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

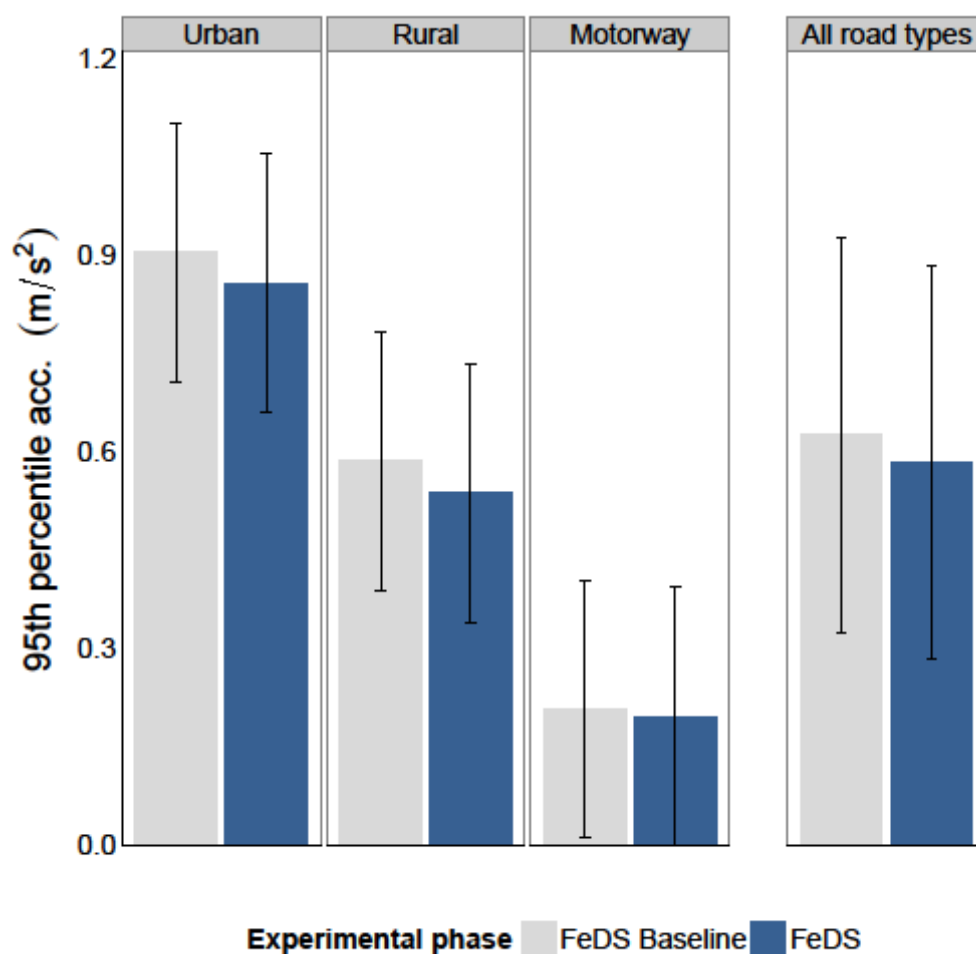


Figure 153: model based average values of 95th percentile positive acceleration for fixed effects.

Table 396: 95th percentile positive acceleration for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	0.90	0.86	0.05	0.005
Rural	0.59	0.54	0.05	<0.001
Motorway	0.21	0.19	0.01	0.921
All roads	0.62	0.58	0.04	<0.001

**Preliminary conclusions:**

The FeDS EcoDriver system significantly reduce 95<sup>th</sup> percentile acceleration on urban and rural roads.

## 7.22.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 397: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.4	0.4	1	4401.1	2.8	0.096
road_type	635.5	635.5	1	4363.5	4093.0	<0.001
Main_effect:road_type	0.2	0.2	1	4362.7	1.2	0.276

Table 398: Model summary for type D comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.42	1.24	1.60	0.004
App	-0.03	-0.07	0.00	0.079
Rural	-0.81	-0.84	-0.78	<0.001
App:Rural	0.03	-0.02	0.08	0.276
Random part	N			
Driver_id	40			
Vmc_id	2			
Number of observations	4432			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

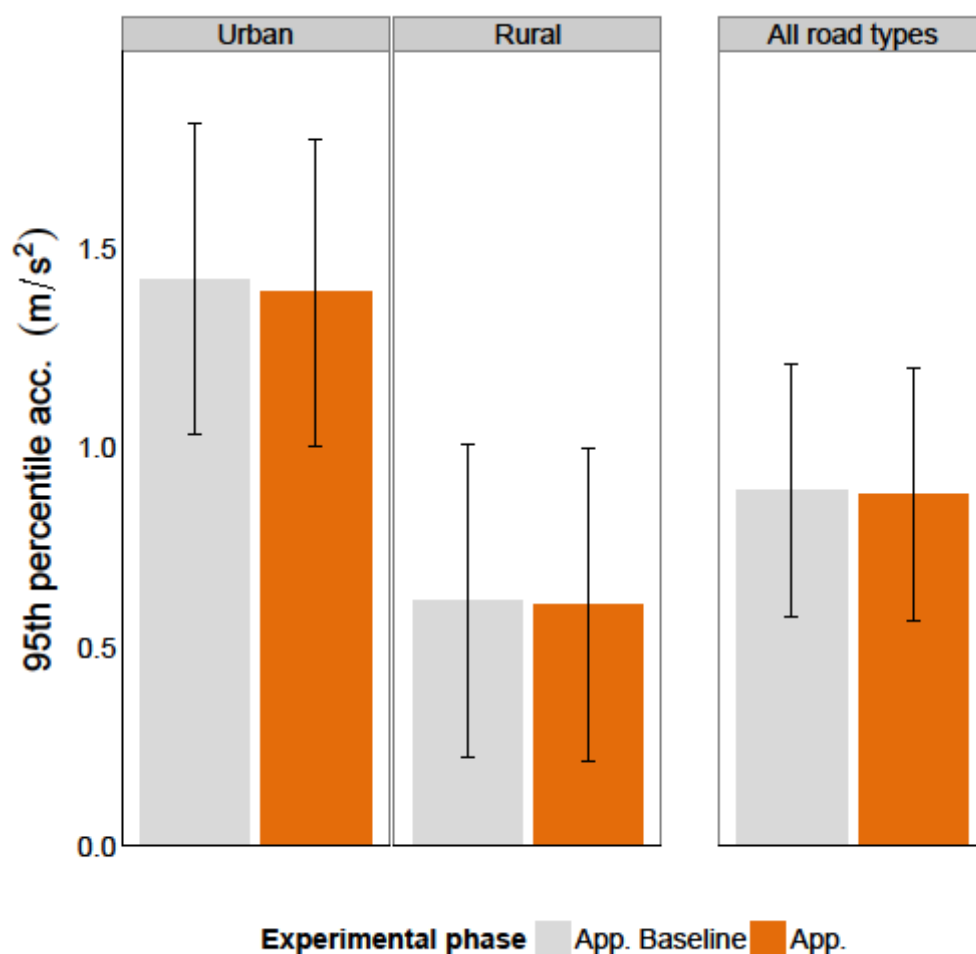


Figure 154: model based average values of 95th percentile positive acceleration for fixed effects.

Table 399: 95th percentile positive acceleration for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	1.42	1.39	0.03	0.291
Rural	0.62	0.61	0.01	0.960
All roads	0.89	0.88	0.01	0.670

#### Preliminary conclusions:

The EcoDriver application (App.) has no significantly effect on 95<sup>th</sup> percentile acceleration.

### 7.22.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 400: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.0	0.0	1	5471.7	0.2	0.631
road_type	41.2	41.2	1	5468.0	299.4	<0.001
Main_effect:road_type	0.4	0.4	1	5442.1	3.0	0.081

Table 401: Model summary for type E comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.57	0.51	0.63	<0.001
Haptic	0.03	-0.01	0.06	0.167
Rural	-0.18	-0.22	-0.14	<0.001
Haptic:Rural	-0.04	-0.08	0.00	0.081
Random part	N			
Driver_id	36			
Vmc_id	2			
Number of observations	5487			

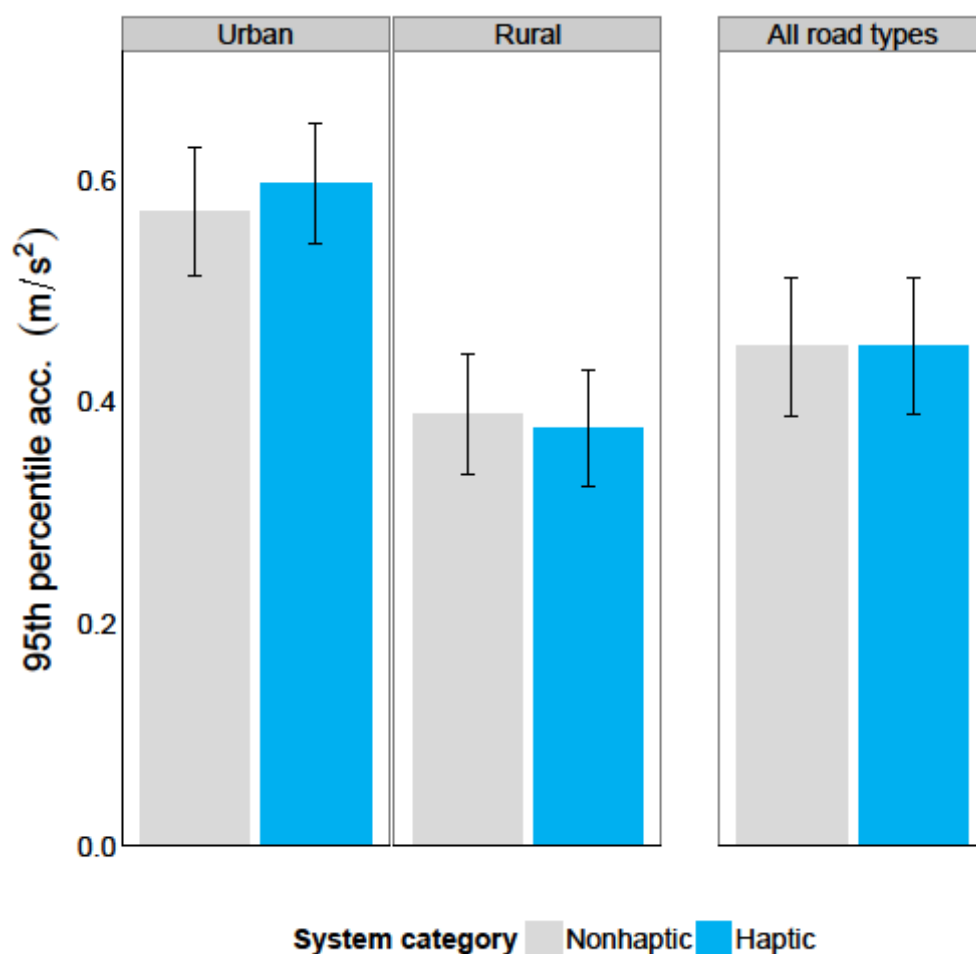


Figure 155: model based average values of 95th percentile positive acceleration for fixed effects.

Table 402: 95th percentile positive acceleration for the different systems and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	0.57	0.60	-0.03	0.504
Rural	0.39	0.38	0.01	0.748
All roads	0.45	0.45	0.00	0.972

#### Preliminary conclusions:

There is no significant effect between nonhaptic and haptic EcoDriver systems in reducing 95<sup>th</sup> percentile acceleration.



## 7.22.2 Naturalistic studies

### 7.22.2.1 TypeA : Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 403: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	10.0	10.0	1	62805.1	54.6	<0.001
road_type	3461.3	1730.7	2	62786.7	9464.8	<0.001
Main_effect:road_type	2.1	1.1	2	62797.0	5.8	0.003

Table 404: Model summary for type A comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.92	0.87	0.98	<0.001
Treatment	-0.04	-0.06	-0.03	<0.001
Rural	-0.41	-0.42	-0.40	<0.001
Motorway	-0.65	-0.66	-0.64	<0.001
Treatment:Rural	0.03	0.01	0.05	0.002
Treatment:Motorway	0.02	0.01	0.04	0.005
Random part	N			
Driver_id	20			
Vmc_id	2			
Number of observations	63362			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

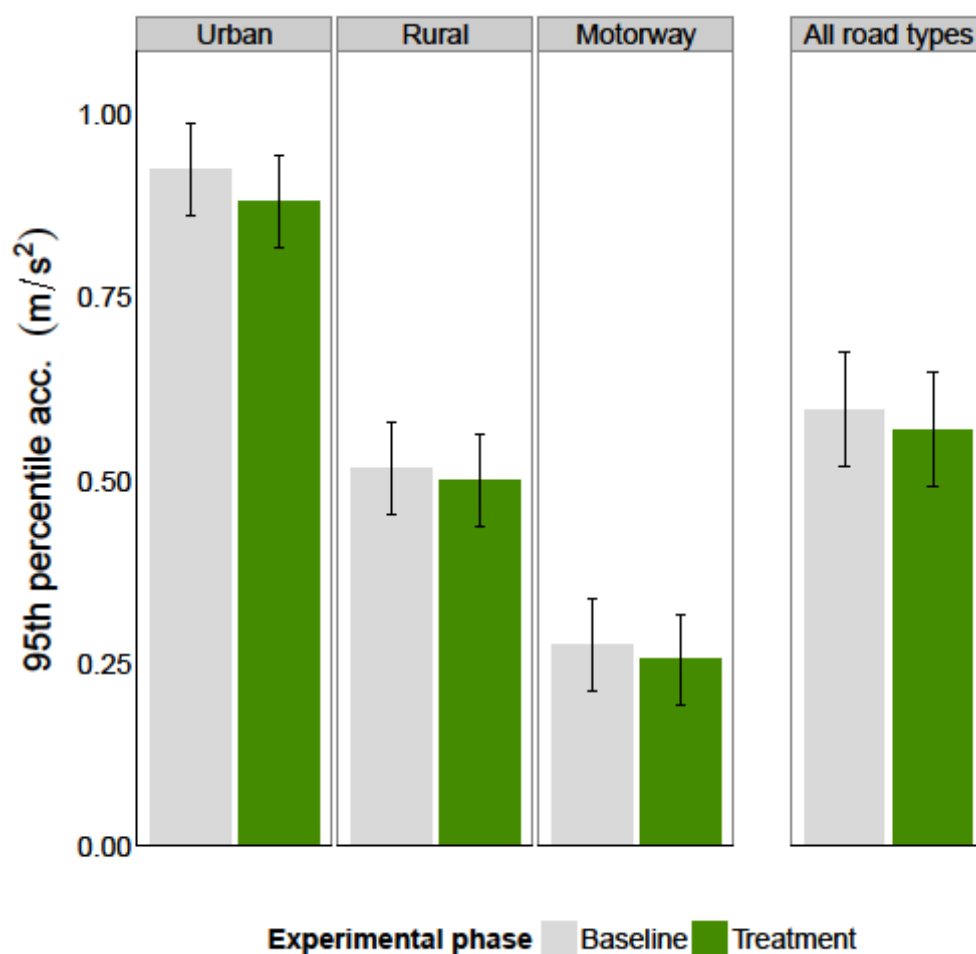


Figure 156: model based average values of 95th percentile positive acceleration for fixed effects.

Table 405: 95th percentile positive acceleration for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	0.92	0.88	0.04	<0.001
Rural	0.52	0.50	0.02	0.129
Motorway	0.28	0.26	0.02	0.003
All roads	0.60	0.57	0.03	<0.001

#### Preliminary conclusions:

In naturalistic drives, the EcoDriver system significantly reduces 95<sup>th</sup> percentile acceleration on urban roads and motorways, but not on rural roads. When considering all road types grouped, there is also a diminishing effect of the ecoDriver system on 95<sup>th</sup> percentile acceleration.

### 7.22.3 Results summary

Table 406: Comparisons of the effect size (difference between system category and its corresponding baseline)

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	0.125	0.071	0.047	0.03 (N.S.)	-0.025 (N.S.)	0.044
Rural	0.025	0.08	0.049	0.01 (N.S.)	0.014 (N.S.)	0.0158 (N.S.)
Motorway	-0.003 (N.S.)	0 (N.S.)	0.012 (N.S.)	-	-	0.0205
All road types	0.055	0.063	0.041	0.01 (N.S.)	-0.0004 (N.S.)	0.027

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	13.12	8.54	5.17	2.11 (N.S.)	-4.38 (N.S.)	4.77
Rural	4.43	13.21	8.42	1.61 (N.S.)	3.59 (N.S.)	3.06 (N.S.)
Motorway	-1.2 (N.S.)	0 (N.S.)	5.8 (N.S.)	-	-	7.44
All road types	8.1	9.81	6.57	1.12 (N.S.)	-0.09 (N.S.)	4.57

### 7.22.4 Conclusions and implications

On urban and rural roads during controlled drives, the EcoDriver system significantly reduces 95<sup>th</sup> percentile acceleration, while on motorways the ecoDriver systems had no effect on 95<sup>th</sup> percentile acceleration. The lack of any effect of ecoDriver on this PI on motorways during controlled drives might be explained by the fact that when driving on motorways acceleration and deceleration is of a smaller magnitude due to vehicle dynamics and traffic conditions; on motorways acceleration and deceleration is likely more dependent on other vehicles in traffic rather than volitional deceleration. On urban and rural roads, also when focusing on the embedded systems or the FeDS a similar reduction of 95<sup>th</sup> percentile acceleration is present. The EcoDriver application (App.) was not found to have a significant effect on this hypothesis' performance indicator. Furthermore, in this data no significant difference between haptic and nonhaptic systems is apparent in changing the acceleration distribution. For naturalistic data there was a significant effect of the ecoDriver system in reducing 95<sup>th</sup> percentile acceleration for urban roads and motorways, but not for rural roads. In general, the ecoDriver system reduced 95<sup>th</sup> percentile acceleration. A reduction of this PI translates into less aggressive driving with lower peak-accelerations.

## 7.23 Hypothesis 32: Using an ecoDriver system, the deceleration distribution will change

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, the 5th percentile negative acceleration will be closer to zero*

1. Using an ecoDriver system, the 5th percentile negative acceleration will be closer to zero. [Type A]
2. Using an embedded ecoDriver system, the 5th percentile negative acceleration will be closer to zero. [Type B]
3. Using the full ecoDriver system (FeDS), the 5th percentile negative acceleration will be closer to zero. [Type C]
4. Using the ecoDriver application, (App), the 5th percentile negative acceleration will be closer to zero. [Type D]
5. Using a haptic ecoDriver, the 5th percentile negative acceleration will be closer to zero. [Type E]

#### Performance indicator (PI):

5th percentile negative acceleration (percentile\_neg\_acc\_5)

#### Data reduction method:

500m sections

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.  
Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> <b>(Type A dataset)</b> <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Speed_limit, Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> <b>(Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b> <b>(Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline App vs App</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>

## Hypothesis analysis summary table

(Type D dataset)	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
Non-haptic vs Haptic (Type E dataset)	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 7.23.1 Controlled studies

#### 7.23.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 407: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	10.0	10.0	1	36778.6	44.4	<0.001
road_type	1504.9	752.5	2	36652.6	3354.2	<0.001
Main_effect:road_type	14.0	7.0	2	36699.5	31.3	<0.001

Table 408: Model summary for type A comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	-0.97	-1.07	-0.87	<0.001
Treatment	0.11	0.09	0.12	<0.001
Rural	0.42	0.40	0.44	<0.001
Motorway	0.77	0.74	0.80	<0.001
Treatment:Rural	-0.08	-0.10	-0.06	<0.001
Treatment:Motorway	-0.11	-0.14	-0.08	<0.001
Random part	N			
Driver_id	143			
Vmc_id	7			
Number of observations	37225			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

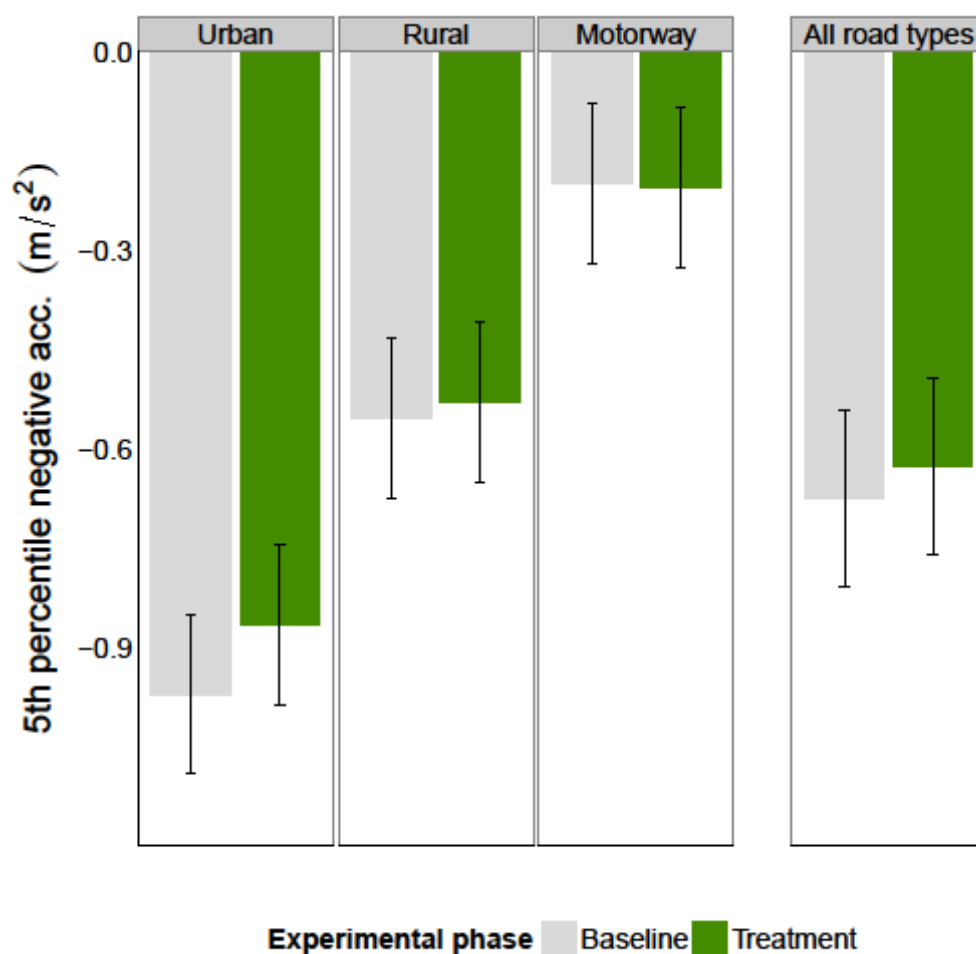


Figure 157: model based average values of 5th percentile negative acceleration for fixed effects.

Table 409: 5th percentile negative acceleration for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	-0.97	-0.86	-0.11	<0.001
Rural	-0.55	-0.53	-0.02	0.020
Motorway	-0.20	-0.20	0.00	0.999
All roads	-0.67	-0.63	-0.05	<0.001

**Preliminary conclusions:**

On Urban and Rural roads, the ecoDriver system significantly reduces 5<sup>th</sup> percentile negative acceleration.

## 7.23.1.2 Type B: Baseline embedded vs embedded

Table 410: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	10.0	10.0	1	32414.5	45.7	<0.001
road_type	976.7	488.3	2	32013.4	2238.5	<0.001
Main_effect:road_type	7.7	3.8	2	32357.1	17.6	<0.001

Table 411: Model summary for type B comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	-0.84	-0.95	-0.73	<0.001
Embedded	0.04	0.02	0.06	<0.001
Rural	0.23	0.21	0.25	<0.001
Motorway	0.65	0.62	0.68	<0.001
Embedded:Rural	0.05	0.02	0.07	<0.001
Embedded:Motorway	-0.04	-0.08	-0.01	0.009
Random part	N			
Driver_id	103			
Vmc_id	6			
Number of observations	32793			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

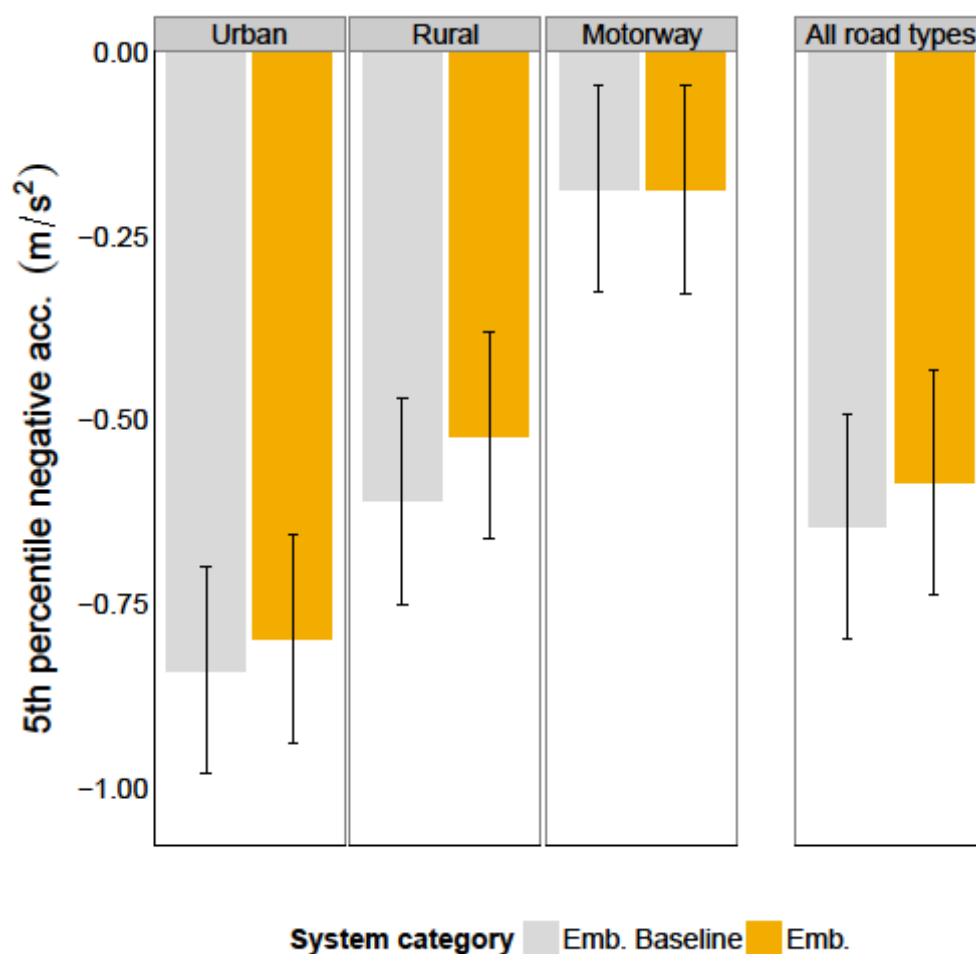


Figure 158: model based average values of 5th percentile negative acceleration for fixed effects.

Table 412: 5th percentile negative acceleration for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	-0.84	-0.80	-0.04	<0.001
Rural	-0.61	-0.52	-0.09	<0.001
Motorway	-0.19	-0.19	0.00	1.000
All roads	-0.64	-0.59	-0.06	<0.001

**Preliminary conclusions:**

Similar to the overall EcoDriver system, embedded EcoDriver systems reduce 5<sup>th</sup> percentile negative acceleration in Urban and Rural setting, but not on motorways.



### 7.23.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 413: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
<b>Main_effect</b>	4.0	4.0	1	16373.5	20.3	<0.001
<b>road_type</b>	675.5	337.7	2	16218.5	1715.0	<0.001
<b>Main_effect:road_type</b>	1.6	0.8	2	16341.6	3.9	0.019

Table 414: Model summary for type C comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
<b>(Intercept)</b>	-0.93	-1.02	-0.83	<0.001
<b>FeDS</b>	0.06	0.03	0.08	<0.001
<b>Rural</b>	0.22	0.19	0.25	<0.001
<b>Motorway</b>	0.65	0.62	0.69	<0.001
<b>FeDS:Rural</b>	-0.01	-0.05	0.03	0.634
<b>FeDS:Motorway</b>	-0.05	-0.09	-0.01	0.012
<b>Random part</b>	<b>N</b>			
<b>Driver_id</b>	59			
<b>Vmc_id</b>	3			
<b>Number of observations</b>	16548			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

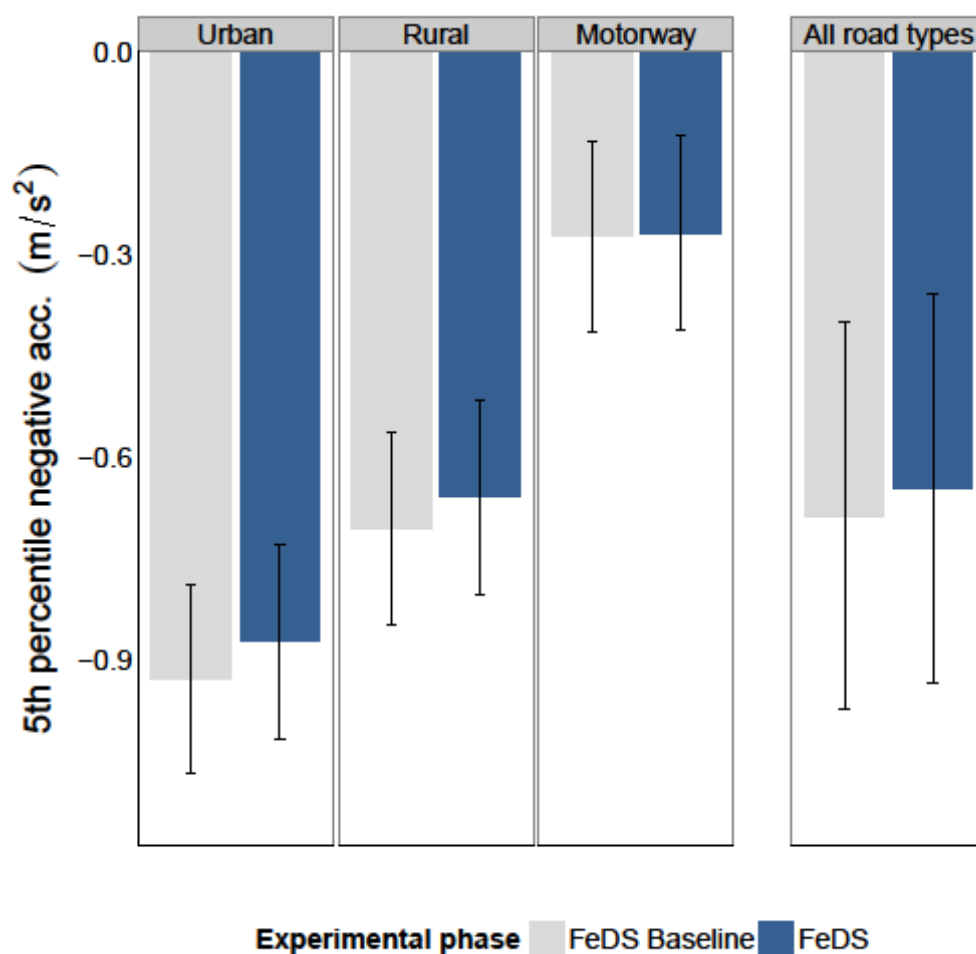


Figure 159: model based average values of 5th percentile negative acceleration for fixed effects.

Table 415: 5th percentile negative acceleration for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	-0.93	-0.87	-0.06	0.003
Rural	-0.70	-0.66	-0.05	<0.001
Motorway	-0.27	-0.27	-0.01	0.999
All roads	-0.69	-0.65	-0.04	<0.001

**Preliminary conclusions:**

Similar to the overall EcoDriver system, embedded EcoDriver systems reduce 5<sup>th</sup> percentile negative acceleration in Urban and Rural setting, but not on motorways.

## 7.23.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 416: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.0	0.0	1	4351.0	0.0	0.840
road_type	784.5	784.5	1	4355.2	4039.5	<0.001
Main_effect:road_type	0.1	0.1	1	4354.6	0.6	0.448

Table 417: Model summary for type D comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	-1.54	-1.87	-1.21	0.011
App	0.01	-0.03	0.06	0.543
Rural	0.89	0.86	0.93	<0.001
App:Rural	-0.02	-0.08	0.03	0.448
Random part	N			
Driver_id	40			
Vmc_id	2			
Number of observations	4432			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

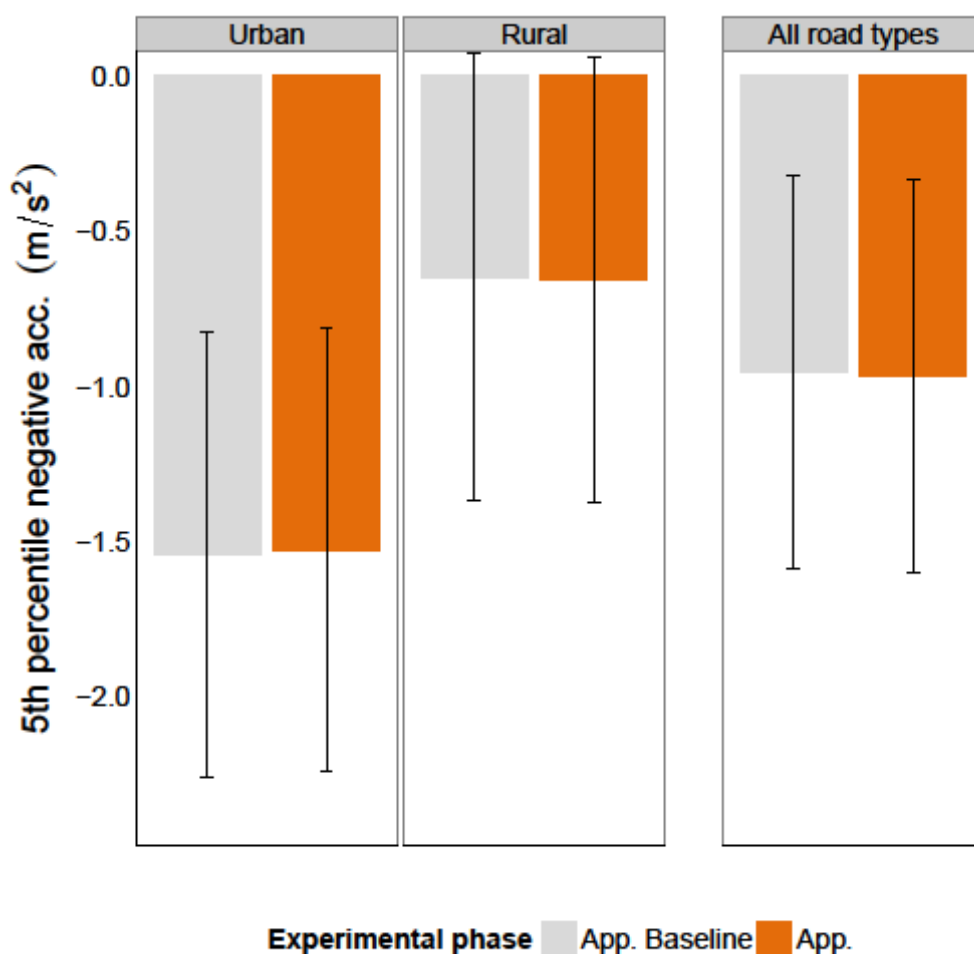


Figure 160: model based average values of 5th percentile negative acceleration for fixed effects.

Table 418: 5th percentile negative acceleration for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	-1.54	-1.53	-0.01	0.929
Rural	-0.65	-0.66	0.01	0.971
All roads	-0.95	-0.97	0.01	0.503

#### Preliminary conclusions:

The EcoDriver Application (App.) does not significantly change the 5<sup>th</sup> percentile deceleration for the two road types on which this system was used (urban and rural roads).

### 7.23.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 419: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.1	0.1	1	5475.5	0.7	0.418
road_type	82.5	82.5	1	5475.7	402.5	<0.001
Main_effect:road_type	0.2	0.2	1	5442.0	0.7	0.387

Table 420: Model summary for type E comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	-0.70	-0.76	-0.65	<0.001
Haptic	0.00	-0.04	0.04	0.991
Rural	0.27	0.23	0.32	<0.001
Haptic:Rural	0.02	-0.03	0.08	0.387
Random part	N			
Driver_id	36			
Vmc_id	2			
Number of observations	5487			

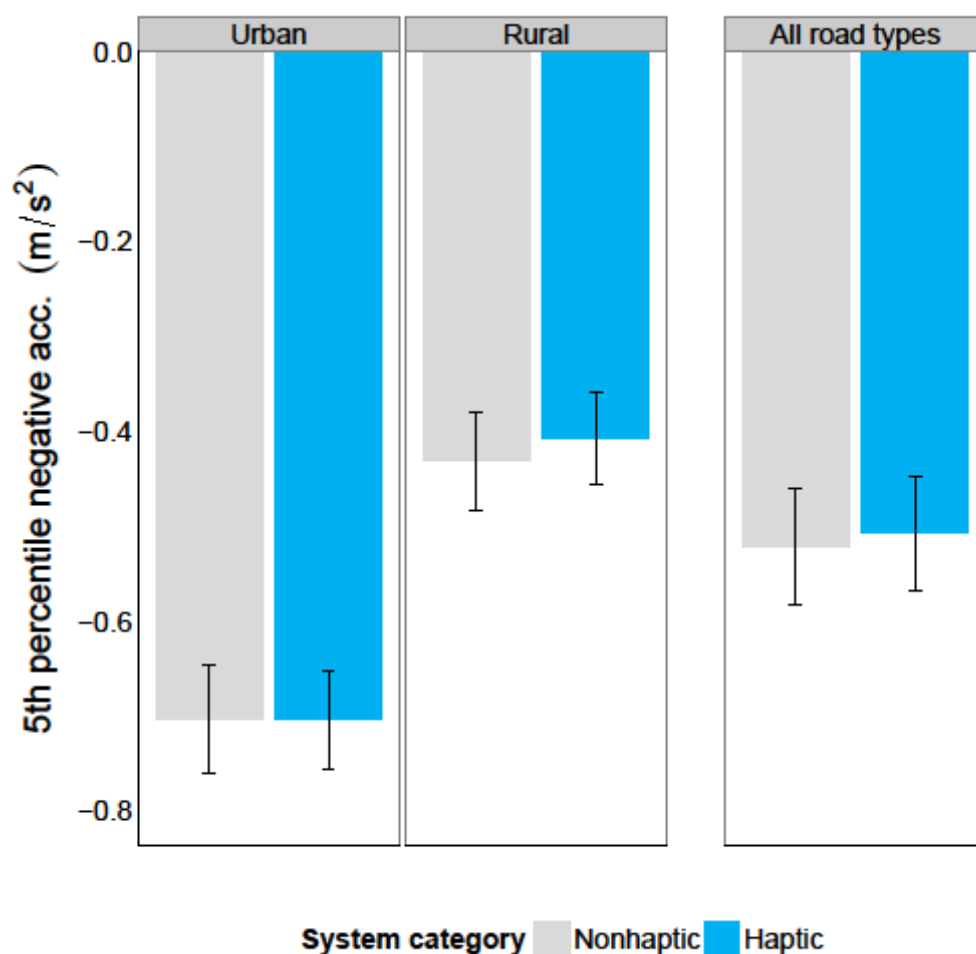


Figure 161: model based average values of 5th percentile negative acceleration for fixed effects.

Table 421: 5th percentile negative acceleration for the different systems and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	-0.70	-0.70	0.00	1.000
Rural	-0.43	-0.41	-0.02	0.510
All roads	-0.52	-0.51	-0.01	0.300

**Preliminary conclusions:**

There was no significant difference in the effect of nonhaptic versus haptic EcoDriver systems on reducing 5<sup>th</sup> percentile deceleration.

### 7.23.2 Naturalistic studies

#### 7.23.2.1 TypeA : Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 422: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	9.9	9.9	1	62228.0	36.6	<0.001
road_type	3798.8	1899.4	2	62209.2	7003.9	<0.001
Main_effect:road_type	0.9	0.5	2	62247.0	1.7	0.174

Table 423: Model summary for type A comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	-0.99	-1.06	-0.92	<0.001
Treatment	0.04	0.02	0.05	<0.001
Rural	0.41	0.39	0.42	<0.001
Motorway	0.68	0.66	0.69	<0.001
Treatment:Rural	-0.02	-0.04	0.00	0.079
Treatment:Motorway	-0.02	-0.04	0.00	0.136
Random part	N			
Driver_id	20			
Vmc_id	2			
Number of observations	63362			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

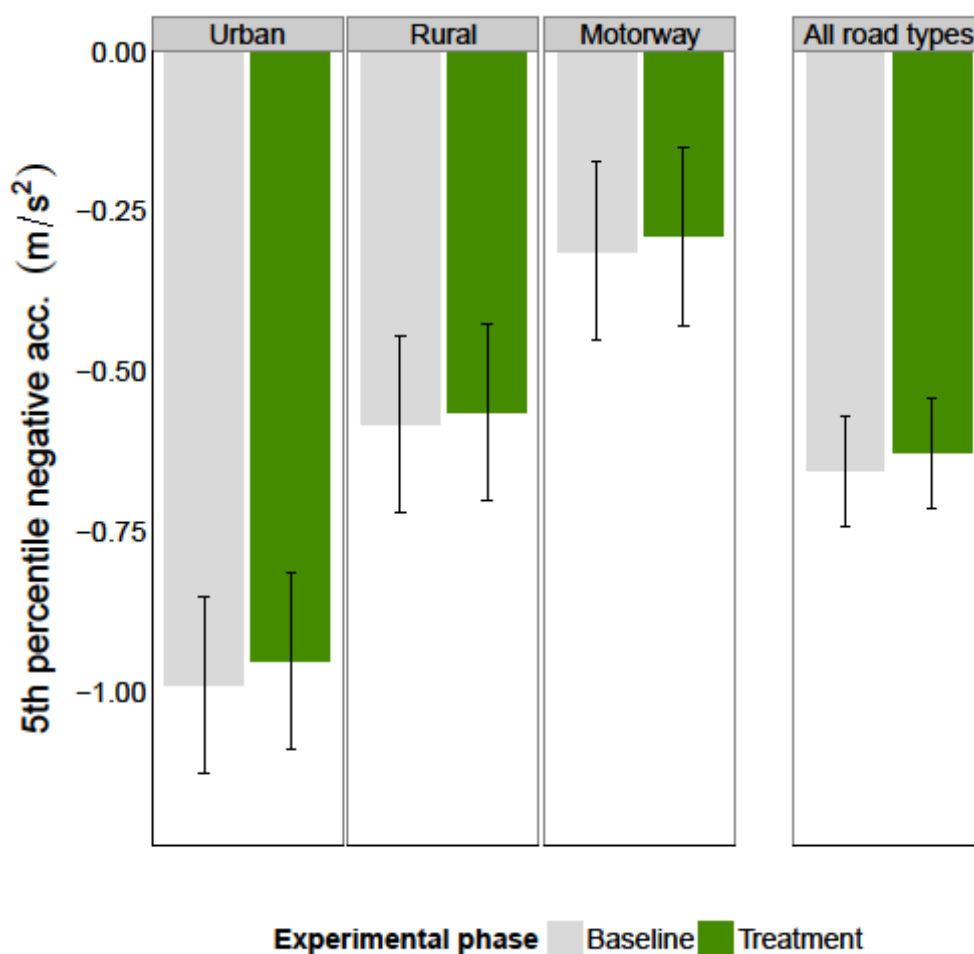


Figure 162: model based average values of 5th percentile negative acceleration for fixed effects.

Table 424: 5th percentile negative acceleration for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	-0.99	-0.95	-0.04	<0.001
Rural	-0.58	-0.56	-0.02	0.142
Motorway	-0.31	-0.29	-0.02	0.009
All roads	-0.66	-0.63	-0.03	<0.001

#### Preliminary conclusions:

In urban and motorway conditions, the EcoDriver system significantly reduced 5<sup>th</sup> percentile deceleration. For rural roads, however, this was not the case. Compared to controlled drives on urban roads, the naturalistic drives lead to a larger reduction of 5<sup>th</sup> percentile deceleration.



### 7.23.3 Results summary

Table 425: Comparisons of the effect size (difference between system category and its corresponding baseline).

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	-0.11	-0.04	-0.06	-0.01 (N.S.)	0 (N.S.)	-0.04
Rural	-0.02	-0.09	-0.05	0.01 (N.S.)	-0.02 (N.S.)	-0.0191 (N.S.)
Motorway	0 (N.S.)	0 (N.S.)	-0.01 (N.S.)	-	-	-0.02
All road types	-0.05	-0.06	-0.04	0.01 (N.S.)	-0.01 (N.S.)	-0.03

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	11.34	5.11	6.45	0.65 (N.S.)	0 (N.S.)	3.88
Rural	3.64	14.65	7.14	-1.54 (N.S.)	4.65 (N.S.)	3.28 (N.S.)
Motorway	0 (N.S.)	0 (N.S.)	3.7 (N.S.)	-	-	7.38
All road types	7.46	9.02	5.8	-1.05 (N.S.)	1.92 (N.S.)	4.31

### 7.23.4 Conclusions and implications

In controlled drives the ecoDriver system leads to reduction in 5<sup>th</sup> percentile deceleration on urban and rural roads. On urban roads this effect might be larger than 10% reduction. This effect can also be seen in the subset of embedded and FeDS, but is not present in the data on the ecoDriver application (App). Furthermore, no significant difference between nonhaptic and haptic systems in reducing 5<sup>th</sup> percentile deceleration as found. For naturalistic drives the ecoDriver system had a similar effect. However, the reduction of 5 percentile deceleration was less pronounced on urban roads, non-significant on rural roads, but significant on motorways. The lack of an effect of the various ecoDriver systems during controlled drives on motorways is most likely due to the considerably different driving environment compared to urban and rural roads. Stopping and accelerating occurs especially in urban conditions, e.g. due to traffic lights, where the distribution of (negative) acceleration is of most interest since there is most to gain in terms of driving behaviour. The overall reduction of 5<sup>th</sup> percentile acceleration that was found in controlled and naturalistic drives when using the ecoDriver compared to baseline could translate to safer and more fuel efficient driving behaviour. In addition a reduction of (unnecessary) deceleration is beneficial to traffic flow.

## 7.24 Hypothesis 33: Using an ecoDriver system, the maximum acceleration after being stationary will be reduced

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, the maximum acceleration after being stationary will be reduced*

*Using an ecoDriver system, acceleration after being stationary will be less aggressive*

1. Using an ecoDriver system, the maximum acceleration after being stationary will be reduced. [Type A]
2. Using an embedded ecoDriver system, the maximum acceleration after being stationary will be reduced. [Type B]
3. Using the full ecoDriver system (FeDS), the maximum acceleration after being stationary will be reduced. [Type C]
4. Using the ecoDriver application, (App), the maximum acceleration after being stationary will be reduced. [Type D]
5. Using a haptic ecoDriver, the maximum acceleration after being stationary will be reduced. [Type E]

#### Performance indicator (PI):

maximum acceleration (max\_acc)

#### Data reduction method:

segments Acceleration\_after\_standstill

Only urban road\_type, and 50kph speed\_limit\_start (over 90% of after standstill data fell into this category)

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.

Satterthwaite approximation for ddf, and Tukey multiple comparison test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> <b>(Type A dataset)</b> <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline</li> <li>• Treatment</li> </ul>
	Additional fixed effect	Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> <b>(Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_embedded</li> <li>• Embedded</li> </ul>
	Additional fixed effect	Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b> <b>(Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_FeDS</li> <li>• FeDS</li> </ul>
	Additional fixed effect	Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline App vs App</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_App</li> <li>• App</li> </ul>

## Hypothesis analysis summary table

(Type D dataset)	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
Non-haptic vs Haptic (Type E dataset)	Main effect	<ul style="list-style-type: none"> <li>• Non-haptic</li> <li>• Haptic</li> </ul>
	Additional fixed effect	Main_effect
	Random effects	Driver_id

### 7.24.1 Controlled studies

#### 7.24.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 426: Anova type III table for type A comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	1.4	1.4	1	4781.6	9.6	0.002

Table 427: Model summary for type A comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.74	1.57	1.91	<0.001
Treatment	-0.04	-0.06	-0.01	0.002
Random part	N			
Driver_id	109			
Vmc_id	8			
Number of observations	5887			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

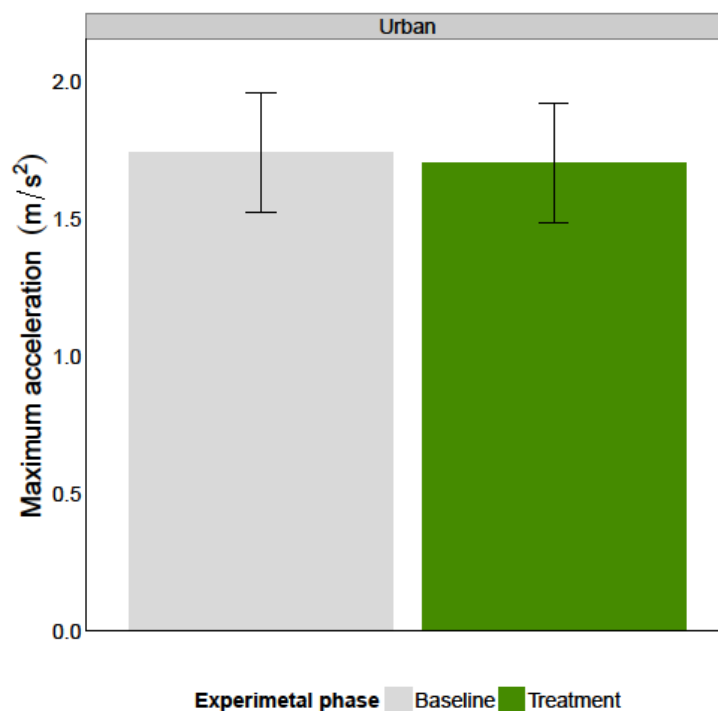


Figure 163: model based average values of maximum acceleration for fixed effects.

Table 428: maximum acceleration for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	1.743	1.704	0.039	0.002

**Preliminary conclusions:**

The ecoDriver system reduces maximum acceleration after standstill. The effect is significant but the effect size is small (about 2%).

## 7.24.1.2 Type B: Baseline embedded vs embedded

Table 429: Anova type III table for type B comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.9	0.9	1	2177.0	6.6	0.010

Table 430: Model summary for type B comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.75	1.53	1.97	<0.001
Embedded	-0.05	-0.09	-0.01	0.010
Random part	N			
Driver_id	69			
Vmc_id	7			
Number of observations	3273			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

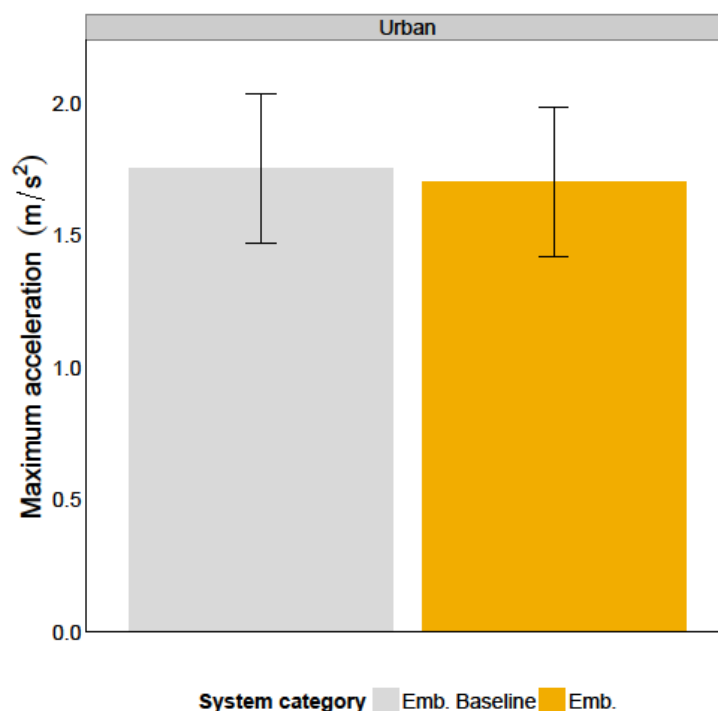


Figure 164: model based average values of maximum acceleration for fixed effects.

Table 431: maximum acceleration for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	1.752	1.701	0.052	0.010

**Preliminary conclusions:**

The embedded ecoDriver system reduces maximum acceleration after standstill. The reducing effect of the embedded ecoDriver systems is more pronounced than for ecoDriver systems overall (about 3%).

## 7.24.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 432: Anova type III table for type C comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.0	0.0	1	754.1	0.2	0.661

Table 433: Model summary for type C comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.86	1.74	1.99	<0.001
FeDS	-0.01	-0.07	0.05	0.661
Random part	N			
Driver_id	40			
Vmc_id	4			
Number of observations	1846			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

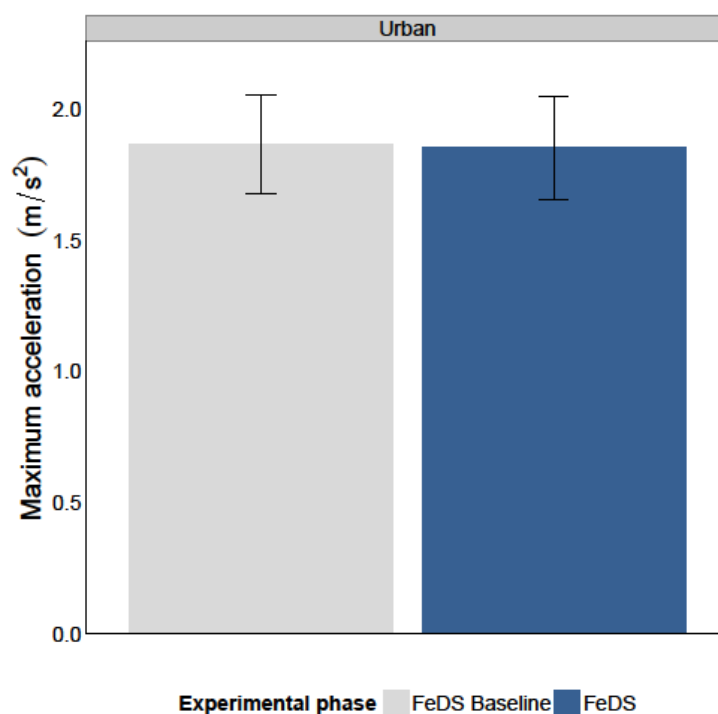


Figure 165: model based average values of maximum acceleration for fixed effects.

Table 434: maximum acceleration for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	1.865	1.852	0.013	0.661

**Preliminary conclusions:**

The FeDS system when considered by itself does not significantly reduce maximum acceleration after standstill.



#### 7.24.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 435: Anova type III table for type D comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.6	0.6	1	2608.7	4.0	0.045

Table 436: Model summary for type D comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.81	1.75	1.87	<0.001
App	-0.03	-0.06	0.00	0.045
Random part		N		
Driver_id		41		
Vmc_id		3		
Number of observations		3699		

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

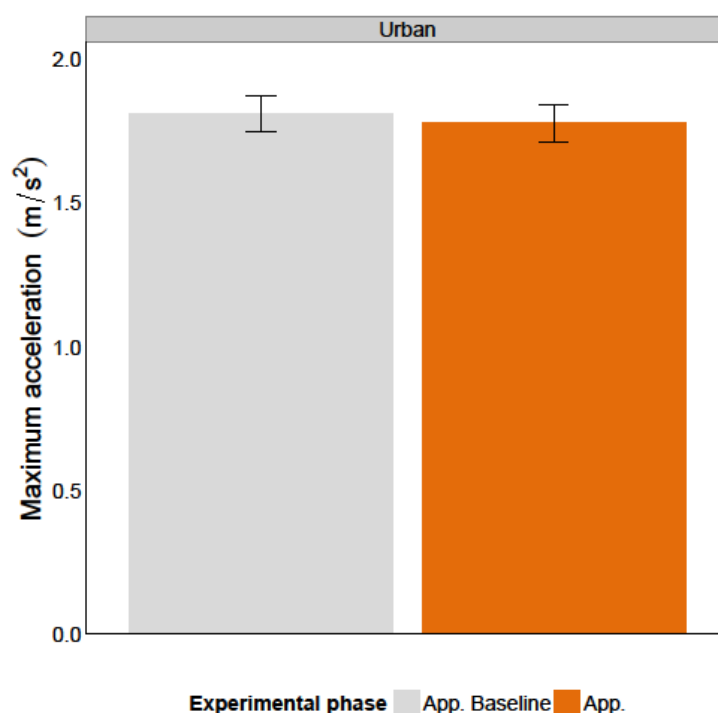


Figure 166: model based average values of maximum acceleration for fixed effects.

Table 437: maximum acceleration for the different levels of Main\_effect and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	1.810	1.778	0.032	0.045

**Preliminary conclusions:**

The Android application (App.) EcoDriver system reduces maximum acceleration after standstill and thus lead to less aggressive acceleration.

**7.24.1.5 Type E: Non-haptic vs Haptic**

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 438: Anova type III table for type E comparison.

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.3	0.3	1	453.8	2.0	0.157

Table 439: Model summary for type E comparison.

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.59	1.48	1.70	<0.001
Haptic	0.07	-0.03	0.16	0.157
Random part	N			
Driver_id	21			
Vmc_id	3			
Number of observations	1553			

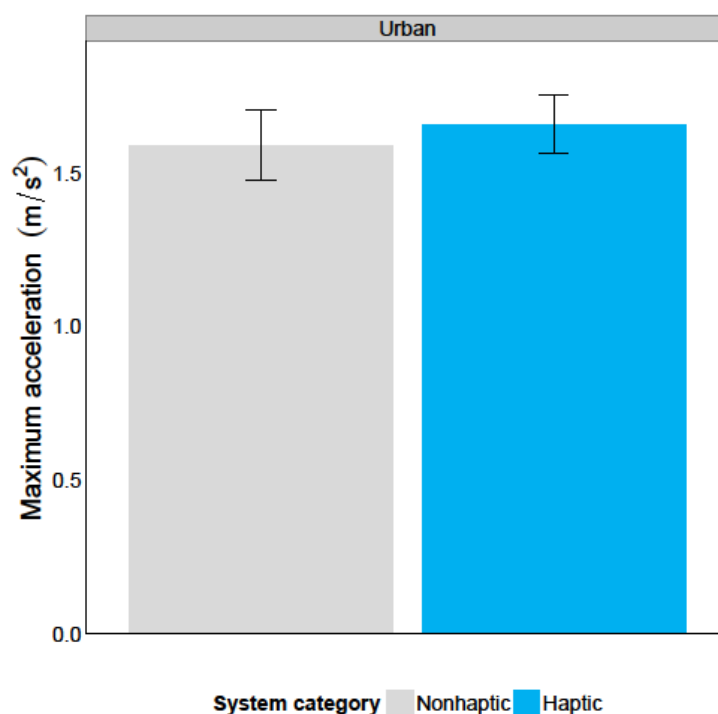


Figure 167: model based average values of maximum acceleration for fixed effects.

Table 440: Maximum acceleration for the different systems and road type, together with Tukey multiple comparison results.

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	1.590	1.657	-0.067	0.156

**Preliminary conclusions:**

There was no significant difference in nonhaptic versus haptic EcoDriver systems on reducing maximum acceleration after standstill.

## 7.24.2 Naturalistic studies

### 7.24.2.1 TypeA : Baseline vs Treatment

*There is (currently) no data on acceleration after standstill for naturalistic data.*

### 7.24.3 Results summary

Table 441: Comparisons of the effect size (difference between system category and its corresponding baseline).

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	0.0387	0.0516	0.013 (N.S.)	0.032	-0.067 (N.S.)	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	2.22	2.94	0.7 (N.S.)	1.77	-4.21 (N.S.)	-

### 7.24.4 Conclusions and implications

Note that since this hypothesis is concerned with acceleration after standstill, only urban roads are considered since the majority of stopping events took place on urban roads. In controlled drives, the ecoDriver system reduced maximum acceleration after standstill by 2.2%. When considering only embedded systems this effect was even more pronounced with a 2.94% reduction compared to baseline. However, when considering only the FeDS, there was no significant effect of these systems on maximum acceleration when comparing to baseline. The ecoDriver App on the other hand did show a significant reduction of approximately 2% in maximum acceleration compared to baseline. No significant effect was found of haptic ecoDriver systems compared to nonhaptic ecoDriver systems. There is no segmentation of data based on post standstill driving behaviour for naturalistic drives, thus results for this category are absent. Overall, the ecoDriver system reduced maximum acceleration after standstill, which translates into less aggressive driving when going from a standstill situation.

## 7.25 Hypothesis 34: Using an ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before intersections

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before intersections*

1. Using an ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before intersections. [Type A]
2. Using an embedded ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before intersections. [Type B]
3. Using the full ecoDriver system (FeDS), the 95th percentile of the negative acceleration will be closer to zero before intersections. [Type C]
4. Using the ecoDriver application, (App), the 95th percentile of the negative acceleration will be closer to zero before intersections. [Type D]
5. Using a haptic ecoDriver, the 95th percentile of the negative acceleration will be closer to zero before intersections. [Type E]

#### Performance indicator (PI):

95th percentile of the negative acceleration before intersections (sqrt\_percentil\_neg\_acc\_95)

#### Data reduction method:

Event-based

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced. Satterthwaite approximation for DoF, and Tukey multiple comparisons test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> <b>(Type A dataset)</b> <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline</li> <li>• Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> <b>(Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_embedded</li> <li>• Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b> <b>(Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_FeDS</li> <li>• FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id

## Hypothesis analysis summary table

<b>Baseline App vs App (Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id
<b>Non-haptic vs Haptic (Type E dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 7.25.1 Controlled studies

#### 7.25.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 442: Anova type III table for type A comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	14.3	14.3	1	227322.9	129.7	<0.001
road_type	1053.2	1053.2	1	227318.2	9570.9	<0.001
Main_effect:road_type	31.3	31.3	1	227212.9	284.2	<0.001

Table 443: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.93	0.86	1.01	<0.001
Treatment	-0.05	-0.05	-0.04	<0.001
Rural	-0.19	-0.19	-0.18	<0.001
Treatment:Rural	0.05	0.05	0.06	<0.001
Random part	N			
Speed_limit	0			
Driver_id	143			
Vmc_id	7			
Number of observations	231660			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

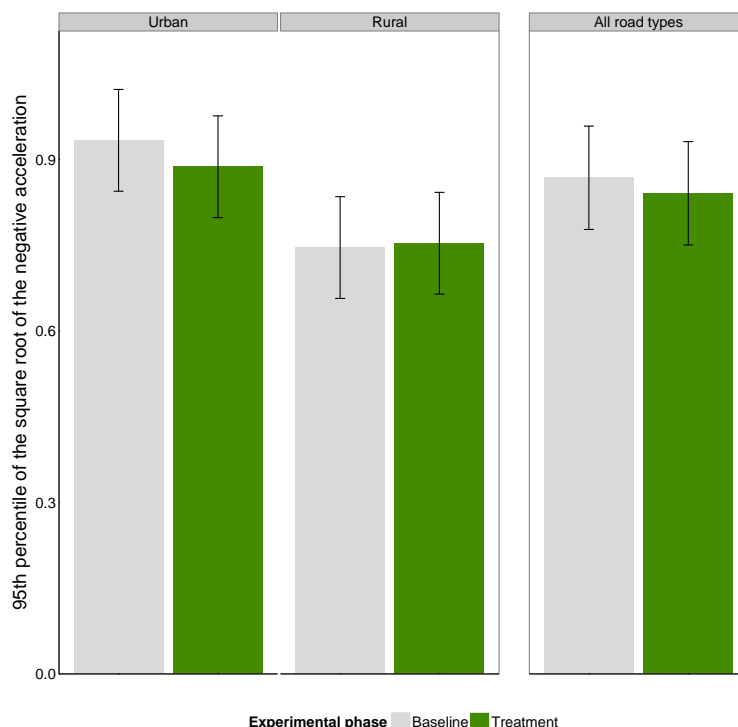


Figure 168: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 444: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	0.933	0.887	0.046	<0.001
Rural	0.746	0.753	-0.007	0.023
All road types	0.868	0.841	0.027	<0.001

#### Preliminary conclusions:

The treatment condition decreases significantly the PI compared to baseline in urban driving environments. The back transformed model-based estimates for extreme deceleration are reduced from  $-0.87 \text{ m/s}^2$  to  $-0.79 \text{ m/s}^2$ . On rural roads, the PI is slightly increased.

#### 7.25.1.2 Type B: Baseline embedded vs embedded

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 445: Anova type III table for type B comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	40.9	40.9	1	178583.7	353.8	<0.001
road_type	356.7	356.7	1	178566.5	3086.4	<0.001
Main_effect:road_type	0.5	0.5	1	178511.7	4.4	0.036

Table 446: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.88	0.82	0.94	<0.001
Embedded	-0.04	-0.05	-0.04	<0.001
Rural	-0.12	-0.12	-0.11	<0.001
Embedded:Rural	0.01	0.00	0.02	0.036
Random part	N			
Speed_limit	0			
Driver_id	103			
Vmc_id	6			
Number of observations	182559			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.



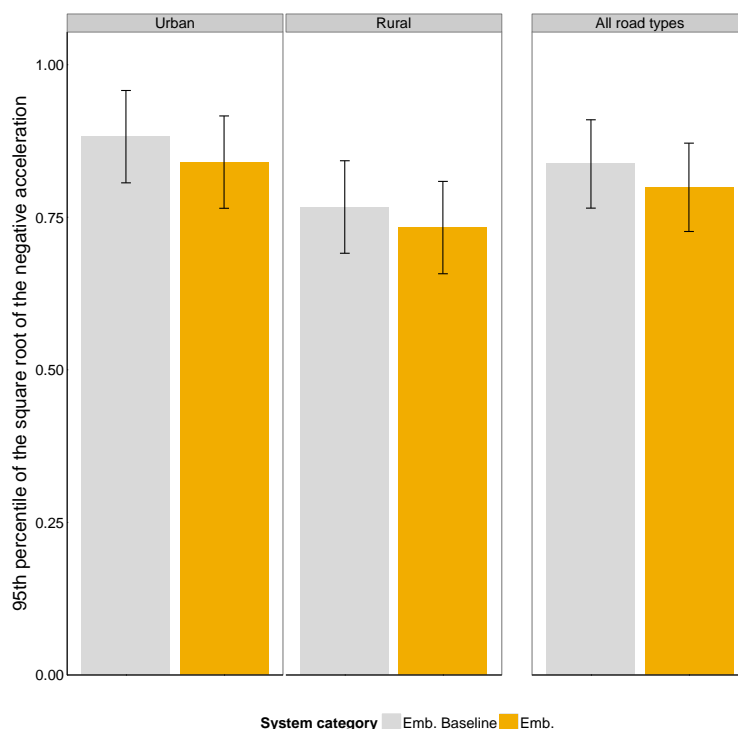


Figure 169: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 447: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	0.882	0.840	0.042	<0.001
Rural	0.767	0.733	0.034	<0.001
All road types	0.837	0.799	0.038	<0.001

**Preliminary conclusions:**

The usage of an embedded system yields significantly lower model based estimation average decelerations compared to the embedded baseline.

### 7.25.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 448: Anova type III table for type C comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	12.9	12.9	1	59143.4	126.7	<0.001
road_type	290.5	290.5	1	59123.3	2852.9	<0.001
Main_effect:road_type	0.2	0.2	1	59101.6	2.4	0.123

Table 449: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.94	0.91	0.97	<0.001
FeDS	-0.04	-0.04	-0.03	<0.001
Rural	-0.17	-0.17	-0.16	<0.001
FeDS:Rural	0.01	0.00	0.02	0.123
Random part	N			
Speed_limit	0			
Driver_id	59			
Vmc_id	3			
Number of observations	60099			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

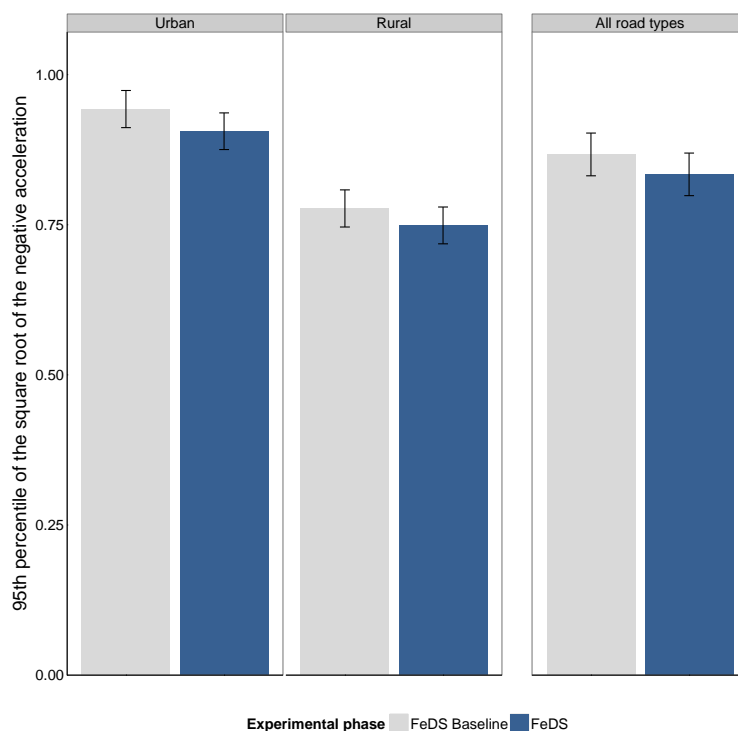


Figure 170: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 450: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	0.943	0.906	0.037	<0.001
Rural	0.777	0.749	0.028	<0.001
All road types	0.867	0.834	0.033	<0.001

**Preliminary conclusions:**

The FeDS significantly lowers the expected extreme deceleration values on urban and rural roads.

## 7.25.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 451: Anova type III table for type D comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.3	0.3	1	48241.5	3.6	0.057
road_type	943.1	943.1	1	48703.9	11390.4	<0.001
Main_effect:road_type	0.2	0.2	1	48699.0	3.0	0.085

Table 452: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.11	1.10	1.13	<0.001
App	0.00	-0.01	0.01	0.818
Rural	-0.33	-0.34	-0.33	<0.001
App:Rural	0.01	0.00	0.02	0.085
Random part	N			
Speed_limit	0			
Driver_id	40			
Vmc_id	2			
Number of observations	49101			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

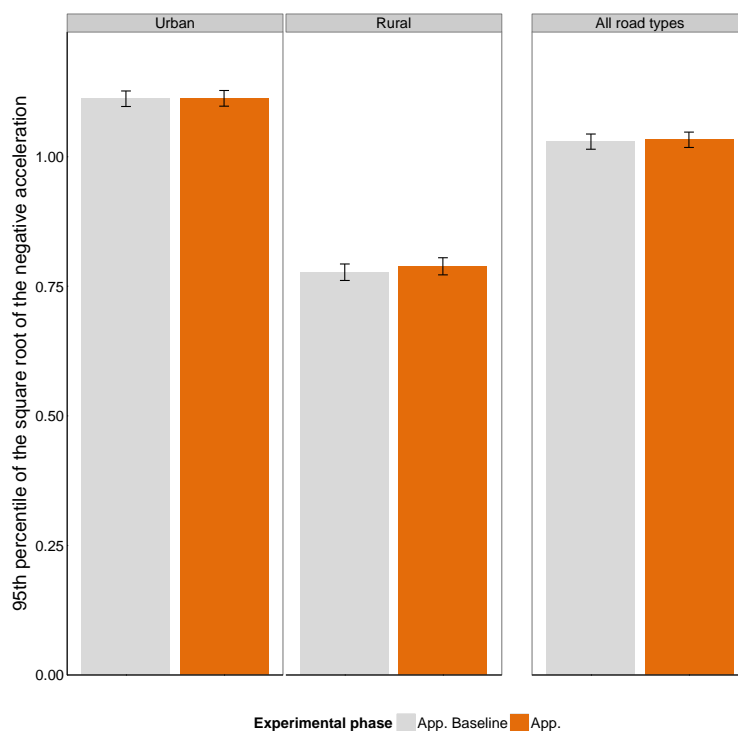


Figure 171: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 453: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	1.112	1.113	-0.001	0.996
Rural	0.777	0.789	-0.011	0.151
All road types	1.029	1.033	-0.004	0.233

**Preliminary conclusions:**

There is only a small difference between the ecoDriver App and its baseline, and it is not statistically significant.

## 7.25.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 454: Anova type III table for type E comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	1.8	1.8	1	38803.9	15.2	<0.001
road_type	57.4	57.4	1	38780.5	496.1	<0.001
Main_effect:road_type	0.7	0.7	1	38770.4	6.4	0.011

Table 455: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.80	0.76	0.84	<0.001
Haptic	-0.03	-0.04	-0.02	<0.001
Rural	-0.11	-0.12	-0.09	<0.001
Haptic:Rural	0.02	0.00	0.04	0.011
Random part	N			
Speed_limit	0			
Driver_id	36			
Vmc_id	2			
Number of observations	39543			

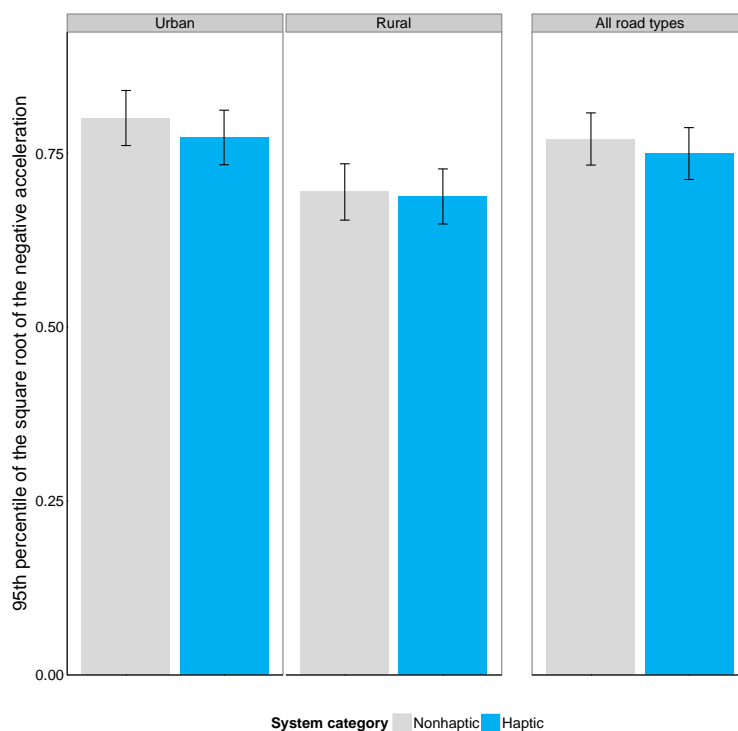


Figure 172: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 456: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	0.801	0.773	0.028	<0.001
Rural	0.694	0.688	0.007	0.792
All road types	0.770	0.750	0.021	<0.001

**Preliminary conclusions:**

The usage of a haptic feedback significantly further reduces the estimated extreme deceleration values on urban roads. On rural roads, however, there is no significant difference.

### 7.25.2 Results summary

Table 457: Comparisons of the effect size (difference between system category and its corresponding baseline).

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	0.046	0.042	0.037	-0.001 (N.S.)	0.028	-
Rural	-0.007	0.034	0.028	-0.011 (N.S.)	0.007 (N.S.)	-
All road types	0.027	0.038	0.033	-0.004 (N.S.)	0.021	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	4.95	4.74	3.94	-0.09 (N.S.)	3.5	-
Rural	-0.94	4.38	3.64	-1.42 (N.S.)	1.01 (N.S.)	-
All road types	3.12	4.59	3.84	-	-	-

### 7.25.3 Conclusions and implications

The usage of the ecoDriver systems significantly reduces the deceleration before intersections in urban driving environments. The back transformed model-based estimates for extreme deceleration are reduced from  $-0.87 \text{ m/s}^2$  to  $-0.79 \text{ m/s}^2$  between baseline and treatment of all the systems on urban roads.

Similar values are found for the embedded systems and the FeDS. In contrast to the analysis of all the systems, a significant positive effect was found on rural roads also.

Between the Android ecoDriver App and its baseline, there is only a small difference, and it is not statistically significant.

The haptic systems have no significant effect compared to the non-haptic system on rural roads. On urban roads, however, the back transformed estimates for extreme deceleration are further reduced from  $-0.64 \text{ m/s}^2$  to  $-0.60 \text{ m/s}^2$ .



## 7.26 Hypothesis 35: Using an ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before zebra crossings

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before zebra crossings*

1. Using an ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before zebra crossings. [Type A]
2. Using an embedded ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before zebra crossings. [Type B]
3. Using the full ecoDriver system (FeDS), the 95th percentile of the negative acceleration will be closer to zero before zebra crossings. [Type C]
4. Using the ecoDriver application, (App), the 95th percentile of the negative acceleration will be closer to zero before zebra crossings. [Type D]
5. Using a haptic ecoDriver, the 95th percentile of the negative acceleration will be closer to zero before zebra crossings. [Type E]

#### Performance indicator (PI):

95th percentile of the negative acceleration before zebra crossings (sqrt\_percentil\_neg\_acc\_95)

#### Data reduction method:

Event-based

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced. Satterthwaite approximation for DoF, and Tukey multiple comparisons test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> <b>(Type A dataset)</b> <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline</li> <li>• Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> <b>(Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_embedded</li> <li>• Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b> <b>(Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_FeDS</li> <li>• FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id

## Hypothesis analysis summary table

<b>Baseline App vs App (Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Non-haptic vs Haptic (Type E dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 7.26.1 Controlled studies

#### 7.26.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 458: Anova type III table for type A comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	1.3	1.3	1	24522.4	9.8	0.002
road_type	6.6	6.6	1	24410.5	51.3	<0.001
Main_effect:road_type	3.7	3.7	1	24471.3	28.9	<0.001

Table 459: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.81	0.75	0.88	<0.001
Treatment	-0.02	-0.03	-0.01	<0.001
Rural	-0.11	-0.14	-0.08	<0.001
Treatment:Rural	0.10	0.06	0.13	<0.001
Random part	N			
Speed_limit	0			
Driver_id	117			
Vmc_id	5			
Number of observations	28422			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

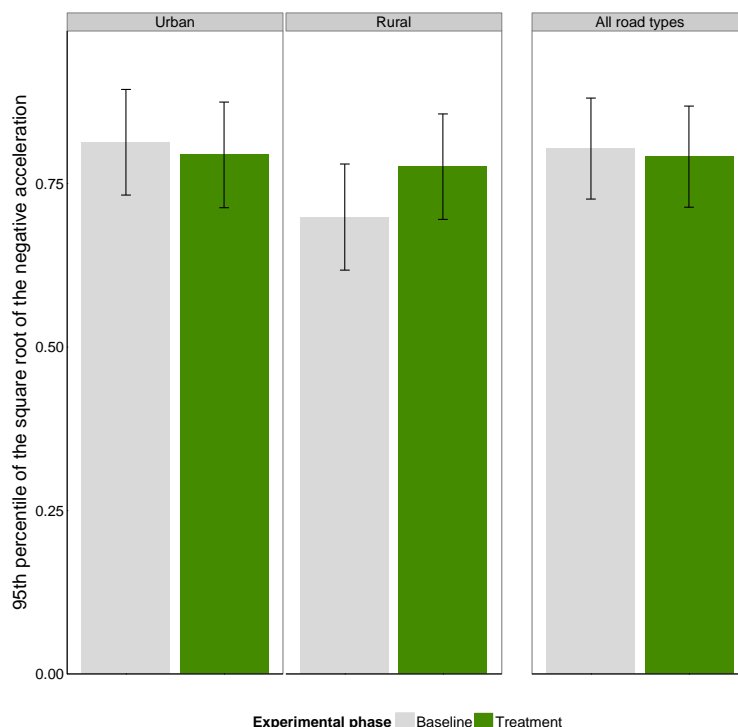


Figure 173: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 460: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	0.813	0.794	0.019	0.002
Rural	0.699	0.776	-0.077	<0.001
All road types	0.804	0.791	0.012	0.018

#### Preliminary conclusions:

The treatment condition decreases significantly the PI compared to baseline in urban driving environments. The back transformed deceleration model based estimates are reduced from  $-0.66 \text{ m/s}^2$  to  $-0.63 \text{ m/s}^2$  for urban driving. On rural roads, there is an unexpected significant increase of the PI.

### 7.26.1.2 Type B: Baseline embedded vs embedded

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 461: Anova type III table for type B comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	1.1	1.1	1	11290.6	8.7	0.003
road_type	2.6	2.6	1	7802.8	21.3	<0.001
Main_effect:road_type	0.2	0.2	1	11327.0	1.9	0.164

Table 462: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.77	0.73	0.80	<0.001
Embedded	-0.02	-0.04	0.00	0.024
Rural	0.08	0.03	0.12	<0.001
Embedded:Rural	-0.04	-0.08	0.01	0.164
Random part	N			
Speed_limit	0			
Driver_id	77			
Vmc_id	4			
Number of observations	14318			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

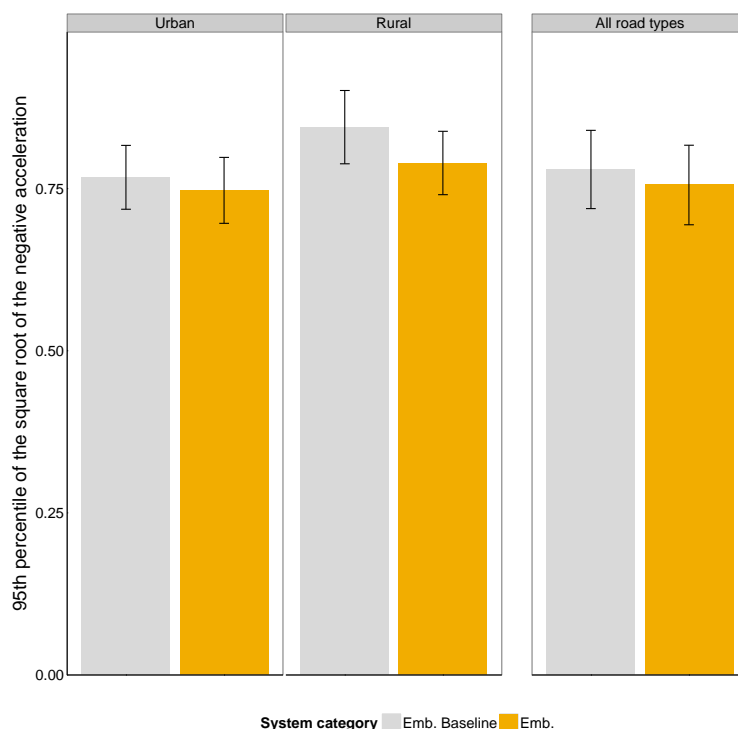


Figure 174: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 463: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	0.767	0.747	0.020	0.097
Rural	0.845	0.790	0.055	0.083
All road types	0.780	0.756	0.024	0.004

**Preliminary conclusions:**

The usage of an embedded system yields significantly lower model based estimation average decelerations compared to the embedded baseline on all road types. For the individual road types urban and rural, the change is not significant.

## 7.26.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 464: Anova type III table for type C comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	1.6	1.6	1	2235.1	12.9	<0.001
road_type	1.5	1.5	1	1057.0	12.1	<0.001
Main_effect:road_type	0.7	0.7	1	2225.7	5.4	0.021

Table 465: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.74	0.69	0.79	<0.001
FeDS	-0.03	-0.06	0.00	0.080
Rural	0.15	0.07	0.23	<0.001
FeDS:Rural	-0.11	-0.20	-0.02	0.021
Random part	N			
Speed_limit	0			
Driver_id	41			
Vmc_id	2			
Number of observations	2513			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

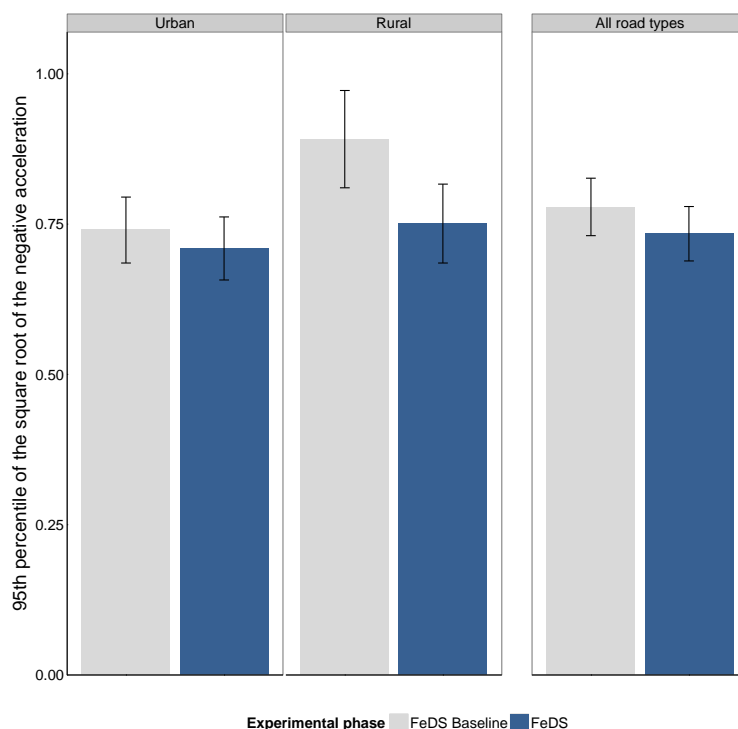


Figure 175: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 466: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	0.740	0.710	0.031	0.279
Rural	0.891	0.751	0.140	0.007
All road types	0.779	0.734	0.045	0.006

#### Preliminary conclusions:

The FeDS condition lowers the expected system deceleration. However, this difference is only significant in rural environments, whereas in urban environments the difference to the baseline is not significant.

## 7.26.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 467: Anova type III table for type D comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.3	0.3	1	12766.5	2.2	0.137
road_type	28.6	28.6	1	10253.4	215.0	<0.001
Main_effect:road_type	0.5	0.5	1	13008.5	4.0	0.046

Table 468: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.92	0.88	0.96	0.002
App	-0.01	-0.02	0.01	0.279
Rural	-0.25	-0.29	-0.21	<0.001
App:Rural	0.06	0.00	0.12	0.046
Random part	N			
Speed_limit	0			
Driver_id	40			
Vmc_id	2			
Number of observations	14104			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.



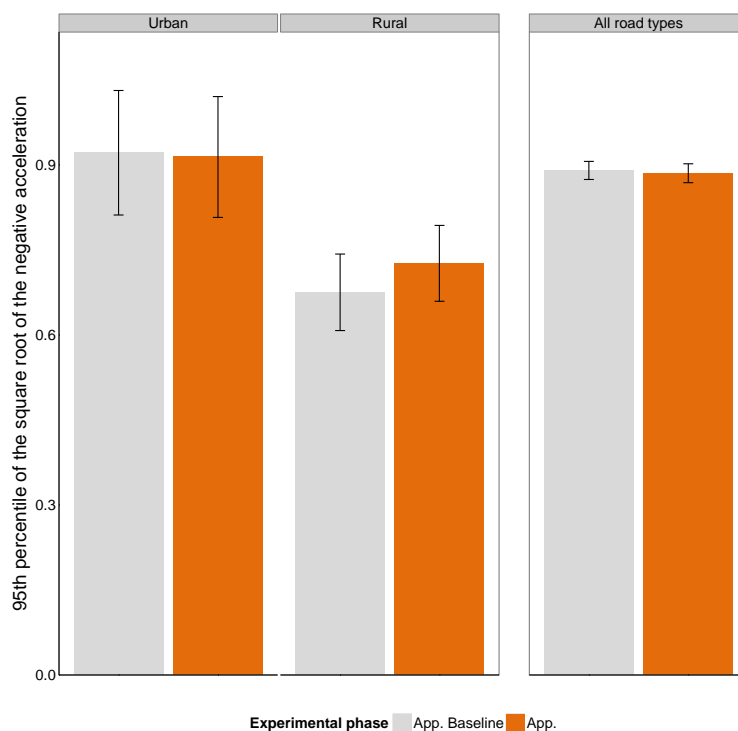


Figure 176: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 469: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	0.922	0.914	0.007	0.672
Rural	0.675	0.726	-0.051	0.249
All road types	0.890	0.885	0.005	0.449

**Preliminary conclusions:**

The difference between the ecoDriver App and its baseline is highly non-significant. Furthermore, the estimated model based average deceleration is stronger for the App condition in rural environments, but also not significant.

### 7.26.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 470: Anova type III table for type E comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.0	0.0	1	2884.5	0.1	0.714
road_type	0.0	0.0	1	2886.2	0.1	0.767
Main_effect:road_type	0.2	0.2	1	2880.7	1.4	0.241

Table 471: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.76	0.73	0.79	<0.001
Haptic	-0.04	-0.07	-0.01	0.021
Rural	-0.02	-0.11	0.07	0.627
Haptic:Rural	0.06	-0.04	0.16	0.241
Random part	N			
Speed_limit	0			
Driver_id	36			
Vmc_id	2			
Number of observations	3653			

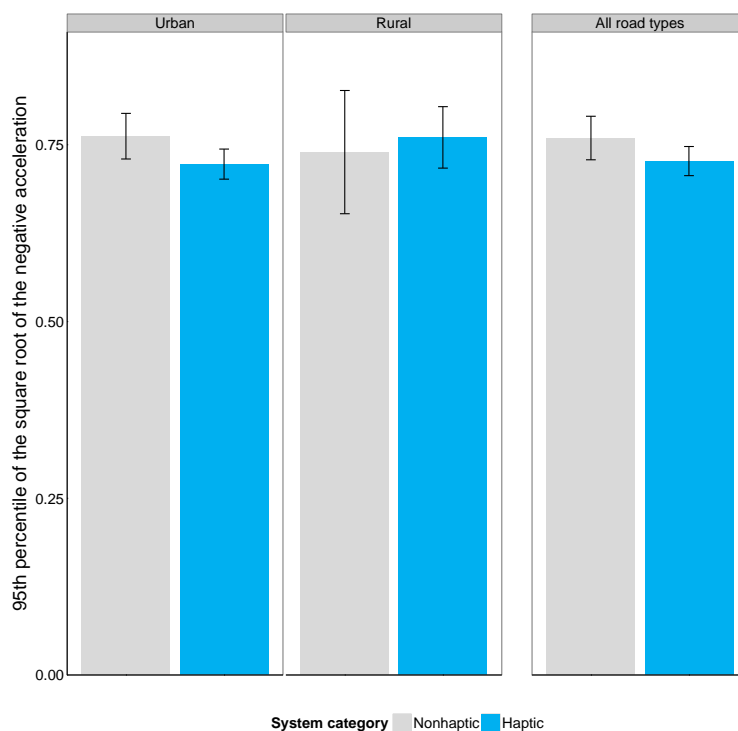


Figure 177: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 472: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	0.762	0.723	0.040	0.085
Rural	0.740	0.760	-0.021	0.971
All road types	0.760	0.727	0.033	0.044

**Preliminary conclusions:**

The usage of a haptic feedback does not significantly reduce the estimated average deceleration for both urban and rural driving environments.

### 7.26.2 Results summary

Table 473: Comparisons of the effect size (difference between system category and its corresponding baseline).

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	0.019	0.02 (N.S.)	0.031 (N.S.)	0.007 (N.S.)	0.04 (N.S.)	-
Rural	-0.077	0.055 (N.S.)	0.140	-0.051 (N.S.)	-0.021 (N.S.)	-
All road types	0.012	0.024	0.045	0.005 (N.S.)	0.033	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	2.39	2.61 (N.S.)	4.19 (N.S.)	0.76 (N.S.)	5.25 (N.S.)	-
Rural	-11.03	6.51 (N.S.)	15.75	-7.55 (N.S.)	-2.84 (N.S.)	-
All road types	1.53	3.07	5.72	0.56 (N.S.)	4.3	-

### 7.26.3 Conclusions and implications

The usage of the ecoDriver systems reduces significantly the extreme deceleration values before zebra crossings in urban driving environments. The back transformed extreme deceleration model based estimates are reduced from  $-0.66 \text{ m/s}^2$  to  $-0.63 \text{ m/s}^2$  for urban driving. In rural environments, the extreme decelerations significantly increase when all ecoDriver systems are evaluated together, which is an unexpected effect.

Looking at embedded systems only, the deceleration values are reduced both for urban and rural roads, but the significance condition is only met when all road types are considered together.

For the FeDS system, the reduction of extreme deceleration values is significant when considering only rural roads and for all road types.

The expected average differences are not significant for the App baseline vs. App condition and are also not significant for the non-haptic vs. haptic condition in both urban and rural environments.

This implies there is significant evidence that the usage of an ecoDriver system can have an influence on the actual driving behaviour before the event of zebra crossings. However, as this effect is only significant for some configurations, there is still room for improvement, especially for the app in urban and rural environments.

## 7.27 Hypothesis 36: Using an ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before speed bumps

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before speed bumps*

1. Using an ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before speed bumps. [Type A]
2. Using an embedded ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before speed bumps. [Type B]
3. Using the full ecoDriver system (FeDS), the 95th percentile of the negative acceleration will be closer to zero before speed bumps. [Type C]
4. Using the ecoDriver application, (App), the 95th percentile of the negative acceleration will be closer to zero before speed bumps. [Type D]
5. Using a haptic ecoDriver, the 95th percentile of the negative acceleration will be closer to zero before speed bumps. [Type E]

#### Performance indicator (PI):

95th percentile of the negative acceleration before speed bumps (sqrt\_percentil\_neg\_acc\_95)

#### Data reduction method:

Event-based

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced. Satterthwaite approximation for DoF, and Tukey multiple comparisons test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> <b>(Type A dataset)</b> <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline</li> <li>• Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> <b>(Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_embedded</li> <li>• Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b> <b>(Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_FeDS</li> <li>• FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id

## Hypothesis analysis summary table

<b>Baseline App vs App (Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Non-haptic vs Haptic (Type E dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	none
	Random effects	Driver_id

### 7.27.1 Controlled studies

#### 7.27.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 474: Anova type III table for type A comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	2.46	2.46	1	2652.8	29.2	<0.001
road_type	2.53	2.53	1	2459.2	30.0	<0.001
Main_effect:road_type	0.37	0.37	1	2642.5	4.3	0.037

Table 475: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.04	0.96	1.13	<0.001
Treatment	-0.07	-0.09	-0.04	<0.001
Rural	0.18	0.11	0.25	<0.001
Treatment:Rural	-0.08	-0.16	-0.01	0.037
Random part	N			
Speed_limit	0			
Driver_id	78			
Vmc_id	4			
Number of observations	2889			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

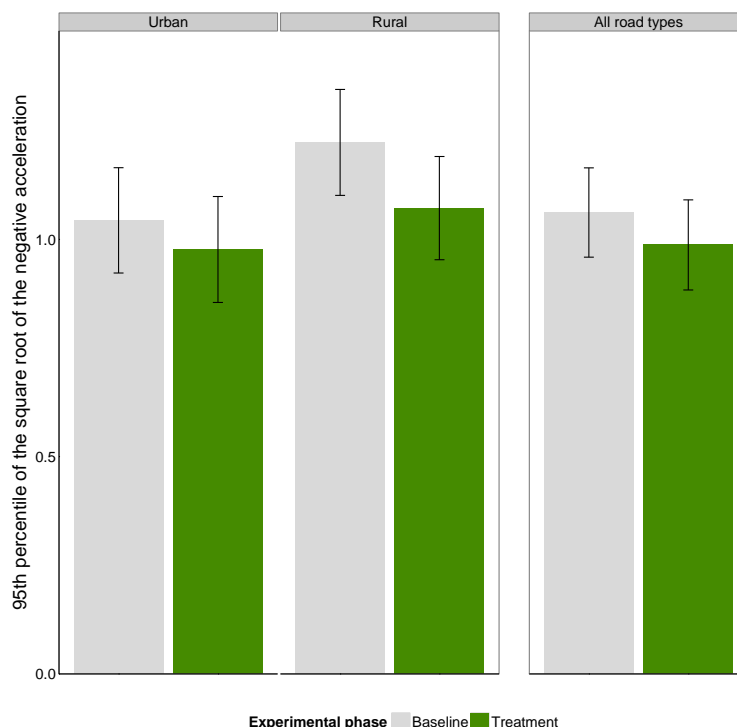


Figure 178: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 476: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	1.044	0.977	0.067	<0.001
Rural	1.223	1.072	0.151	<0.001
All road types	1.062	0.987	0.075	<0.001

#### Preliminary conclusions:

The treatment condition decreases significantly the PI compared to baseline. The model based estimates are lower for urban driving. The ecoDriver system's positive impact when driving on rural is stronger compared to urban driving. The back transformed extreme deceleration model based estimates are reduced from  $-1.50 \text{ m/s}^2$  to  $-1.15 \text{ m/s}^2$  for rural driving.

### 7.27.1.2 Type B: Baseline embedded vs embedded

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 477: Anova type III table for type B comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	2.02	2.02	1	1069.1	20.6	<0.001
road_type	1.97	1.97	1	1032.1	20.0	<0.001
Main_effect:road_type	0.05	0.05	1	1056.7	0.5	0.473

Table 478: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.07	0.93	1.21	<0.001
Embedded	-0.12	-0.17	-0.07	<0.001
Rural	0.19	0.08	0.29	<0.001
Embedded:Rural	-0.04	-0.16	0.08	0.473
Random part	N			
Speed_limit	0			
Driver_id	38			
Vmc_id	3			
Number of observations	1266			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.



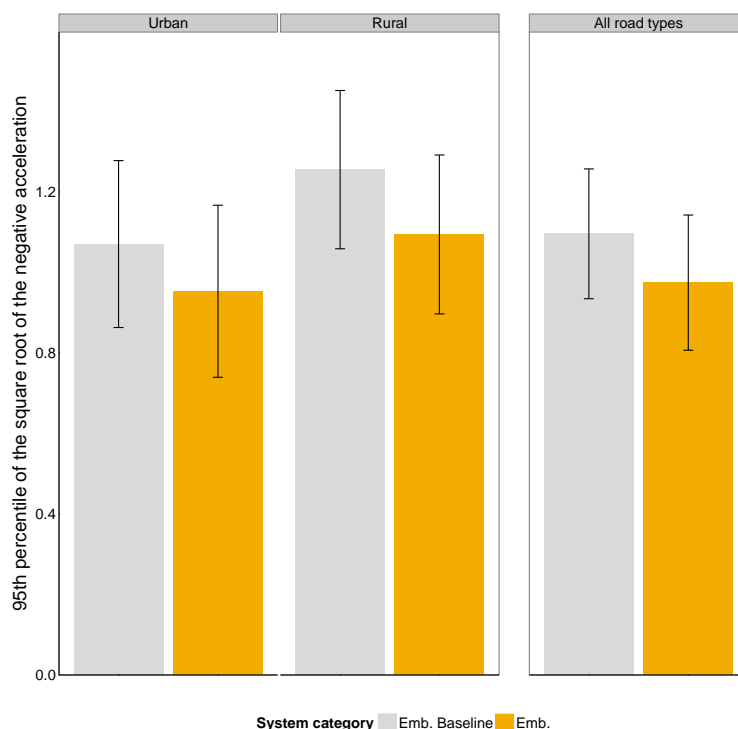


Figure 179: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 479: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	1.071	0.953	0.117	<0.001
Rural	1.256	1.095	0.161	0.019
All road types	1.096	0.975	0.121	<0.001

**Preliminary conclusions:**

Embedded systems lower the PI significantly compared to their baseline on urban and rural roads.

## 7.27.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 480: Anova type III table for type C comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	2.84	2.84	1	516.0	26.0	<0.001
road_type	1.80	1.80	1	504.4	16.5	<0.001
Main_effect:road_type	0.02	0.02	1	506.5	0.2	0.692

Table 481: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.13	0.92	1.34	0.006
FeDS	-0.19	-0.26	-0.12	<0.001
Rural	0.14	0.03	0.26	0.014
FeDS:Rural	0.03	-0.11	0.16	0.692
Random part	N			
Speed_limit	0			
Driver_id	26			
Vmc_id	2			
Number of observations	531			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

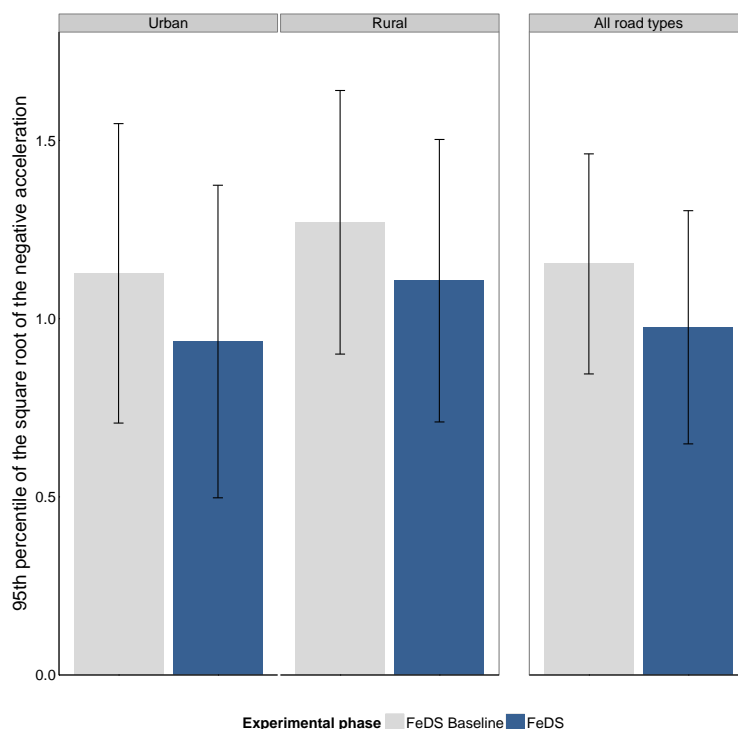


Figure 180: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 482: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	1.127	0.936	0.191	<0.001
Rural	1.270	1.107	0.164	0.028
All road types	1.154	0.976	0.178	<0.001

**Preliminary conclusions:**

The FeDS condition lowers the expected system extreme deceleration significantly in urban and rural driving environments.

## 7.27.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 483: Anova type III table for type D comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.83	0.83	1	1580.8	11.1	<0.001
road_type	0.57	0.57	1	1005.3	7.6	0.006
Main_effect:road_type	0.21	0.21	1	1580.4	2.8	0.094

Table 484: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.02	0.99	1.05	<0.001
App	-0.05	-0.07	-0.02	0.002
Rural	0.14	0.04	0.23	0.005
App:Rural	-0.09	-0.20	0.02	0.094
Random part	N			
Speed_limit	0			
Driver_id	40			
Vmc_id	2			
Number of observations	1623			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

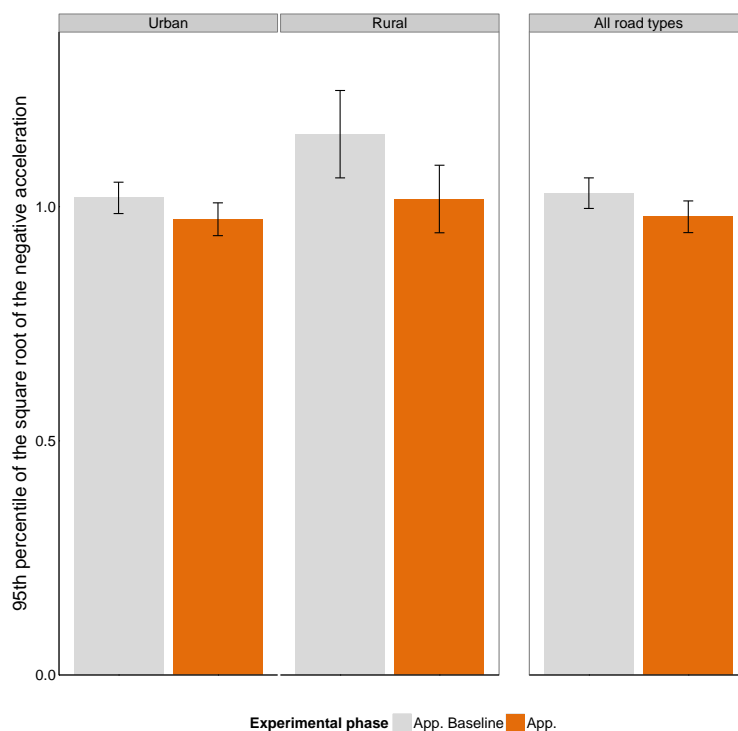


Figure 181: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 485: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	1.019	0.973	0.046	0.008
Rural	1.155	1.017	0.138	0.040
All road types	1.029	0.979	0.050	<0.001

**Preliminary conclusions:**

The ecoDriver App lowers the expected system extreme deceleration significantly in urban and rural driving environments, but the effect is somewhat smaller than with the other systems.

## 7.27.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 486: Anova type III table for type E comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.01	0.01	1	182.0	0.1	0.736

Table 487: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.92	0.83	1.02	<0.001
Haptic	-0.02	-0.13	0.09	0.736
Random part	N			
Speed_limit	0			
Driver_id	12			
Vmc_id	1			
Number of observations	228			

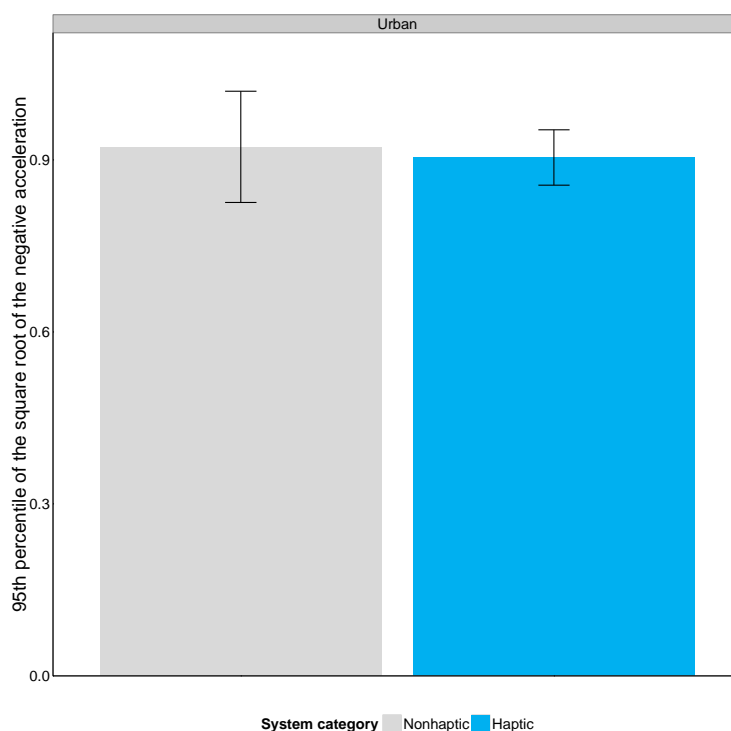


Figure 182: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 488: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	0.92	0.90	0.02	0.736

**Preliminary conclusions:**

The use of a haptic feedback does not significantly change the estimated average extreme deceleration.

### 7.27.2 Results summary

Table 489: Comparisons of the effect size (difference between system category and its corresponding baseline).

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	0.067	0.117	0.191	0.046	0.019 (N.S.)	-
Rural	0.151	0.161	0.164	0.138	-	-
All road types	0.075	0.121	0.178	0.050	-	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	6.43	10.95	16.96	4.49	2.06 (N.S.)	-
Rural	12.37	12.82	12.89	11.98	-	-
All road types	7.02	11.06	15.4	4.91	-	-

### 7.27.3 Conclusions and implications

The usage of the ecoDriver systems reduces significantly the extreme deceleration values before speed bumps. The back transformed extreme deceleration model based estimates are reduced from  $-1.50 \text{ m/s}^2$  to  $-1.15 \text{ m/s}^2$  for rural driving. There is also a reduction of the expected average extreme deceleration for the hypotheses ecoDriver system, embedded systems, FeDS, and App system compared to their respective baselines. The expected average differences are significant for the baseline vs. treatment condition, embedded baseline vs. embedded condition, and FeDS baseline vs. FeDS. Only the haptic condition does not show a significant change compared to the non-haptic condition.

This implies there is significant evidence that the usage of an ecoDriver system has an influence on the actual driving behaviour before the event of speed bumps. Furthermore, assuming that less

deceleration corresponds to longer coasting and hence the predictive awareness is increased before the event of speed bumps.

Compared to other events i.e. sharp curves and zebra crossings the difference of the model based average estimates is much stronger. Furthermore, in the evaluation data set, only data for urban driving environments were available.



## 7.28 Hypothesis 37: Using an ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before sharp curves

### Hypothesis analysis summary table

Hypotheses formulations:

*Using an ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before sharp curves*

1. Using an ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before sharp curves. [Type A]
2. Using an embedded ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before sharp curves. [Type B]
3. Using the full ecoDriver system (FeDS), the 95th percentile of the negative acceleration will be closer to zero before sharp curves. [Type C]
4. Using the ecoDriver application, (App), the 95th percentile of the negative acceleration will be closer to zero before sharp curves. [Type D]
5. Using a haptic ecoDriver, the 95th percentile of the negative acceleration will be closer to zero before sharp curves. [Type E]

#### Performance indicator (PI):

95th percentile of the negative acceleration before sharp curves (sqrt\_percentil\_neg\_acc\_95)

#### Data reduction method:

Event-based

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced. Satterthwaite approximation for DoF, and Tukey multiple comparisons test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> <b>(Type A dataset)</b> <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline</li> <li>• Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> <b>(Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_embedded</li> <li>• Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b> <b>(Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_FeDS</li> <li>• FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id

## Hypothesis analysis summary table

<b>Baseline App vs App (Type D dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Non-haptic vs Haptic (Type E dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 7.28.1 Controlled studies

#### 7.28.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 490: Anova type III table for type A comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	3.0	3.0	1	11327.4	39.9	<0.001
road_type	19.4	19.4	1	11310.0	261.9	<0.001
Main_effect:road_type	0.0	0.0	1	11226.2	0.2	0.680

Table 491: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.07	0.97	1.16	<0.001
Treatment	-0.04	-0.05	-0.02	<0.001
Rural	-0.09	-0.11	-0.07	<0.001
Treatment:Rural	0.00	-0.03	0.02	0.680
Random part	N			
Speed_limit	0			
Driver_id	143			
Vmc_id	7			
Number of observations	11434			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

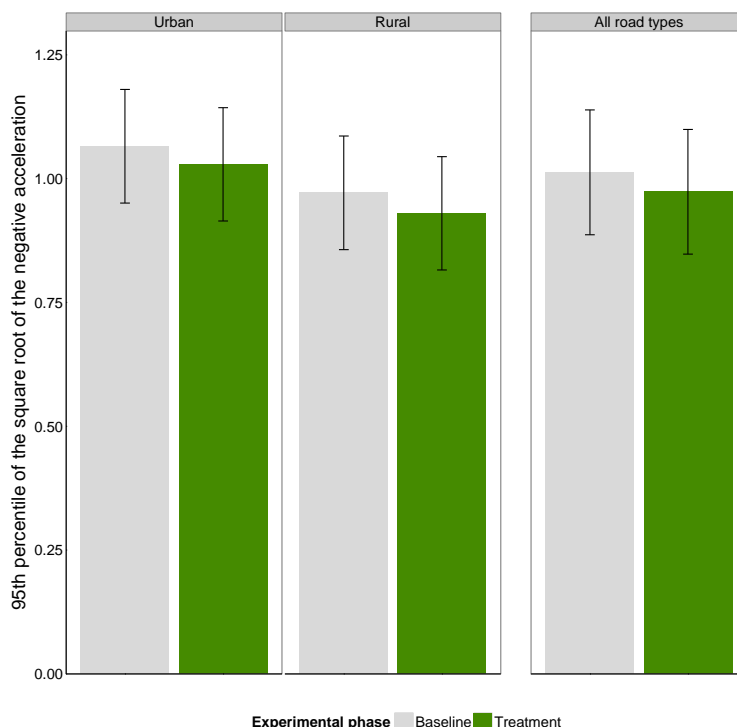


Figure 183: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 492: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	1.066	1.029	0.037	<0.001
Rural	0.971	0.930	0.041	<0.001
All road types	1.013	0.974	0.039	<0.001

#### Preliminary conclusions:

The treatment condition decreases significantly the PI compared to baseline. The back transformed extreme deceleration model based estimates are reduced from  $-1.14 \text{ m/s}^2$  to  $-1.06 \text{ m/s}^2$  for urban driving. The ecoDriver systems positive impact when driving on rural compared to urban is equal.

#### 7.28.1.2 Type B: Baseline embedded vs embedded

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 493: Anova type III table for type B comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	3.5	3.5	1	9727.5	45.7	<0.001
road_type	12.1	12.1	1	9725.0	157.6	<0.001
Main_effect:road_type	0.0	0.0	1	9674.2	0.4	0.504

Table 494: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.04	0.93	1.15	<0.001
Embedded	-0.04	-0.06	-0.02	<0.001
Rural	-0.08	-0.11	-0.06	<0.001
Embedded:Rural	-0.01	-0.04	0.02	0.504
Random part	N			
Speed_limit	0			
Driver_id	103			
Vmc_id	6			
Number of observations	9831			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

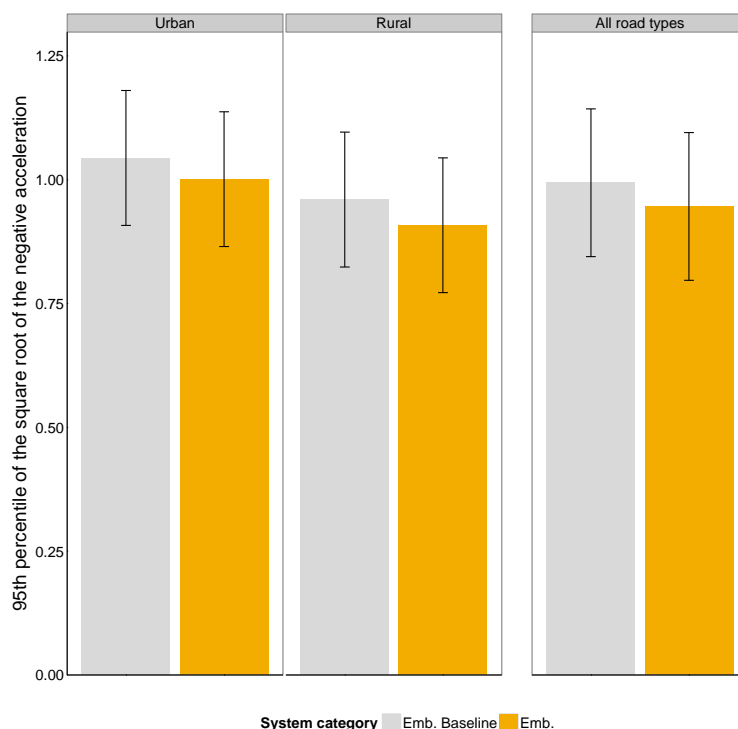


Figure 184: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 495: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	1.044	1.001	0.043	<0.001
Rural	0.960	0.908	0.052	<0.001
All road types	0.994	0.946	0.048	<0.001

**Preliminary conclusions:**

Embedded systems lower the PI significantly compared to their baseline. The effect is in rural environments even stronger than in urban environments.

## 7.28.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 496: Anova type III table for type C comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.4	0.4	1	2109.5	6.2	0.013
road_type	5.9	5.9	1	2109.1	91.7	<0.001
Main_effect:road_type	0.0	0.0	1	2077.0	0.6	0.446

Table 497: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.12	1.02	1.22	<0.001
FeDS	-0.02	-0.06	0.02	0.274
Rural	-0.12	-0.16	-0.08	<0.001
FeDS:Rural	-0.02	-0.07	0.03	0.446
Random part	N			
Speed_limit	0			
Driver_id	59			
Vmc_id	3			
Number of observations	2127			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

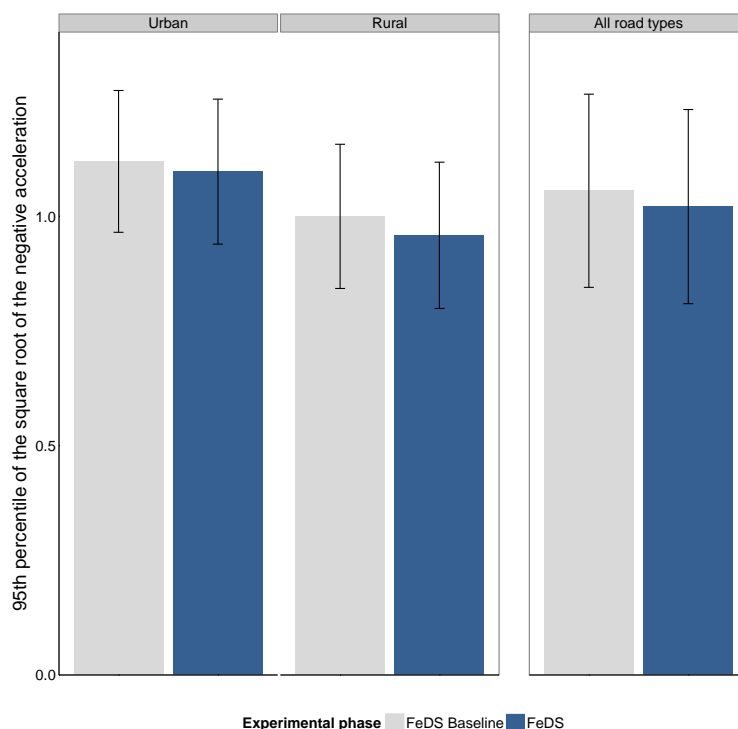


Figure 185: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 498: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	1.120	1.098	0.022	0.688
Rural	1.000	0.959	0.041	0.029
All road types	1.056	1.021	0.035	0.006

**Preliminary conclusions:**

The FeDS condition lowers the expected system extreme deceleration. However, this difference is only significant in rural environments, whereas in urban environments the difference to the baseline is not significant.

## 7.28.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 499: Anova type III table for type D comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.0	0.0	1	1594.2	0.0	0.976
road_type	6.5	6.5	1	1567.9	112.8	<0.001
Main_effect:road_type	0.0	0.0	1	1565.3	0.4	0.511

Table 500: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.15	1.12	1.18	<0.001
App	0.01	-0.02	0.04	0.644
Rural	-0.12	-0.15	-0.09	<0.001
App:Rural	-0.02	-0.06	0.03	0.511
Random part	N			
Speed_limit	0			
Driver_id	40			
Vmc_id	2			
Number of observations	1603			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.



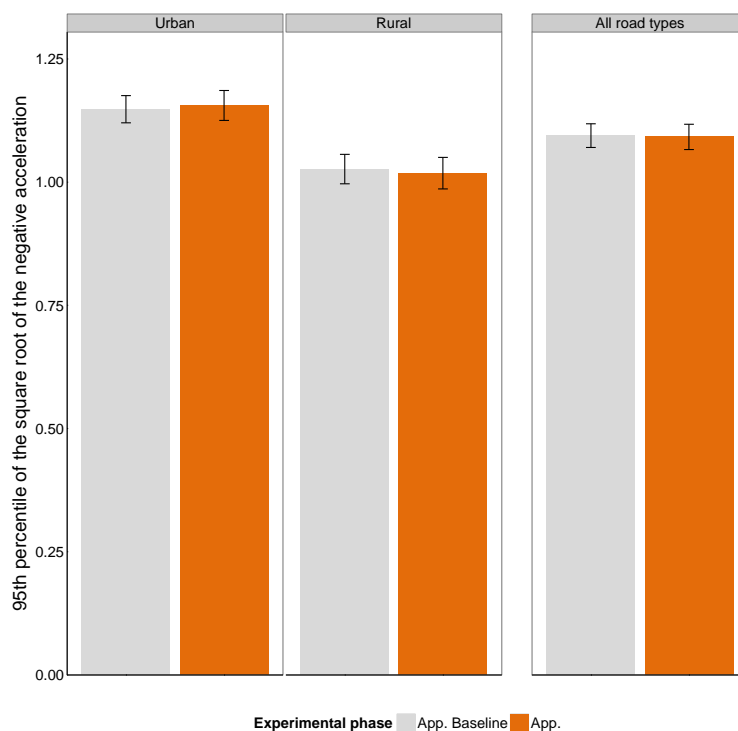


Figure 186: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 501: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	1.148	1.156	-0.008	0.967
Rural	1.027	1.018	0.008	0.968
All road types	1.094	1.092	0.002	0.852

**Preliminary conclusions:**

The difference between the ecoDriver App and its baseline is highly non-significant. Furthermore, the estimated model based average extreme deceleration is stronger for the App condition in urban environments.

### 7.28.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 502: Anova type III table for type E comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.9	0.9	1	2758.9	11.9	<0.001
road_type	7.3	7.3	1	2748.6	91.7	<0.001
Main_effect:road_type	0.6	0.6	1	2742.0	8.0	0.005

Table 503: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.94	0.87	1.00	<0.001
Haptic	-0.08	-0.11	-0.04	<0.001
Rural	-0.15	-0.19	-0.11	<0.001
Haptic:Rural	0.07	0.02	0.11	0.005
Random part	N			
Speed_limit	0			
Driver_id	36			
Vmc_id	2			
Number of observations	2815			

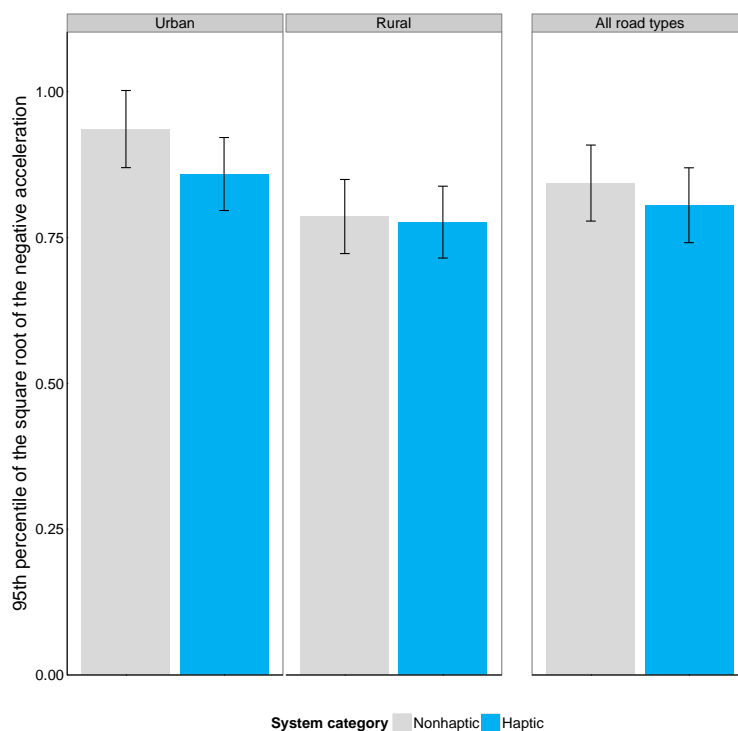


Figure 187: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 504: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	0.936	0.859	0.077	<0.001
Rural	0.786	0.776	0.010	0.931
All road types	0.843	0.805	0.038	0.003

**Preliminary conclusions:**

The use of a haptic feedback can further reduce the estimated average extreme deceleration. This is in rural environments however not significant. In contrast, the difference in urban environments is highly significant, as a haptic feedback can additionally guide the driver when he is distracted by the traffic situation. The back transformed extreme deceleration model based estimates are reduced from  $-0.88 \text{ m/s}^2$  to  $-0.74 \text{ m/s}^2$  for the haptic condition compared to the non-haptic condition in urban driving environments.

### 7.28.2 Results summary

Table 505: Comparisons of the effect size (difference between system category and its corresponding baseline).

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	0.037	0.043	0.022 (N.S.)	-0.008 (N.S.)	0.077	-
Rural	0.041	0.052	0.041	0.008 (N.S.)	0.01 (N.S.)	-
All road types	0.039	0.048	0.035	0.002 (N.S.)	0.038	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	3.44	4.09	1.96 (N.S.)	-0.7 (N.S.)	8.24	-
Rural	4.25	5.41	4.13	0.78 (N.S.)	1.27 (N.S.)	-
All road types	3.88	4.8	3.28	0.18 (N.S.)	4.51	-

### 7.28.3 Conclusions and implications

The usage of the ecoDriver systems reduces significantly the extreme deceleration values before sharp curves. The back transformed extreme deceleration model based estimates are reduced from  $-1.14 \text{ m/s}^2$  to  $-1.06 \text{ m/s}^2$  for urban driving. There is also a reduction of the expected average extreme deceleration for all five hypotheses, i.e. for all ecoDriver system, embedded systems, FeDS, App, and haptic system compared to their respective baselines. Only the App has a stronger expected average extreme deceleration in rural driving environment, compared to the baseline. The expected average differences are significant for the baseline vs. treatment condition, embedded baseline vs. embedded condition, FeDS baseline vs. FeDS condition (only in rural environments), and non-haptic vs. haptic condition (only in urban environments). The back transformed extreme deceleration model based estimates are reduced from  $-0.88 \text{ m/s}^2$  to  $-0.74 \text{ m/s}^2$  for the haptic condition compared to the non-haptic condition in urban driving environments. The expected average differences are not significant for the FeDS baseline vs. FeDS condition (in urban environments), non-haptic vs. haptic condition (in rural environments), and especially for the App baseline vs. App condition.

This implies there is significant evidence that the usage of an ecoDriver system has an influence on the actual driving behaviour before the event of sharp curves. Furthermore, assuming that less deceleration corresponds to longer coasting and hence the predictive awareness is increased before the event of sharp curves.

Presumably, the deceleration reduction has the largest effect when using an embedded system, which can be further strengthened if a haptic accelerator pedal is used in urban environments. In general, the model based average estimated extreme deceleration values before sharp curves are much stronger in urban areas compared to rural environments.

## 7.29 Hypothesis 38: Using an ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero at crests

### Hypothesis analysis summary table

Hypotheses formulations:

*Compared to baseline the acceleration distribution will change when using an ecoDriver system at crests*  
*Using an ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero at crests*

1. Using an ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero at crests. [Type A]
2. Using an embedded ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero at crests. [Type B]
3. Using the full ecoDriver system (FeDS), the 95th percentile of the negative acceleration will be closer to zero at crests. [Type C]
4. Using the ecoDriver application, (App), the 95th percentile of the negative acceleration will be closer to zero at crests. [Type D]
5. Using a haptic ecoDriver, the 95th percentile of the negative acceleration will be closer to zero at crests. [Type E]

#### Performance indicator (PI):

95th percentile of the negative acceleration at crests (sqrt\_percentil\_neg\_acc\_95)

#### Data reduction method:

Event-based

#### Statistical models

Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced.  
 Satterthwaite approximation for DoF, and Tukey multiple comparisons test.

#### Statistical analysis information

<b>Baseline vs Treatment</b> <b>(Type A dataset)</b> <b>For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline</li> <li>• Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded</b> <b>(Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_embedded</li> <li>• Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b> <b>(Type C dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>• Baseline_FeDS</li> <li>• FeDS</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id

## Hypothesis analysis summary table

<b>Baseline App vs App</b> (Type D dataset)	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	none
	Random effects	Driver_id
<b>Non-haptic vs Haptic</b> (Type E dataset)	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	none
	Random effects	Driver_id

### 7.29.1 Controlled studies

#### 7.29.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 506: Anova type III table for type A comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
<b>Main effect</b>	0.09	0.09	1	1418.5	1.8	0.184
<b>road_type</b>	0.43	0.43	1	1365.9	8.3	0.004
<b>Main effect:road type</b>	0.05	0.05	1	1396.8	1.0	0.319

Table 507: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.76	0.63	0.89	<0.001
Treatment	-0.01	-0.06	0.05	0.841
Rural	0.07	0.02	0.13	0.010
Treatment:Rural	-0.03	-0.09	0.03	0.319
<b>Random part</b>	<b>N</b>			
Speed_limit	0			
Driver_id	110			
Vmc_id	7			
Number of observations	1431			

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

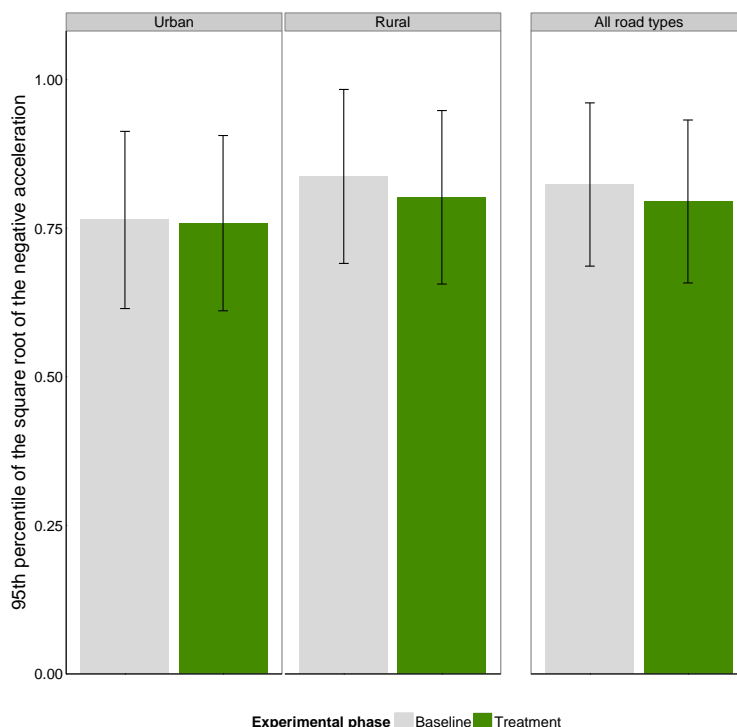


Figure 188: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 508: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	0.764	0.759	0.005	0.997
Rural	0.837	0.802	0.035	0.103
All road types	0.823	0.795	0.028	0.035

#### Preliminary conclusions:

On urban roads, there is no significant change in the 95<sup>th</sup> percentile of negative acceleration from baseline to treatment. On rural roads, the negative acceleration was reduced by a similar amount as before sharp curves. The Tukey test indicator of 0.10 is, however, somewhat above the maximum 0.05 for a significant result. For the sharp curves approach, there are almost 10 times as many observations as for crests. It is therefore quite likely that a significant effect could be found for crests if more samples were available.

### 7.29.1.2 Type B: Baseline embedded vs embedded

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 509: Anova type III table for type B comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.15	0.15	1	1232.3	3.0	0.085
road_type	0.46	0.46	1	1201.4	9.2	0.002
Main_effect:road_type	0.10	0.10	1	1217.6	2.0	0.161

Table 510: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.76	0.61	0.91	<0.001
Embedded	-0.01	-0.05	0.04	0.838
Rural	0.08	0.03	0.14	0.004
Embedded:Rural	-0.04	-0.10	0.02	0.161
Random part	N			
Speed_limit	0			
Driver_id	80			
Vmc_id	6			
Number of observations	1241			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.



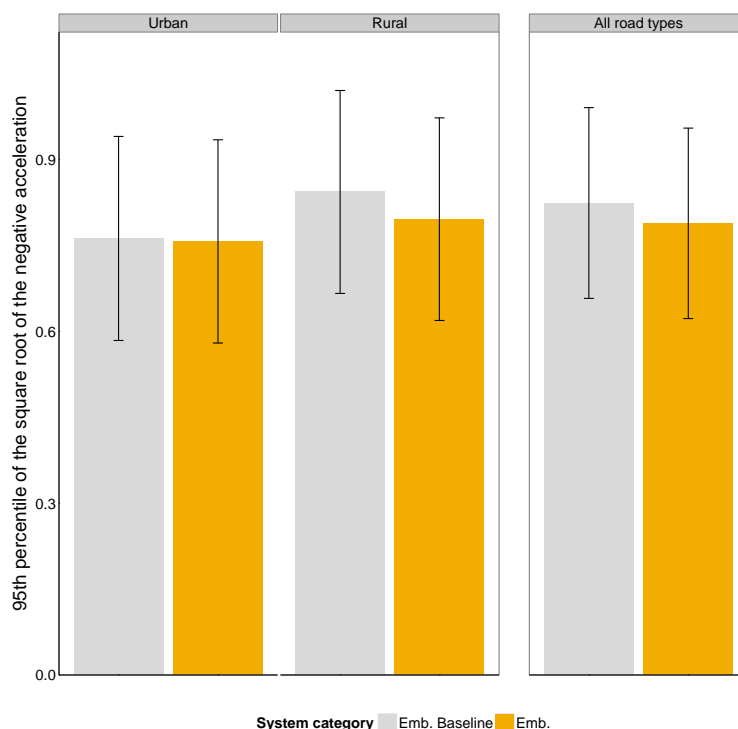


Figure 189: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 511: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	0.762	0.757	0.005	0.997
Rural	0.844	0.796	0.047	0.025
All road types	0.824	0.789	0.036	0.012

**Preliminary conclusions:**

For embedded systems, the 95<sup>th</sup> percentile of negative acceleration is lowered significantly for rural roads. The amount of change is similar to the type A comparison with all the systems where the change was, however, not significant. On urban roads, there is no significant effect.

## 7.29.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 512: Anova type III table for type C comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.15	0.15	1	871.6	2.5	0.117
road_type	0.73	0.73	1	854.8	12.1	<0.001
Main_effect:road_type	0.10	0.10	1	873.8	1.7	0.197

Table 513: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.85	0.68	1.02	<0.001
FeDS	-0.01	-0.06	0.05	0.849
Rural	0.10	0.04	0.17	0.002
FeDS:Rural	-0.05	-0.12	0.02	0.197
Random part	N			
Speed_limit	0			
Driver_id	43			
Vmc_id	3			
Number of observations	885			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

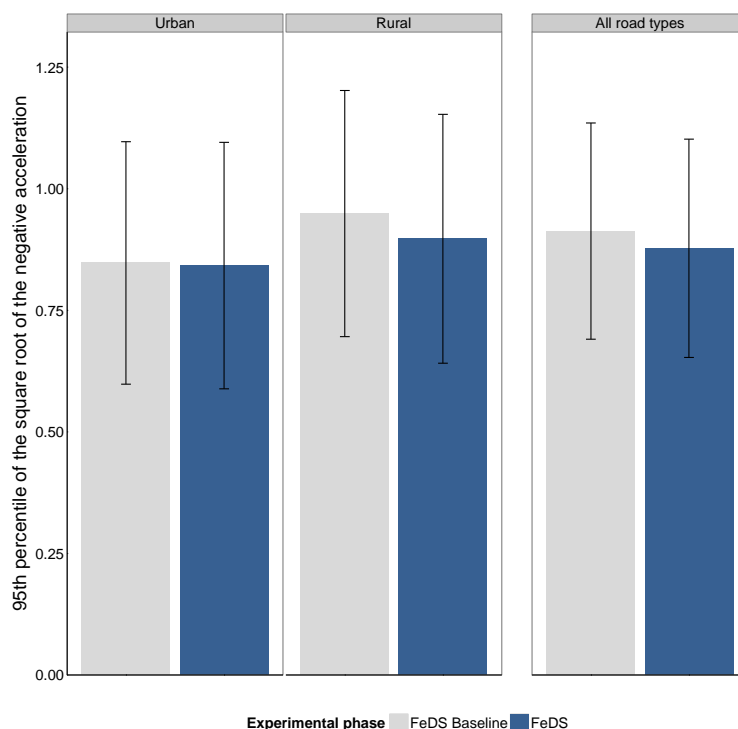


Figure 190: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 514: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	0.848	0.842	0.005	0.997
Rural	0.949	0.897	0.052	0.105
All road types	0.913	0.877	0.036	0.048

#### Preliminary conclusions:

With the FeDS, there is no significant change of the 95<sup>th</sup> percentile of negative acceleration at crests on urban roads. On rural roads, the significance condition is violated only slightly and the 95<sup>th</sup> percentile of negative acceleration was lowered by a similar amount as by the embedded systems.

## 7.29.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 515: Anova type III table for type D comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.01	0.01	1	177.2	0.1	0.742

Table 516: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.83	0.78	0.88	<0.001
Haptic	0.01	-0.07	0.09	0.742
Random part	N			
Speed_limit	0			
Driver_id	30			
Vmc_id	1			
Number of observations	189			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

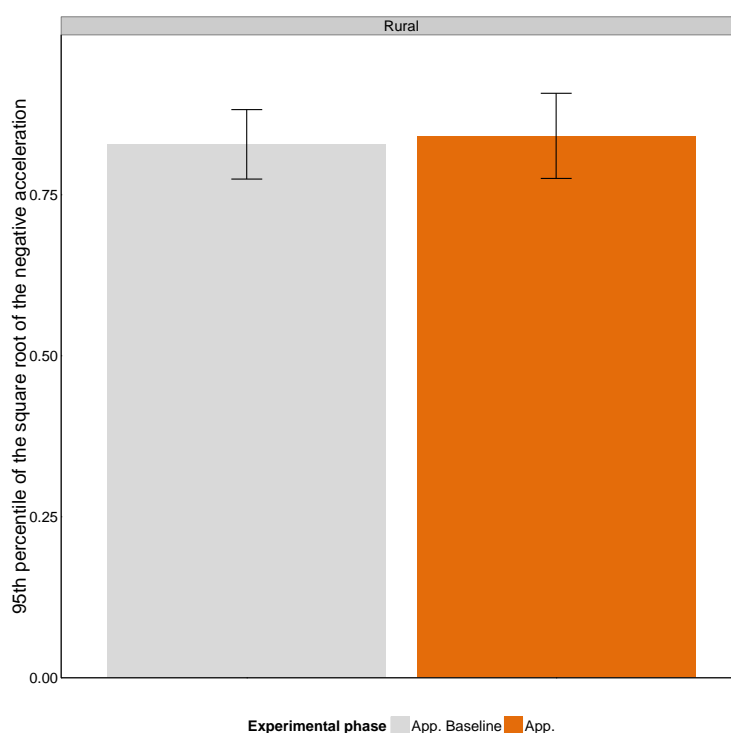


Figure 191: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 517: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

Model based average estimates				
	Baseline	App	Difference (B-A)	Tukey multiple comparisons significance test
Rural	0.828	0.842	-0.013	0.741

**Preliminary conclusions:**

For the Android App analysis, there are only samples for rural roads. There is no significant effect on the 95<sup>th</sup> percentile of negative acceleration at crests.

**7.29.1.5 Type E: Non-haptic vs Haptic**

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 518: Anova type III table for type E comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.02	0.02	1	120.7	1.1	0.290

Table 519: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.61	0.56	0.67	<0.001
Haptic	0.02	-0.02	0.07	0.290
Random part	N			
Speed_limit	0			
Driver_id	36			
Vmc_id	2			
Number of observations	150			

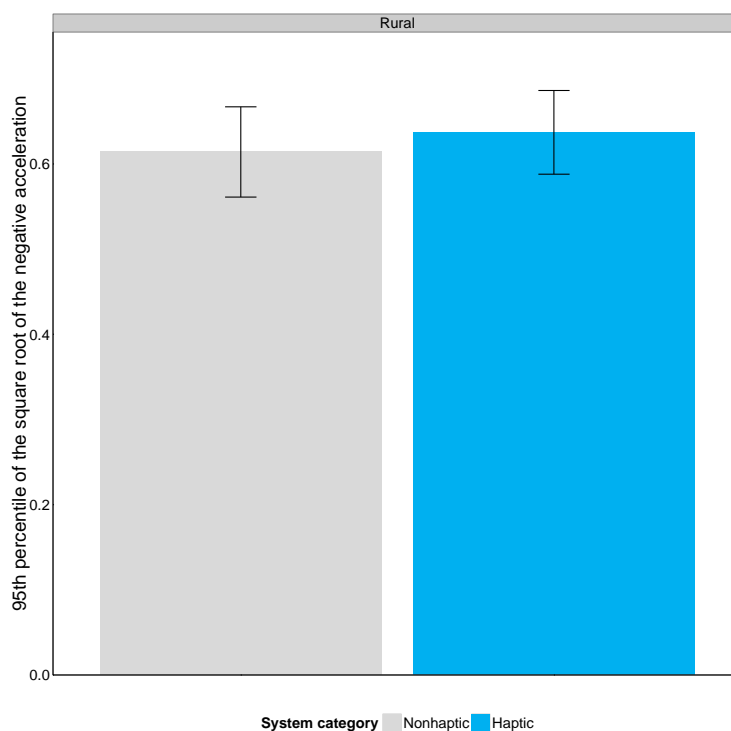


Figure 192: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 520: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Rural	0.614	0.637	-0.023	0.288

**Preliminary conclusions:**

There is no significant change introduced by the haptic system.

### 7.29.2 Results summary

Table 521: Comparisons of the effect size (difference between system category and its corresponding baseline).

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom )
Urban	0.005 (N.S.)	0.005 (N.S.)	0.005 (N.S.)	- (N.S.)	- (N.S.)	-
Rural	0.035 (N.S.)	0.047	0.052 (N.S.)	-0.013 (N.S.)	-0.023 (N.S.)	-
All road types	0.028	0.036	0.036	- (N.S.)	- (N.S.)	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom )
Urban	0.65 (N.S.)	0.66 (N.S.)	0.59 (N.S.)	-	-	-
Rural	4.18 (N.S.)	5.62	5.48 (N.S.)	-1.57 (N.S.)	-3.75 (N.S.)	-
All road types	3.44	4.31	3.89	-	-	-

### 7.29.3 Conclusions and implications

Probably due to the smaller number of samples compared to the sharp curve approach, most analyses of the effect of the ecoDriver system on deceleration at crests do not show statistically significant results. Only the effect of embedded systems at crests on rural roads is significant. In that comparison, the model-based average estimate of the 95<sup>th</sup> percentile of negative acceleration changes from 0.844 to 0.796 by using the ecoDriver system. Transformed back to deceleration, this is a change from -0.71 to -0.63 m/s<sup>2</sup>. The magnitude of this effect is similar to the one for the significant effects before sharp curves.

The effects of all systems (treatment in type A comparison) and the FeDS have a similar magnitude for rural roads but the significance condition is violated slightly. For urban roads, the effect is almost 0 and not significant at all in all the comparisons. The Android App shows no effect either, like in the case before sharp curves.

There is no significant change introduced by the haptic system.

The results suggest that the ecoDriver system does have a positive effect on the driving behaviour at crests, lowering deceleration, although the results do not have such strong significance values as other comparisons. Note that the change of the 95<sup>th</sup> percentile of negative acceleration at crests normally concerns the approach to the crest since the part after the crest mostly has positive acceleration.

### 7.30 Hypothesis 39: Using an ecoDriver system, the acceleration distribution will change before speed limit changes

Hypothesis analysis summary table		
Hypotheses formulations:		
<p><i>Compared to the corresponding baseline the acceleration distribution will change when using an ecoDriver system before speed limit changes (change from a higher speed limit to a lower speed limit)</i></p> <p><i>Using an ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before speed limit changes</i></p>		
<ol style="list-style-type: none"> <li>Using an ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before speed limit changes. [Type A]</li> <li>Using an embedded ecoDriver system, the 95th percentile of the negative acceleration will be closer to zero before speed limit changes. [Type B]</li> <li>Using the full ecoDriver system (FeDS), the 95th percentile of the negative acceleration will be closer to zero before speed limit changes. [Type C]</li> <li>Using the ecoDriver application, (App), the 95th percentile of the negative acceleration will be closer to zero before speed limit changes. [Type D]</li> <li>Using a haptic ecoDriver, the 95th percentile of the negative acceleration will be closer to zero before speed limit changes. [Type E]</li> </ol>		
<b>Performance indicator (PI):</b>		
95th percentile of the negative acceleration before speed limit changes (sqrt_percentil_neg_acc_95)		
<b>Data reduction method:</b>		
Event-based		
<b>Statistical models</b>		
Generalized linear mixed models, with type III errors being reported if the dataset is unbalanced. Satterthwaite approximation for DoF, and Tukey multiple comparisons test.		
<b>Statistical analysis information</b>		
<b>Baseline vs Treatment (Type A dataset) For both controlled and naturalistic data</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline</li> <li>Treatment</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline Emb. vs Embedded (Type B dataset)</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_embedded</li> <li>Embedded</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
<b>Baseline FeDS vs FeDS</b>	Main effect	<ul style="list-style-type: none"> <li>Baseline_FeDS</li> <li>FeDS</li> </ul>



Hypothesis analysis summary table		
(Type C dataset)	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
Baseline App vs App (Type D dataset)	Main effect	<ul style="list-style-type: none"> <li>Baseline_App</li> <li>App</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id, Vmc_id
Non-haptic vs Haptic (Type E dataset)	Main effect	<ul style="list-style-type: none"> <li>Non-haptic</li> <li>Haptic</li> </ul>
	Additional fixed effect	Road_type, Road_type*Main_effect
	Random effects	Driver_id

### 7.30.1 Controlled studies

#### 7.30.1.1 Type A: Baseline vs Treatment

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 522: Anova type III table for type A comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	1.1	1.1	1	10071.9	10.3	0.001
road_type	19.7	19.7	1	9758.2	185.0	<0.001
Main_effect:road_type	0.2	0.2	1	10023.6	2.3	0.129

Table 523: Model summary for type A comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.99	0.94	1.03	<0.001
Treatment	-0.01	-0.04	0.01	0.240
Rural	-0.09	-0.12	-0.07	<0.001
Treatment:Rural	-0.02	-0.05	0.01	0.129
Random part	N			
Speed_limit	8			

Driver_id	143
Vmc_id	7
Number of observations	10208

Reference of the model is baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

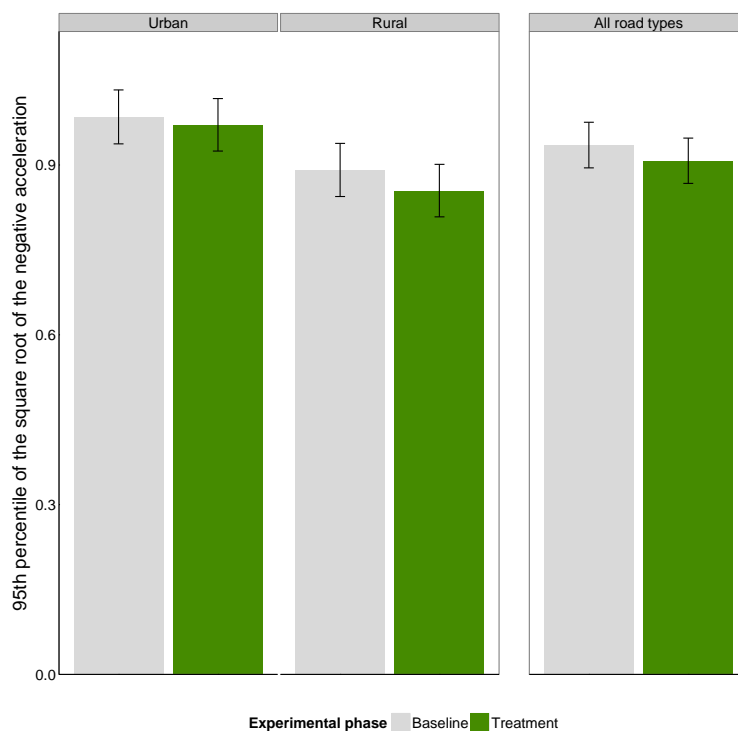


Figure 193: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 524: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-T)	Tukey multiple comparisons significance test
	Baseline	Treatment		
Urban	0.985	0.971	0.014	0.637
Rural	0.891	0.855	0.037	<0.001
All road types	0.935	0.908	0.028	<0.001

#### Preliminary conclusions:

The treatment condition decreases significantly the PI compared to baseline in rural driving environments. The back transformed extreme deceleration model based estimates are reduced from  $-0.79 \text{ m/s}^2$  to  $-0.73 \text{ m/s}^2$  for rural driving. The differences of the model based average estimates in urban driving environments however are not significant.

### 7.30.1.2 Type B: Baseline embedded vs embedded

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 525: Anova type III table for type B comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	1.6	1.6	1	8338.9	14.5	<0.001
road_type	16.1	16.1	1	5821.8	150.3	<0.001
Main_effect:road_type	0.1	0.1	1	8300.6	1.1	0.295

Table 526: Model summary for type B comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.97	0.94	1.01	<0.001
Embedded	-0.02	-0.05	0.00	0.067
Rural	-0.10	-0.13	-0.07	<0.001
Embedded:Rural	-0.02	-0.05	0.02	0.295
Random part	N			
Speed_limit	8			
Driver_id	103			
Vmc_id	6			
Number of observations	8455			

Reference of the model is the embedded baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

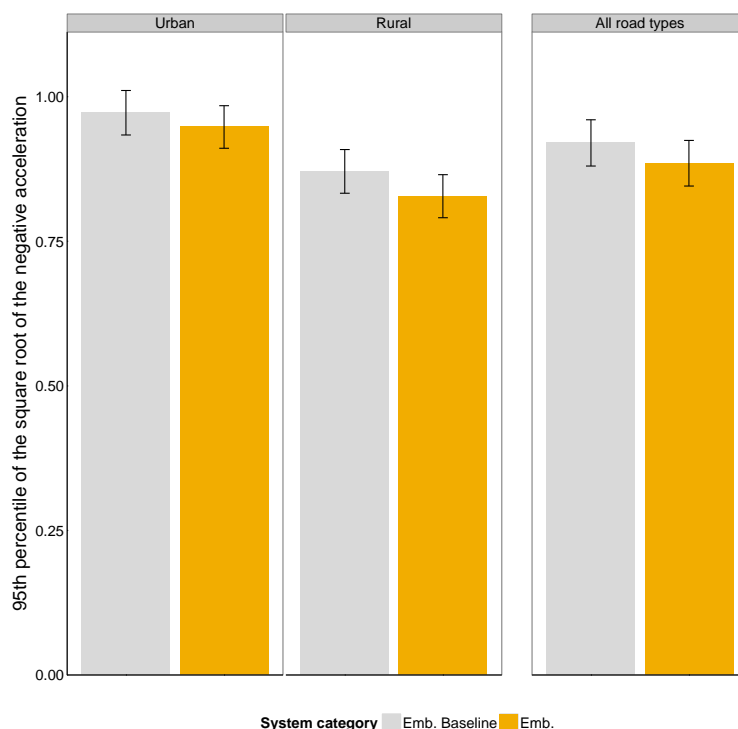


Figure 194: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 527: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-E)	Tukey multiple comparisons significance test
	Baseline	Embedded		
Urban	0.972	0.948	0.025	0.249
Rural	0.871	0.828	0.043	<0.001
All road types	0.920	0.885	0.035	<0.001

#### Preliminary conclusions:

Embedded systems lower the PI significantly compared to their baseline in rural environments. The differences of the model based average estimates in urban driving environments however are not significant.

## 7.30.1.3 Type C: Baseline FeDS vs FeDS

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 528: Anova type III table for type C comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.26	0.26	1	2719.9	2.7	0.103
road_type	14.53	14.53	1	2232.0	148.8	<0.001
Main_effect:road_type	0.04	0.04	1	2687.8	0.4	0.535

Table 529: Model summary for type C comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.01	0.95	1.07	<0.001
FeDS	-0.03	-0.07	0.01	0.125
Rural	-0.18	-0.22	-0.14	<0.001
FeDS:Rural	0.02	-0.03	0.07	0.535
Random part	N			
Speed_limit	8			
Driver_id	59			
Vmc_id	3			
Number of observations	2761			

Reference of the model is the FeDS baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

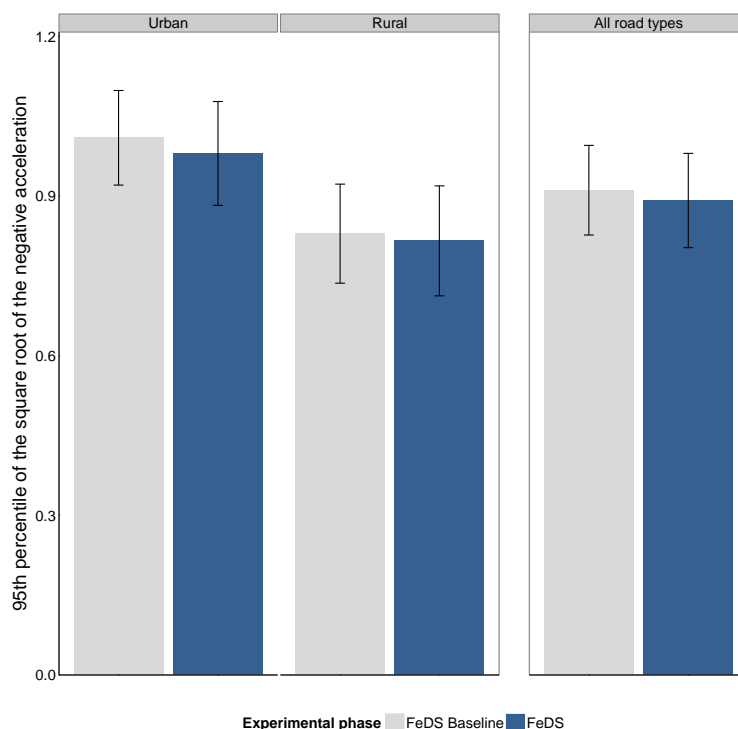


Figure 195: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 530: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-F)	Tukey multiple comparisons significance test
	Baseline	FeDS		
Urban	1.009	0.980	0.029	0.413
Rural	0.829	0.816	0.014	0.867
All road types	0.911	0.892	0.019	0.154

**Preliminary conclusions:**

The model based average estimates of the FeDS condition are in urban environments, as well as in rural environments lower than the FeDS baseline condition. However, this difference is in both urban and rural environments not significant.

## 7.30.1.4 Type D: Baseline App vs App

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 531: Anova type III table for type D comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.03	0.03	1	1731.5	0.3	0.596
road_type	2.44	2.44	1	1727.6	23.6	<0.001
Main_effect:road_type	0.05	0.05	1	1725.3	0.4	0.506

Table 532: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	1.05	1.01	1.08	<0.001
App	0.02	-0.04	0.08	0.477
Rural	-0.07	-0.12	-0.03	0.001
App:Rural	-0.02	-0.09	0.04	0.506
Random part	N			
Speed_limit	5			
Driver_id	40			
Vmc_id	2			
Number of observations	1753			

Reference of the model is the App baseline during urban driving condition. The estimated effect is the change on average when current condition is compared to the reference.

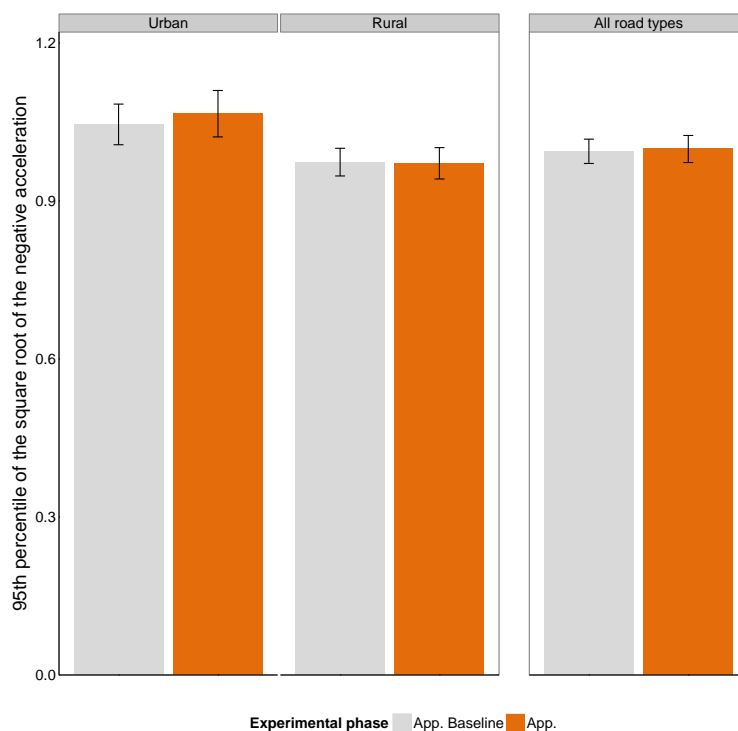


Figure 196: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 533: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (B-A)	Tukey multiple comparisons significance test
	Baseline	App		
Urban	1.045	1.066	-0.021	0.890
Rural	0.974	0.971	0.002	0.999
All road types	0.994	0.999	-0.004	0.779

**Preliminary conclusions:**

The difference between the ecoDriver App and its baseline is for both urban and rural driving environments highly non-significant. Furthermore, the estimated model based average extreme deceleration is stronger for the App condition in urban environments.



### 7.30.1.5 Type E: Non-haptic vs Haptic

Results for the mixed model analysis are provided below, taking into account the Satterthwaite approximation for the degrees of freedom.

Table 534: Anova type III table for type E comparison

Analysis of Variance Table of type III errors with Satterthwaite approximation for degrees of freedom						
	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Main_effect	0.03	0.03	1	1671.0	0.3	0.577
road_type	3.18	3.18	1	1659.3	31.8	<0.001
Main_effect:road_type	0.07	0.07	1	1687.4	0.7	0.400

Table 535: Model summary for type D comparison

Model summary				
Fixed part	Estimated effect	Lower bound	Upper bound	p-value
(Intercept)	0.92	0.87	0.97	<0.001
Haptic	0.03	-0.03	0.08	0.354
Rural	-0.09	-0.16	-0.03	0.006
Haptic:Rural	-0.03	-0.11	0.04	0.400
Random part	N			
Speed_limit	5			
Driver_id	36			
Vmc_id	2			
Number of observations	1707			

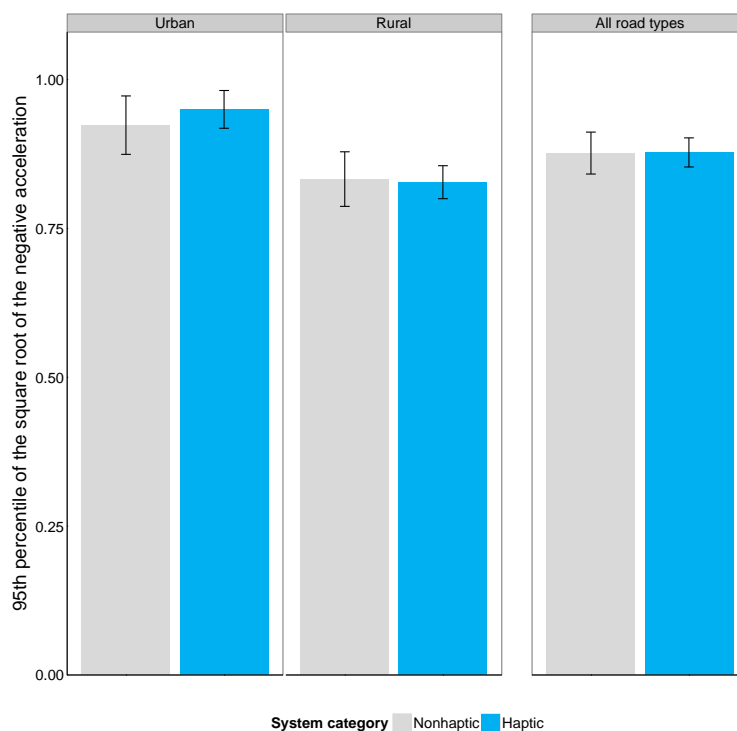


Figure 197: Model based average values of sqrt\_percentil\_neg\_acc\_95 for fixed effects

Table 536: Model based average estimates of the transformed sqrt\_percentil\_neg\_acc\_95 for the different levels of Main\_effect and road type, together with Tukey multiple comparison results

	Model based average estimates		Difference (NH-H)	Tukey multiple comparisons significance test
	Non-haptic	Haptic		
Urban	0.924	0.950	-0.026	0.783
Rural	0.833	0.828	0.005	0.996
All road types	0.877	0.878	-0.001	0.958

**Preliminary conclusions:**

The difference between the haptic condition and the non-haptic condition is for both urban and rural driving environments highly non-significant. Furthermore, the estimated model based average extreme deceleration is stronger for the haptic condition in urban environments.

### 7.30.2 Results summary

Table 537: Comparisons of the effect size (difference between system category and its corresponding baseline).

Effect sizes (differences from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	0.014 (N.S.)	0.025 (N.S.)	0.029 (N.S.)	-0.021 (N.S.)	0.077	-
Rural	0.037	0.043	0.014 (N.S.)	0.002 (N.S.)	0.01 (N.S.)	-
All road types	0.028	0.035	0.019 (N.S.)	-0.004 (N.S.)	0.038	-

Effect sizes in percentages (differences in % from relevant baseline)						
Road type	Treatment (all systems)	Embedded	FeDS	App	Haptic	Naturalistic (App&TomTom)
Urban	1.42 (N.S.)	2.57 (N.S.)	2.87 (N.S.)	-2.01 (N.S.)	8.24	-
Rural	4.11	4.94	1.69 (N.S.)	0.21 (N.S.)	1.27 (N.S.)	-
All road types	2.96	3.83	2.09 (N.S.)	-0.4 (N.S.)	4.51	-

### 7.30.3 Conclusions and implications

The usage of the ecoDriver systems reduces significantly the extreme deceleration values before speed limit changes to a lower speed limit in rural environments. The back transformed extreme deceleration model based estimates are reduced from  $-0.79 \text{ m/s}^2$  to  $-0.73 \text{ m/s}^2$  for rural driving. There is also a significant reduction of the expected average extreme deceleration for the hypothesis of embedded systems compared to their baselines. The differences of the model based average estimates are not significant for all other conditions, i.e. FeDS vs. FeDS baseline, App vs. App baseline, and haptic vs. non-haptic. Also there is no significant difference in all conditions for urban driving environments.

This implies there is significant evidence that the usage of an ecoDriver system has an influence on the actual driving behaviour before the event of speed limit changes in rural driving environments. Furthermore, assuming that less deceleration corresponds to longer coasting and hence the predictive awareness is increased before the event of speed limit changes.

For this hypothesis the condition embedded is the only one, which significantly decreases the extreme deceleration values before speed limit changes.

**For more information about *ecoDriver***

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