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## Using a highly instrumented car for naturalistic driving research

### A small-scale study in Spain

Deliverable D3.5

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## Abstract

The PROLOGUE project constitutes a first step for understanding the methodology involved in carrying out naturalistic driving (ND) research. ND is defined in Deliverable 1.1 as “...unobtrusively observing normal drivers in their normal driving context while driving their own vehicles.” In order to clarify this methodology, 5 different field trials set in different parts of Europe have been performed. These trials use different approaches, instrumental, and portray different goals. The common goal is a picture of the possibilities, drawbacks and potential applications of ND research.

This document reports the PROLOGUE Field Trial in Valencia, Spain. This trial uses a highly instrumented car named ARGOS for evaluating the on-road behaviour of a small sample of drivers using in-vehicle information systems. The report includes a description of the capabilities and technology of the ARGOS car, a description of a field trial planned to evaluate the use of a navigator while driving, the logistic and technical challenges of this field trial, and the lessons learnt for future studies using this methodology and equipment.

We regard the experience gained running this field trial as very valuable. The ARGOS car has shown to be potentially useful in the context of naturalistic observation studies. However, we have also realized that without a deep knowledge of its characteristics, results may not be as satisfactory as would be desirable.

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## Executive Summary

The PROLOGUE project constitutes a first step for understanding the methodology involved in carrying out naturalistic driving (ND) research. ND is defined in Deliverable 1.1 as “...unobtrusively observing normal drivers in their normal driving context while driving their own vehicles.” ND research is regarded necessary because there is evidence that there are driving behaviours that cannot be elicited in the laboratory or studied using other methodologies such as surveys, group discussions, epidemiological studies, etc.

In naturalistic driving studies, one important methodological issue is the trade-off between amount of data, cost and other considerations. In an ideal world, we would choose collecting as much data as possible in order to test various kinds of hypotheses. However, in the real world, increasing the information excessively carries larger costs, more difficult experimental settings, and so on. It may be the case that advantages prevail over the disadvantages, or it may be the opposite. Either way, without experience on experiments of this type, it is very difficult to discern what the best option is. It may even be the case that there is not a best option at all, but that different types of equipment and methodology can be appropriate for different studies.

The field trial in Spain explores using a highly instrumented car for performing research on ND. The capabilities of this car include video recording of the internal and external scenario, measurements of the longitudinal control and lateral control, eye-tracking, fuel consumption, and many others. This car, named ARGOS (derived from the greek mythology where according to a legend ARGOS was a giant with 100 eyes appearing as an effective watchman), was funded by the DGT<sup>1</sup> in Spain and developed in collaboration with the UPM<sup>2</sup>. However, as it had not been tested in practice before, it was not clear whether it would perform adequately in actual trials. Therefore, we set up a trial with the primary objective of exploring its functioning, but in order to establish a realistic setting for testing the car, we also set as an objective of the trial to observe the effects of the use of Nomadic Devices (NOD while driving. This second objective can be regarded as secondary/instrumental with respect to the main objective of evaluating the capabilities and limitations of the ARGOS car.

This report describes the lessons learnt in the process of setting up the trial, running it and analyzing the data. In this process, we found out a number of specific issues that are important for the success of trials with the conditions described here. Research carried out with the ARGOS or similar cars should pay attention to these issues in order to avoid jeopardizing the results. One that has special relevance is, that the use of the ARGOS car for conducting ND research contradicts the strict definition of naturalistic driving which implies that subjects drive in their normal driving context and in their own cars, but trials with the ARGOS car require driving a new car for roads different from that the subjects normally drive.

In the analysis of the data we have paid special attention to the identification and description of incidents while driving. The ARGOS car renders itself as an excellent tool for very in depth dissection of specific incidents that may be difficult to summarize statistically. The reference here is the accident reconstruction methodology, but with the goal of understanding the circumstances surrounding incidents instead of crashes. The advantage is that, once an incident has been identified in the data, there is a wealth of information that makes it possible to analyze it in a very detailed way. For this goal, instrumented cars may prove to be invaluable.

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As a general conclusion, we think that the ARGOS car or similar instrumented cars can be useful for research on naturalistic driving, or other type of on-road research. However, it is very important to know the tool and its limitations in order to avoid the several possible pitfalls along the way that might jeopardize the results obtained with it.

# 1 Introduction

The PROLOGUE (PRoMoting real Life Observation for Gaining Understanding of road user behavior in Europe) project intends to demonstrate the interest of Naturalistic Driving (ND) research for investigating traffic safety of road users. ND is defined in Deliverable 1.1 of this project as “...unobtrusively observing normal drivers in their normal driving context while driving their own vehicles.” In the context of this project, several field trials in different countries will be carried out, using different instrumentations in order to gain experience on the strengths, weaknesses and potentials of ND methodology. This deliverable will report the field trial in Spain, which has as main goal exploring the features of a highly instrumented car—called ARGOS- for conducting ND research.

In naturalistic driving studies, one important methodological issue is the trade-off between amount of data, cost and other considerations. In an ideal world, we would choose collecting as much data as possible in order to test various kinds of hypotheses. However, in the real world, increasing the information excessively carries larger costs, more difficult experimental settings, and so on. It may be the case that advantages prevail over the disadvantages, or it may be the opposite. Either way, without experience on experiments of this type, it is very difficult to discern what the best option is. It may even be the case that there is not a best option at all, but that different types of equipment and methodology can be appropriate for different studies.

The field trial in Spain explores using a highly instrumented car for performing research on ND. This car, named ARGOS, was funded by the DGT in Spain and developed in collaboration with the UPM. The capabilities of this car include video recording of the internal and external scenario, measurements of the car dynamics and driver-car-interactions, eye-tracking, parameters like fuel consumption, and many others. However, as it had not been tested in practice before, it was not clear whether it would perform adequately in actual trials. Therefore, we set up a trial with the primary objective of exploring its functioning, but in order to establish a realistic setting for testing the car, we also set as an objective of the trial to observe the effects of the use of ) while driving. This second objective can be regarded as secondary/instrumental with respect to the main objective of evaluating the capabilities and limitations of the ARGOS car for Naturalistic driving.

Several studies have already investigated on the effects of usage of IVIS on driving performance using mainly traditional methodologies like simulated driving. However real driving includes some more variables that cannot be generated in these traditional research methods like for example complex interactions with other road users or the responsible feeling of the driver driving in real traffic conditions.

Summarized the main objectives of the Spanish small-scale field trial are:

- to get an idea of the use of the ARGOS car in ND studies
- to explore its strength, weaknesses and potentials for ND studies,
- to investigate the effects of using IVIS on driving performance.

This introduction will present the topic of naturalistic driving with regard to the Spanish field trial and a brief introduction of the topic of the distracting effect of using nomadic devices while driving.



## 1.1 Naturalistic driving

McLaughlin et al. (2008) set the common methods for studying driving performance on a continuum, with controlled experiments (high control and low external validity) on the one side and naturalistic studies (low control and high external validity) on the other side. Studies in test tracks would be located somewhat in the middle of this continuum. Although ND studies have more external validity than experiments, they are more costly, both in time and money, and they are more difficult to interpret, as there are more factors potentially intervening.

ND produces information that has a low density in terms of data, i.e., most of the time the information collected is not relevant for the research questions investigated. This feature that could be regarded as a weakness of this methodology is in fact one of its strengths in order to answer research questions such as the effects of driver distraction and inattention on driving. Hence, ND can tell something about the relative risk associated with certain distractions because it gives information about the exposure to a risk factor, i.e., how often the drivers are exposed to a certain risk but also how often they are *not* exposed to this risk.

Another method used for studying driver behavior is self report questionnaires and surveys. Self reports can be focused on the research questions and consequently provide data that are highly relevant for the issue under study. However, these measures are indirect measures of the behavior of interest and are prone to the bias usually associated with this method of investigation (social desirability, inadequate response options, etc.).

Epidemiological studies and crash studies are methods that share the objective of studying accidents rather than the normal behavior. In epidemiological studies, databases of accidents usually collected by the authorities are used for analyzing what variables are usually associated with traffic accidents: types of roads, characteristics of drivers and cars, etc. In crash studies, every accident is analyzed in detail and a rigorous description of the events associated with it is carried out. This is an improvement over simple description of the accidents as carried out by the police or the insurance companies, but still many of the details are not available for the researcher.

ND is a method for the direct observation of the behavior that has the ecological validity, that other methods lack—as the participants drive their cars in their normal contexts without any intervention from the experimenters. However, as the participants are aware of being part of an experiment, it is still possible that they do not behave as they would normally do in normal driving. An important advantage over the other methods is the possibility of studying near crashes or incidents, which are rarely reported by drivers. Additionally, crashes occurring during the trials would constitute a very interesting source of information for understanding the events that precede accidents.

Note that direct observation of the driver may not be enough for understanding the whole driving situation in specific moments. So, in order to understand the events associated with a crash or near crash, we also need observation of the context of the driving (other vehicles, weather, type of road, etc.), measurements of the variables of the car (braking, speed, etc.), position of the car and specific details of the driver's behavior that are not susceptible of being studied without help (i.e. eye glance behavior).

However, increasing the amount of information collected about the driver often implies augmenting the sophistication of the equipment used in the research. In our case, the ARGOS car features a large number of sensors, video cameras and other devices for registering activity both inside and outside of it. These devices turn the car into a mobile laboratory appropriate for studying the on-road behavior of drivers. However, this sophistication comes with the price of greater complexity in the instrumentation, which may hinder the possible usefulness of the tool in some cases. Therefore, obtaining ac-

tual experience on how to carry out field trials is regarded as fundamental towards an adequate utilization of the ARGOS car for naturalistic driving research.

The approach of using a highly instrumented car for research on ND has been used in the PROLOGUE project in Greece and Spain. The car used in Greece, apart from structural differences due to the specific technology used in each case, presents many similarities to the ARGOS car. Therefore, advantages and disadvantages of this approach will be shared in many cases in both trials. The differences between two studies may arise in connection with the different specific research goals set in both studies, namely, the influence of the use of nomadic devices in Spain and the use of advanced driving assistance systems (ADAS).

Trials in Israel and Austria, however, use cars that are not so heavily instrumented. On the one hand, this makes the driving experience more natural for the participants but, on the other hand, the information collected is not that extensive. Depending on the goals of research, this relative lack of information may turn out to be critical. Specifically, analysis of near crashes or incidents may be difficult as some of the key elements for interpreting the event will be missing.

## 1.2 The use of nomadic devices whilst driving

The field trial in Spain explores using a highly instrumented car for performing research on ND. Two objectives, set at different levels, will be explored in this trial, namely:

- 1) Test the technological and methodological aspects of the ARGOS-car and its suitability for ND driving research.
- 2) Investigate the effects of the use of Nomadic devices while driving and the relation with incidents.

Note that our second goal is set mainly for instrumental reasons as our main goal is to test the ARGOS car in a realistic research setting. Therefore, we do not expect to find conclusive results about this topic within the PROLOGUE project. However, we reckon that the experience gained with this trial would be insufficient for accomplishing our first objective without setting a specific goal of research. In particular we decided to test the following specific research questions:

- RQ1: Are there more incidents when the drivers use the IVIS in the car?
- RQ2: Do drivers look at the IVIS when they have incidents?
- RQ3: Are incidents associated with high or low values of certain parameters of the vehicle?

The importance of these questions stems from the lack of naturalistic research about the distractive effects of using nomadic devices. So, although there is an important body of research on this topic carried out using other types of methodologies, ND studies are still scarce on it. These studies are especially important because it is the only way to obtain prevalence data on the use of nomadic devices in the car, which is itself part of the analysis of relative risks associated with distraction factors. It is worth to remark that ND research may challenge the results found with other methodologies: as found by Olson et al. (2009) talking or listening to a hands-free phone might have protective effects for commercial vehicle drivers—probably because of behavioural adaptation consequence of risk perception.

The exponential increase in the use of IVIS while driving is deemed a potentially important risk for the safety of driver and has been the objective of measures taken from the European Commission (EC). Thus, the EC issued the European statement of principles on human-machine interface for in-vehicle information and communication systems (EC, 2006) and supported the creation of a forum on nomadic devices acting as a Eu-

European consensus platform for the different stakeholders. Furthermore, the EC has funded projects that have addressed this topic. AIDE ([www.aide-eu.org](http://www.aide-eu.org)), for example, explored the technological challenges of new innovative solutions for HCs in the car. TeleFOT ([www.telefot.eu](http://www.telefot.eu)) is a large scale collaborative project aimed to test the impacts and functions provided by aftermarket and nomadic devices. However, whereas these efforts have undoubtedly contributed to the general knowledge on the topic and awareness of this issue, there is still considerable territory remaining unexplored.

Research on the consequences of using nomadic devices in the car has been carried out using different approaches. Laboratory tests and test track studies have provided basic knowledge about the potential effects for distraction produced by these devices, as well as ideas for improving them. Epidemiological research has contributed with an estimation of the gross effects of these devices on traffic accidents (Breen Consulting, 2009). Finally, subjective measures such as in-depth interviews and observational methods with an evaluator in the car have also been utilized.

Among the devices studied, the use of mobile phone while driving has received much attention by researchers (Brusque et al., 2006). In general, all studies have concluded that phoning has a negative effect on driving, regardless of the type of phone (hands free or hand held). The effects have been found to be worse than speaking with a passenger. Epidemiological research has found that mobile phone users have a higher risk of collision than non mobile phone users (Stevens & Minton, 2001; Redelmeier & Tibshirani, 1997; Violanti, 1998; Green, 2004). Surveys have been used to evaluate the characteristics of phone users and attitudes, finding that regular users have generally higher annual mileage, more powerful vehicles, riskier driving skills and a poorer perception of the risk while phoning (Sullman & Bass, 2004; Brusque & Alauzet, 2006; Pöysti et al., 2004).

Other tasks that have been studied are related with consulting traffic, weather information and guidance and navigation information. In general, the worst consequences of these devices come from manipulating the device as in introducing destinations in a navigator. For example, Nowakowsky et al. (2000) found that tasks taking too long to complete produced more lane deviations. Tsimhony et al. (2002) observed an increase in the headway distance and the reduction of speed during the execution of a secondary task.

The PROLOGUE field trial in Valencia set the objective of using the naturalistic driving methodology for researching the consequences of the use of nomadic devices. Using the ARGOS car, we wanted to observe drivers that had electronic devices at their disposal with the expectation that they would interact with these devices. The analysis of these interactions would be a good source of insight about the effects of these devices on everyday driving and the hazards associated with their use.

Although the previous research displays a very coherent picture—that nomadic devices are potentially a source of distraction for drivers—there is still the question whether this effect found in laboratories can be reproduced in real conditions. Research on this topic has found that distractions are associated with longer duration of eye glances to the side mirrors and inside the vehicle (Barret et al. 2003), higher levels of no hands at the steering wheel, and other adverse events (Stutts et al. 2005). But also in some cases evidence has been found of protective effects of keeping conversations such as in the aforementioned work by Olson et al. (2009). Therefore, it seems important to carry out research using ND methodology, as the possibility exists that the results may defy those found previously with other methodologies.

The TeleFOT project is probably going to be one of the most important sources of information about this issue. This project is setting several hundreds of equipped cars on the road in order to explore a number of hypotheses related with the use of these devices. FOT's are regarded as different of ND because, as signaled in section 2.1 of the

Deliverable 1.1 of PROLOGUE, in FOT's the emphasis is on testing the technology and improving it, and less on the driver.

### **1.3 Plan of this report**

The plan of this report is the following: firstly it describes the technology used in our trial, i.e., the ARGOS car; secondly, the methodology used in our trial is described, including the analysis carried out. Finally, we will discuss the field trial in terms of technology, methodology and potential for use in further ND studies. The last section will summarize the results and the lessons learnt at this trial.

## 2 ARGOS car: Technology

This section describes the technology used in the field trial in Valencia. We have used the ARGOS instrumented car, a vehicle developed by the Universidad Politécnica de Madrid (UPM) with funding from the Spanish administration (specifically, the General Directorate of Traffic-“DGT”). This car implements a large number of features useful for in-depth studies of drivers’ behaviour. However, carrying out trials with ARGOS has required solving a number of issues related with storage of the information, driver recruitment, data analysis, etc. All these issues, features and problems, will be discussed in this section.

### 2.1 Description of ARGOS

In this section we will describe the physical features of the car and the system, and then provide an in-depth description of the different elements in the car/system.

#### 2.1.1 Physical description

ARGOS is the second generation of a system designed with the purpose of collecting information and analyzing information about the driver. Figure 1 shows an outside view of the car where the system is installed: a standard SEAT Alhambra except for frontal and lateral sensors. Whereas these sensors are not very big, our impression is that they were visible for drivers in other cars and that they may have altered their driving because they suspected something special with this car. So, for example, we noticed fast cars suddenly slowing down when overtaking or too much when stationary at traffic lights.



Figure 1 The ARGOS car (outside view)

Unfortunately, the inside view of the ARGOS car is also quite conspicuous. Computers, screens, and other technical equipment of the system are clearly discernible from the outside (see Figure 2). Although our first impression was that this should not cause any problem of importance, our tests showed that in fact they attracted too much attention. As we were afraid of vandalism or distracting other drivers, we tinted the windows black to get rid of this problem.



Figure 2 View of ARGOS (inside)

The driver's cockpit is displayed in Figure 3. Notice the flat screen and the other elements located near the windscreen. The location of the flat screen forced us to move it aside in order to reach the on-board navigator and the radio, but it can be taken off easily if necessary.



Figure 3 Driver's cockpit

### 2.1.2 Systems in ARGOS

There are 5 computer systems in the ARGOS car, namely:

- SCA: System for control and acquisition of information
- SDA: System for storage of information (except video) and user interface
- SAGI: System for storage and management of video
- SPL: System for detecting the lateral position
- IBEO: System for measuring distances

## 2.2 Measures with ARGOS

The ARGOS car is equipped with a number of sensors recording several parameters that can be grouped in the following categories:

- Dynamics of the car
- Driver vehicle interaction
- Comfort of the driver
- Indicators in the car
- Environmental conditions
- Data acquisition parameters for the driver
- Experimental events
- Video recordings

We will discuss the specific parameters within these categories in the following subsections. The discussion will also include our actual experiences with the measures and the solutions for the problems that we have encountered. Please note that we have chosen to include discussion of some measures that currently are not operational but can and should be fixed in future trials.

### 2.2.1 Dynamics of the car

This section will provide a listing of the parameters related to the dynamics of the car, with special attention to the lateral position system and to the frontal and lateral distance measures.

The ARGOS car measures the following parameters related to the dynamics of the car:

- Distance travelled (cm): This is the distance travelled in each trip.
- Lateral position (cm) (see below).
- Frontal distance (cm) (see below).
- Lateral distance (cm) (see below).
- Speed (km/h): Obtained from the car.
- Instantaneous acceleration. Measured with an external sensor.

As mentioned before, the lateral position and the frontal distance are special in that they use specific equipment for recording such information. Hence, we will describe them separately:

### **2.2.1.1 Lateral position**

The lateral position in the ARGOS car uses the information from the cameras located in the front of the car. These cameras estimate the position of the car on the road. The method employed for estimating the lateral position is based on the automatic analysis of the images during the driving session. Notice that this analysis is carried out online in real-time. It allows to time-stamp the records, what is needed for synchronizing the values with the other sources of data.

Unfortunately, at the moment, the system does not function correctly. Most of the time, the system does not detect the road markings and as a consequence no values are recorded. In the future, if experiments are planned requiring these measurement, it will be necessary to find out how to fix it.

### **2.2.1.2 Frontal distance**

The measurement of the frontal distance in the ARGOS car is based on the ALASCA (Automotive LAsErSCanner), “a multilayer laser-based range finding device which measures the distances to objects surrounding the sensor“.

From the manual, “The ALASCA laser scanner is a measuring instrument based on LIDAR technology (LIght Detection And Ranging). It scans the surroundings by means of a rotating infrared laser beam. The built-in laser transmits short rapid-fire pulses that are reflected by objects in the surroundings. The reflections can be detected by the laser scanner allowing for a measurement of the pulses’ times of flight. From these times and the velocity of light the distances to the objects can be determined. In parallel the direction to each object is known from the angular position of the rotating mirror that deflects the laser beam“.

Using this device, the manual claims that the system is able to register the three nearest obstacles located in front of the car within a distance of 0 and 282 meters of the car. In particular, it measures the absolute distance and the angle of the obstacle in relation to the ARGOS, as well as the relative distance taking into account the measured angle.

As our search for incidents in the data has mainly focused on situations where our car is close to other cars, what would be indicative of critical situations, we are especially interested in close to zero values. However, the lowest observed value for this measurement in our tests has been 1.5 m. Also, when the actual distance is between 1.5 ms and 2.5 ms the reported value fluctuates between -100 (not measurable) and the measured value. As a consequence, we had to filter out missing values before carrying out analysis.

A more convoluted problem is that the system does not have different numerical codes for objects that are either a.) non present, b.) too close, or c.) too far away. Consequently, we need to elaborate a procedure for ensuring proper interpretation of the observed values. Ideally, this would be an automatic procedure, but currently we have to examine the videos to interpret these values.

### **2.2.1.3 Lateral distance**

ARGOS is able to measure the distance to a car/object moving in parallel to it. According to the manual, the range of the distance between the other object and the ARGOS car is 1 to 6 m. However, any value lower than 1.6 m showed up in practice in the actual values measured (even in our own tests setting the car at lower distances than this distance from the other car).



The lateral distance sensors as currently located in the ARGOS car are installed on the passenger back doors. Consequently, the frontal lateral sides are not covered by any radar. This limitation is particularly important for studies about right or left side turns. Figure 4 shows in thicker red line the blind area for the radars set in the ARGOS car.

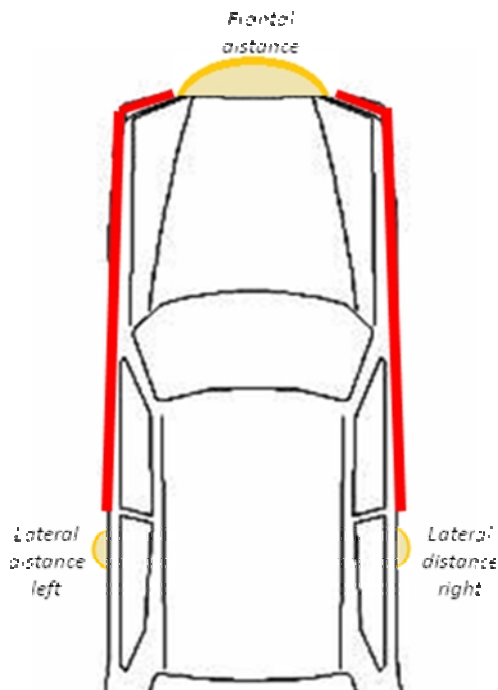


Figure 4 “Blind” areas in the ARGOS car

### 2.2.2 Driver Vehicle interaction

This set of measurements records the steering actions carried out by the driver as well as signals to other drivers, lights, etc. The following measures are obtained:

- Steering wheel rotation angle
- Steering wheel rotation speed
- Position of the gas pedal
- Brake pressure
- Position of the clutch
- Handbrake
- Frequency of revolution of the engine
- Gear shift position
- Turn signals
- Horn
- Status of lights
- Status of fog lights
- Regulation of lights
- Use of flashing signals

The most important measures in this package are probably the steering wheel rotation angle, the steering wheel rotation speed and the brake pressure. The first one is related with lateral control of the vehicle and can be used for computing a number of derived measures such as the standard deviation of the wheel rotation (ISO 2003) The second and third are in principle useful for detecting sudden manoeuvres.

Revolutions of the engine is a parameter related to fuel consumption and can be subjected to analysis in relation to a number of factors: individual drivers, type of road, etc.

Regarding the other parameters (horn, use of flashing signals, etc.), we only expect to use them in exceptional cases and in relation to specific incidents.

### **2.2.3 Comfort parameters**

The comfort parameters are related to functions in the car not directly related to control of the vehicle. The following parameters are recorded:

- Window control
- Lock window control
- Car locking control
- Regulation of thermal window
- Parking assistant
- Internal lights

We only expect to use these parameters in exceptional cases.

### **2.2.4 Dashboard information**

The following elements are recorded:

- Oil temperature
- Water temperature
- Level of fuel
- Indicator of alarm of water temperature
- Indicator of alarm of oil pressure
- Indicator of alarm brake fluid
- Indicator of low level of fuel
- Indicator of ABS activation
- Indicator of Airbag control
- Indicator of ESP activation
- Indicator of safety belt

Most of these indicators will only activate occasionally (ABS, ESP, Airbag, Water or oil temperature, etc.). Level of fuel may be used for estimating consumption.

### **2.2.5 Environment**

The following elements are recorded:

- Ambient light

- Outside temperature
- Inside temperature
- Interior noise

The parameters recorded here may be useful on occasions but we only expect to use them occasionally.

## **2.2.6 Data acquisition parameters for the driver**

This system is designed to provide us with the coordinates that the driver is looking at and the diameter of his/her eye pupil.

The ARGOS car has a system for eye-movement measurement. Specifically, it has the ETS-PC system that consists of an eye camera with mirror tracking system, two IR illuminators, a PC with integrated frame grabber and cursor insert electronics, and installed ETS software. This system is based on determination of the pupil-centre and the cornea-reflex centres of an eye image acquired by the acquisition unit. The eye camera of the acquisition unit takes an image of the eye in a distance from 0.5 to 1 m depending on the setup. The eye is illuminated by two infrared illuminators operating in the 880 nm near IR wavelength region not visible for the human eye.

Unfortunately, there is a technical problem with the camera that the technicians were not able to fix after two weeks of work, so we decided to run the trials without it. We are working to sort out this problem in the future.

## **2.2.7 Monitoring experiments**

The ARGOS car is designed to be used for controlled experiments that can be run while the driver is at the wheel. This means that it is able to record data from the in-vehicle tachistoscope, when the car goes by a bollard, experimental stimulus, codes and comments of the experimenter, etc.

We are not planning to use the experiment capabilities in the ARGOS car so we have not carried out a thorough check of these functions.

## **2.3 Video data**

We will describe the position of the cameras in ARGOS and then we will explain some of the problems we have found when using them.

### **2.3.1 Position of the cameras**

The ARGOS car has several internal and external cameras installed in it. We will describe the positions of the cameras and then we will discuss the possibilities/limitations/problems with them.

Numbers in Figure 5 indicate the approximate field of view of the cameras in the ARGOS car. Cameras 1 to 4 record the internal view, 5 and 6, external, and 7 back.

Camera 1 records the external view from the interior of the car. This camera is set approximately above the shoulder of the driver and allows viewing what the driver is seeing (Figure 6).

Camera 2 points to the interior of the car in order to capture the face of the driver (and the co-pilot). The view of this camera is displayed in Figure 7.

Cameras 3 and 4 are related to the eye tracking system. Camera 3 points to the right eye of the driver and camera 4 integrates the position of the eye with a view of the scene, whereas the “scene” can be the outside scenery as well as the inside of the car. The camera can be adjusted according to the gaze information that is needed. The views are displayed in Figure 8.

Cameras 5 and 6 are on the front part of the car, embedded in the slot for the fog lamps. They cover most of the frontal view of the car, with partial overlapping.

Camera 7 is located at the rear of the car. However, in order to cover the maximum of the field view, it uses a fish-eye lens that distorts the sides considerably.

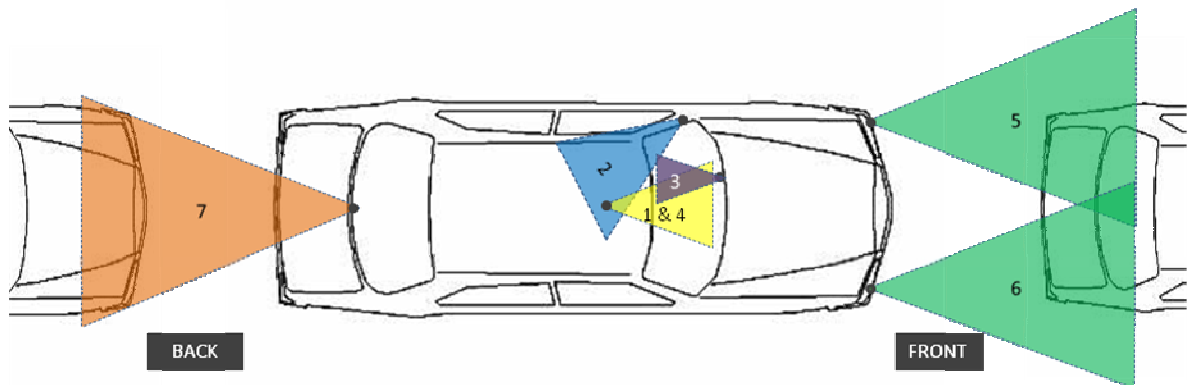


Figure 5 Cameras in ARGOS. Numbers 1 to 4 are internal cameras and 5 to 7 external



Figure 6 View from camera 1



Figure 7 View from camera 2

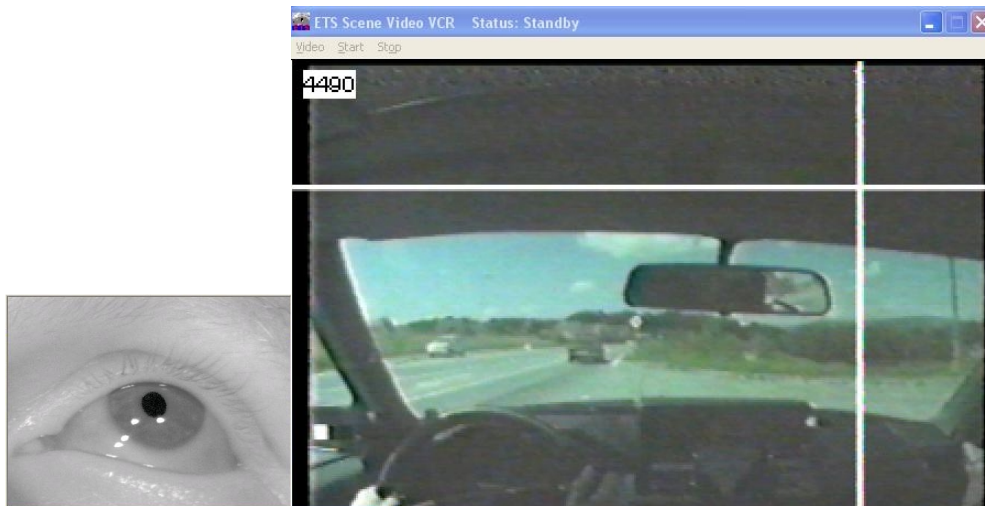


Figure 8 Views of camera 3 (left) and camera 4 (right)



Figure 9 Rear view from camera 7

### 2.3.2 Video issues

The capability of recording video is undoubtedly one of the most important features of ARGOS. Therefore, we strived to fix any technical problem related with it as soon as it turned up, achieving a relatively satisfactory functioning of the system.

The following describes some of the specific problems we encountered:

- Size of the videos

The size of the videos constituted a difficulty for two reasons: the on-board recording limit and the external storage system.

After initial tests with the car, we realized that a maximum of 6 hours of recording would push the capabilities of the system to its limits, so we set that sessions would take approximately 3 hours maximum. This limit worked well in most of the cases but we still

ran out of storage on a few occasions. In the future, we may have to use a still more conservative limit to avoid this.

Another consequence of big video files is that the time for downloading copies to an external system was not insignificant: about 2 hours of copying were typically required per session.

The total size of storage required per hour of recording was about 30 to 40 GB. In our case, all the sessions amounted to 1.34 TB of storage without backup. Multiplying this figure by 2 for backups and adding some extra capacity we finally used 5 TB in total for our trial.

- **Lighting**

Differences in lighting among streets are a source of problems for recording the videos. On the one hand, setting the parameters to the most common levels of glare, in the cases where this was possible, produced videos that were non usable in small and dark streets. This problem affected all the cameras but was even more important for the camera that displayed a general view of the scenario, as it did not adjust automatically for brightness. Additionally, cameras that adjusted automatically for brightness presented their own problems. As an example, if the driver set the sunshade, the face camera received much reflection and the recording turned completely black (however, a black plastic bag covering the sunshade fixed this problem).

- **Connections**

While the design of the ARGOS car is quite robust and able to cope with standard driving conditions, it had not actually been tested sufficiently before we started working with it. So, our tests showed that some of the video connections were not as reliable as they should be and disconnected randomly. In general, after we mended these loose connections the robustness of the system increased in most cases and the problems disappeared.

- **Camera not working**

As mentioned before, the camera for the eye tracking system refused to work and it was not possible to use it for our trials. Technicians worked on this camera for about two weeks unsuccessfully before we decided start the trials without it. The failure of this camera also limited the view of the interior of the car, as other cameras could not be pointed to the interior of the car.

## **2.4 Data storage**

The issue of data storage was discussed previously in relation with the video data. We had a requirement of about 4-5 Tb of storage for our data, separated in two parts: one that would be used for actual analysis, and the other for backup.

After evaluating different solutions, we resorted to a network server from QNAP that has the flexibility of adding more storage if needed. This server allows for easy access from the internet and incorporates data protection measures as well. Backup copies were handed over to the central computer system services of our university and they put them inside a fire-proof closet.

## **2.5 Data preparation**

This section will deal with technical issues related to the analysis of the data collected in our trials. Actual data analysis (and results) will be reported in section 4.5.

There will be two parts in this section. The first part will deal with the numerical output coming from the different sensors in the car, and the second will focus on the analysis of the video data.

### **2.5.1 Numerical data**

The ARGOS car was designed to dump ASCII data files in a format that should be easily imported in standard statistical programs. Actual experience with the data showed that the files obtained did not fit with the description in the manuals. This was solved by programming a new routine that generated the data in a format that we could handle easily.

As the size of each of these files was of about 161 MB, some of the operations you normally take for granted for numerical data (i.e. plotting a graph) turned to be very hard to carry out in practice. So, many of the operations could only be performed with small sub-selections of the dataset. Additionally, the data recorded often contained values that were non-applicable, missing or incorrect. For example, periods of time when the car stood idle had to be filtered out before computing summary statistics.

- **Data cleaning**

Data cleaning was carried out at the same time the videos were being visualized. Gaps in the data, sensors non recording, and technical limitations of the sensors were identified and appropriate actions were undertaken when necessary.

- **Data subsetting**

The numerical data collected in the trial was imported into a data file of the SPSS/PASW statistical program. This file had a size of 3.5 GB and about 13 millions rows. Statistical summaries of this data such as means, standard deviations, etc., could be calculated easily with standard computer equipment but graphics were not possible even for relatively small subsets of this data. Therefore, we had to move subsets of the data to another system (R) for drawing plots. However, given that R relies heavily on RAM memory, we reached its limits on many occasions.

The subsets of data were analyzed using the SPSS programming language running on a standard computer. This combination of software/hardware proved to be sufficient for our purposes but we should not forget that our study is rather small in size. Future studies with more subjects can reach the limits of the software and hardware used here and other options may have to be considered.

### **2.5.2 Video data**

The ARGOS car has a built-in system for visualizing the videos. This system is installed on the computers on board, so, in principle, we were to carry out all the video analysis within the car. This turned out to be impractical for several reasons so we decided to install the video analysis system on a computer set in our facilities. This process took about a week of technician time but we found that the benefits clearly paid off for this effort.

A strong point in the visualization system of the ARGOS car is its capability of displaying the videos together with the numerical data. Although we explored the possibility of using other computer programs for observational data analysis, two reasons finally refrained us from doing that: on the one hand, the aforementioned capability of watching the data parameters jointly with the videos, and, on the other hand, the video codec used for the videos was very difficult to find and to install on our computers. Therefore, we were bound to use the software provided with the car.



The computer program for video analysis turned out to be very limited in some respects. For instance, it was not possible to move to a specific point in the video without restarting it, neither to move forward or backward in higher speeds than normal, nor to repeat specific sequences. Therefore, in order to examine sections of the videos it was necessary to quit the program and restart it again, a process that ended up being very impractical. Besides, after 20 minutes of continuous visualization, the images disappeared as if the data had not been recorded at all. Fortunately, after the problem was identified we managed to solve it without any data loss, and, also, we also were able to improve the software so that specific segments in the data could be selected more easily.

After working with this program, we think that better solutions might have to be explored for the video analysis. In particular, commercial solutions for video analysis have been developed for fields such as sport analysis, race cars, ergonomics, animal behaviour research, etc., that might be appropriate for our kind of video data too. Alternatively, in-house software that fitted the specific requirements of naturalistic research could be developed, but we believe that a sufficient number of research centres should be involved in such effort to make it successful. Alternatively, a set of technical requirements for video and numerical data could be established that will guarantee the exchange of data between research centres as well as the creation of centralized repositories of data available for reanalysis.

## 2.6 Future work

Although we have solved many issues of the ARGOS car, there are still a few remaining. Among them, we regard the following four as the most important:

- **GPS:** The ARGOS car has an on-board GPS system that does not work correctly at the moment. We have developed software for setting the GPS signal on a map but we have not been able to use it yet.
- **Sound and noise:** Sound in the driver cockpit was recorded, but a problem with the codec prevented us from using it.
- **Lateral position:** We have mentioned that the lateral position system did not work well in practice in many occasions. Careful choice of roads may be a solution for this problem.
- **Eye tracking system:** The system in the ARGOS car did not work well and we could not fix it during the time scope of the project. We are exploring the possibility of fixing it or perhaps acquiring a different system.

### 3 Legal/ethical, practical, and bureaucratic issues

We have described the technical issues with the ARGOS car previously. However, we knew that running trials with this car might present challenges in other areas apart from that, so, in order to clarify these issues, we had a number of meetings with different experts from the university. Also, as we borrowed the ARGOS car from the DGT, we had to establish the terms of the contract and get it signed by the official representatives of our organizations. Furthermore, there are legal requirements for driving a car (e.g. taxes). Last but not least, as the experiments involved a significant amount of time and effort for the participants in the experiment, we had to find a way to pay them.

In summary, the following subsections provide an account of the different issues we had to deal with, grouped in 6 categories, namely, legal/ethical, informed consent, insurance, car maintenance, contract, and technical inspections

#### 3.1 Legal/Ethical

Legal and ethical issues must be taken into account seriously at an early stage within the planning of a field trial. In our case, we identified two main areas that could be potentially important and we sought legal advice about them. These two issues were data privacy and safety of participants in the trials.

Regarding data privacy, the University of Valencia has an expert in charge of diagnosing conflicts in this area. This expert pointed out critical content and mentioned necessary elements to integrate in the contract. More specifically, he raised the issue that a sentence about image rights had to be included, as well as details about what was going to be recorded and how we were going to manage the data. Fortunately, the Spanish law is very specific about these issues and fulfilling the requirements stated in it was straightforward. After we made the changes he requested, the expert in data privacy reviewed our informed consent (discussed below) and approved it.

The safety of the participants in the trials was evaluated by the department “Health and Safety at Work” of the university. This system evaluated the ARGOS car and determined that there was not any element on it that could be regarded as an additional risk to what is normal in a car. However, the person evaluating the car brought up the issue of whether the participants in the experiment should be regarded as workers of the university, workers for a different company that provided services for the university, or research collaborators. Initially, we had considered that research collaborators was the right answer to that question, but then we were informed that research collaborators cannot receive any type of payment according to Spanish laws. Given that the trials we were planning required that participants spent a significant amount of time, we were afraid that no payment would make it impossible to recruit participants for the trial.

Finally, we found a company whose business it is to offer driving services to other companies or to individuals. This company was able to provide us with the 5 drivers of different profiles that we required for our trial.

#### 3.2 Informed consent

Subjects participating in the experiment signed an informed consent before starting the trials. The informed consent used in our case was designed according to inputs from different sources and included the following subsections:

- General description of the project.

- Description of the procedure of the study and the responsibilities of the participant. This included subsections on preparation, data collection, timing, maintaining of the vehicle, telephone number in case of incidences, car insurance, and medical insurance.
- Description of risks.
- Confidentiality of the information.
- Payments
- Conditions for withdrawal of the experiment

A copy of this informed consent (in Spanish) is included in this report Annex I.

### 3.3 Insurance

The insurance of the ARGOS car involved two different aspects. On the one hand, we had to insure the car as a vehicle, and on the other hand we had to insure the equipment in the car (radars, computers, etc.).

The University of Valencia has an agreement with an insurance company. However, the coverage refers mainly to static scientific equipment; a car like ARGOS was rather unusual so they had problems assigning a monetary value to it. However, they found what they thought was an equivalent type of vehicle (TV vans used for mobile retransmissions) and attributed a value to the car according to what they would charge for one of these vehicles. However, if there had not been an agreement with the university, they might have refused to insure the car due to its specific characteristics and high economical value.

Finally, we explored the possibility of insuring the drivers in case of an accident or fatality that could happen. However, the insurance company assured us that this type of insurance was not necessary if we made sure that the car followed the standard safety regulations. As the health service had already checked the car and issued a positive report (see 3.1) we dismissed the need of this extra insurance.

### 3.4 Car Maintenance

Before starting the trials we took the car for mechanical maintenance, changing tyres, oil, etc. There were no major problems with servicing the car except for payment as we were informed that repair shops only accept direct payment *before* the car is recovered by the owner and the university generally transfers money with a delay of about a month. Fortunately, the university agreed to make an exception in this case and paid without delay.

The car also carries a big battery that provides power to the computers on board. We had to buy a new one and again, the seller just accepted direct payment.

In summary, car maintenance is not a problem in general, but payment for the service or the pieces can be in many cases.

### 3.5 Transfer of the car ARGOS

The DGT, the owner of the car ARGOS, had showed interest in lending the car to our research centre. Therefore, we counted on this car for performing the field trial within the project PROLOGUE.

The transfer of the car required signing a contract between the DGT and the University of Valencia. Terms of the contract were drafted and agreed quite easily, but, the legal

services of the Spanish administration had to review whether those terms were according to the law. Unfortunately, the revision took a very long time and, furthermore, the outcome was negative. Apparently, the legal terms used for the contract were not appropriate for our case and a new reformulation was necessary. After a new wait, the new contract was approved but we had lost a few months in the process.

Actually, the car had already been transferred to our facilities before we got the permission to use it, but we were not allowed to use it outdoors before the contract was signed. Therefore, our activities during this time were limited to learning about the technical capabilities of the car without testing them in practice.

The contract was signed on the 3<sup>rd</sup> of May, 2010.

### **3.6 Technical inspection**

A certificate of technical inspection is required in Spain for driving any type of vehicle on the road. Cars are bound to be inspected after 4 years of being manufactured and then every 2 years. Although the ARGOS car was in excellent condition, we were afraid the non-standard modifications implemented in it might be problematic. Fortunately, the inspectors understood the specific characteristics of the car and granted permission.

## 4 Methodology

This section will give a description of all the procedures followed in the field trial, data handling and data analysis administered throughout the progression of the trial. The following subsections will be discussed: Participants, installation specification, geographical location, data collection, data handling and data analysis.

### 4.1 Participants

Naturalistic driving requires that subjects behave as natural as possible. However, we soon realized that the ARGOS car might be a limitation for such requirement. Driving for long periods was regarded as necessary because after a period of habituation we expected that subjects would behave as desired. We assumed that having several sessions consecutively would help the drivers to get accustomed to the driving situation, the car, etc. In summary, the trial used 5 subjects that drove the car for 4 consecutive days each.

In Table 1 some key characteristics of the participants are presented. The categories considered are:

- Age of the participant
- Gender of the participant
- 1000km/y: Estimation of kilometres driven per year in thousands
- Use Navigator in his own vehicle (Yes, Often, No)
- Use Telephone in his own vehicle (Yes, Often, No)
- Manipulate radio (Yes, Often, No)
- Manipulate other devices (Yes, Often, No)
- Indicate what other devices

Of course, such a small sample does not permit having sufficient representativeness of the different conditions of interest. So, we have in general middle age subjects, with good balance between gender and that use devices in their own vehicles occasionally.

Table 1 Descriptive data for participants in the trial

Age	Gender	1000km/y	Use Navig.	Use Tel.	Use Radio	Other dev.	What
45	M	>30	Yes	Yes	Yes	Often	CD
43	M	15-30	No	Often	Often	No	-
45	F	5-15	Yes	No	Yes	No	-
44	F	<5	No	No	Often	No	-
36	M	15-30	No	No	Yes	No	-

### 4.2 Geographical location of trial tracks

The geographical location of the trials was Valencia, Spain. Drivers started driving from the Institute of Traffic Safety (INTRAS) location, in the Los Naranjos campus of the University of Valencia at 8:30 AM, heading off to a point located at the North of Valencia. This section is characterized by a two-way motorway that is usually very congested

in the mornings. This first part of driving gave data that could be easily comparable inter- and intra- individuals.

The second part involved finding a number of addresses in Valencia chosen so that we considered that their exact location would be unknown to the participants. The drivers had to locate these addresses either using the navigator on board or using a map. They did not have any time limit, but they knew that finishing earlier would not be penalized economically so they had an incentive for working at a good pace.

Figure 10 shows as an example the journey of one of our drivers (second day of third driver). Position G marks the location of the INTRAS. The journey starts at this position and follows the sequence B, C, D, E, F and G again. B is the point outside of Valencia where the subjects drove to in first place. All the subjects drove from A(=G in the map in Figure 10) to B section every day. After that, this subject drove to C, which is a point near the historical centre of Valencia characterized by narrow streets and dense traffic. D is a point in a relatively new area of Valencia with more fluid traffic most of the time. E is located besides the harbour and F is in the old district near the coastline. The circle in the figure indicates the area where the destinations that the drivers have to find every day were located.

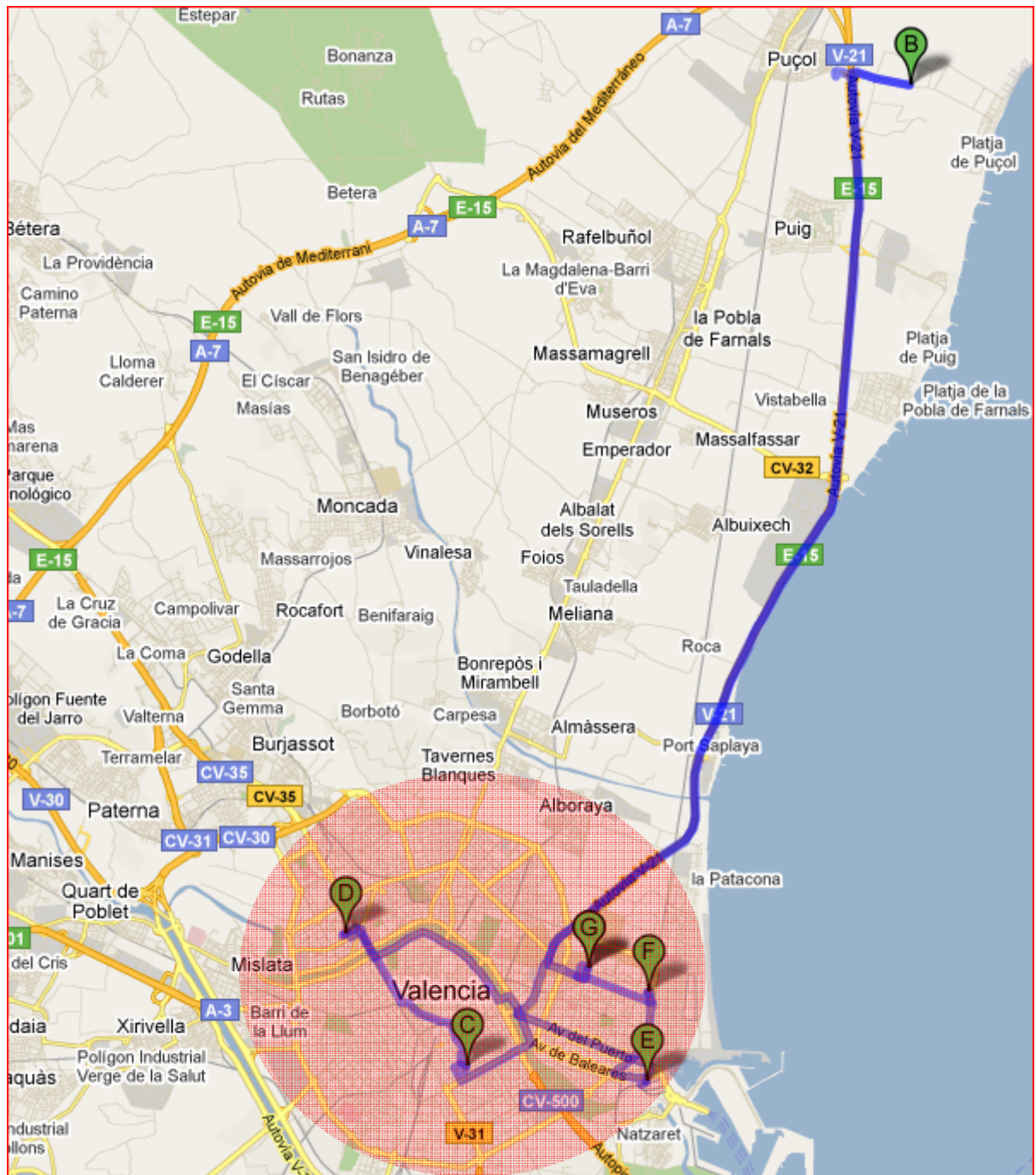


Figure 10 A journey of a driver

### 4.3 Data collection

Data was collected continuously during every trip. The data collected included numerical data from the sensors in the car and video data. Description of the numerical measures taken is available in section 2.2 and of video data in section 2.3. The sections there also include discussions of problems and issues that arose when collecting this data.

Subjects were allowed to use the navigator to find the addresses on the second and fourth day of driving. Therefore, the first and third day were used as the baseline for comparison purposes. The subjects were given instructions about how to use the navigator in the car, but not about when to use it, or whether to use it at all.

## 4.4 Data handling

Data was downloaded from the car daily after each journey. Once the car was parked in our facilities, data was transferred to the network server described in section 2.4. This process took about 1,5 hours of time every day after about two hours of driving. A second copy was recorded afterwards and taken to a safety closet located in a different building.

## 4.5 Data analysis

As stated in the description of work of the PROLOGUE project, the field trials planned in this project are principally aimed at exploring the methodological and practical challenges of naturalistic driving research. In order to explore these issues, we designed various research questions to be tested in the field trials. In this way, the reliability and usefulness of the technical and methodological systems could be investigated in pilot field trials. However, given the low number of subjects tested in our trial, expecting significant scientific results would be fairly optimistic. On the other hand, the experience gained should lead to successful subsequent studies. Thus, as stated in the introduction, we set a number of simple research questions related with the use of electronic devices in the car, namely:

- RQ1: Are there more incidents when the drivers use the IVIS in the car?
- RQ2: Do drivers look at the IVIS when they have incidents?
- RQ3: Are incidents associated with high or low values of certain parameters of the vehicle?

We will provide further explanation of these hypotheses jointly with results in the following subsections. However, as these results are connected with the definition of an incident, we will provide a short account of what we consider an incident before discussing the results. Then, we will describe how the data was analyzed.

### 4.5.1 Definition of incident

The research hypotheses mentioned above are related to the identification of critical incidents in driving. In order to define incidents, we use a category system suggested by Dingus et al. (2005) and Hickman et al. (2005) that was adapted by the VTTI<sup>3</sup>. They distinguish among 5 categories from more dangerous to less dangerous: crash, near-crash, crash-relevant conflict, unintentional lane deviation and illegal manoeuvre. Definitions of these categories are provided below.

- **Crash.** Any contact with an object, either moving or fixed, at any speed in which kinetic energy is measurably transferred or dissipated. Includes other vehicles, roadside barriers, and objects on or off of the roadway, pedestrians, cyclists, or animals.
- **Near-Crash.** Any circumstance requiring a rapid, evasive manoeuvre by the subject vehicle, or any other vehicle, pedestrian, cyclist, or animal to avoid a crash, OR any circumstance that results in extraordinarily close proximity of the subject vehicle to any other vehicle, pedestrian, cyclist, animal, or fixed object where, due to apparent unawareness on the part of the driver(s), pedestrians, cyclists or animals, there is no avoidance manoeuvre or response. A rapid, evasive manoeuvre is defined as a steering, braking, accelerating, or any combination of control inputs that approaches the limits of the vehicle capabilities.

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<sup>3</sup> Virginia Tech Transportation Institute, Blacksburg, USA



- **Crash-Relevant Conflict.** Any circumstance that requires a crash avoidance response on the part of the subject vehicle, any other vehicle, pedestrian, cyclist, or animal that is less severe than a rapid evasive manoeuvre (as defined above), but greater in severity than a “normal manoeuvre” to avoid a crash OR any circumstance that results in close proximity of the subject vehicle to any other vehicle, pedestrian, cyclist, animal, or fixed object where, due to apparent unawareness on the part of the driver(s), pedestrians, cyclists or animals, there is no avoidance manoeuvre or response. A crash avoidance response can include braking, steering, accelerating, or any combination of control inputs. A “normal manoeuvre” for the subject vehicle is defined as a control input that falls within the 99% confidence limit for control inputs for the initial study data sample. Examples of potential crash-relevant conflicts include hard braking by a driver because of a specific crash threat, or proximity to other vehicles.
- **Unintentional Lane Deviation.** Any circumstance where the subject vehicle crosses over a solid lane line (e.g., onto the shoulder) where there is not a hazard (guardrail, ditch, vehicle, etc.) present.
- **Illegal Manoeuvre.** Any circumstance where, either the subject vehicle or the other vehicle, performs an illegal manoeuvre, such as passing another vehicle across the double yellow line or on a shoulder. For many of these cases, neither driver performs an evasive action.

We did not expect any crash during the trial. However, incidents of the other types are certainly possible. In the next section we will provide the number of incidents in these categories. This information will be used for calculating a rough estimation of the number of hours of recording needed for obtaining incidents of the different types.

#### 4.5.2 Identification of incidents

This section describes the methodology used for identifying incidents in the data. Our first attempt consisted in setting thresholds for the numerical parameters that would be indicative of interesting events. This methodology is suggested in D2.2 of the PROLOGUE project in section 5.2.2. (Groenewoud et al., 2010) and they mention Klauer (2006) as an antecedent of the procedure. The idea is to define trigger variables that point to interesting events, such as a large deceleration that might indicate a near collision. The problem is to define appropriate thresholds so that too many false positives are not produced but the important events are still detected. The suggestion is to use statistical design for identifying the correct thresholds. Using a sample of incidents detected by trained observers and a sample of non-incidents, the experiment could be to identify the variables that discriminate better between the two samples<sup>4</sup>.

In our case, we started with values that looked reasonable according to our experiences with the car as thresholds should be defined for each individual car or model of car. For example, as the equipment of the car ARGOS makes the car very heavy, the drivers needed to put more brake pressure than would be required in a standard car of the same size. In order to establish normal and extraordinary values, we carried out several test drives. The resulting values are listed below:

- § Speed of steering wheel rotation: **> +/-500 degrees/s**
- § Brake pressure: **> 70N**
- § Frontal distance: **< 1,5m**
- § Lateral distance (left and right): **< 1,5m**

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<sup>4</sup> Actually, there are statistical methods that can provide this result automatically such as supervised classification methods (e.g. Ripley, 1996).

As the format of the files produced by the ARGOS car systems could not be read by standard programs for observational analysis, we could not use triggering software to simplify that process. Therefore the filtering process was carried out in a spreadsheet and the results transferred to the video analysis software in the ARGOS car—a very cumbersome process.

Unfortunately, the results were rather disappointing. First of all, we identified many incidents which in their majority emerged as false alarms. As a typical example, sudden speed changes are common when stopping at a traffic light and driving in urban roads produced many of these. Secondly, there were real incidents that did not show up when analyzing the numerical data. This happened principally in incidents that we classified as “Unintentional lane deviation” and “Illegal maneuver”, because the numerical values associated with them were usually not very alarming. Moreover, many of the parameters are related with actions of the driver on the instruments of the car (brake, throttle, etc.) and in many incidents there is no such action, either because the driver lacks awareness of the critical situation or because there is no need of performing any extreme action (for example, braking softly may be sufficient). Third, we found that the measurement of the distance to other cars did not work correctly. So, values of lateral distance lower than 1.61m never turned up in the data file although the system was capable of detecting objects set at 1 meter. Similarly, the lowest frontal distance value we recorded was 1,50m and, as mentioned in section 2.2.1.2., values below 2.50m are actually very unreliable.

Given the lack of an adequate software tool for the application of the thresholds and once we had established the difficulties stemming from employing the numerical data for identifying the incidents, we set about looking for the incidents directly in the videos. This was realized using the system in the ARGOS car, which permits playing the different views simultaneously as well as the numerical parameters. This manner of analyzing the data revealed itself as very adequate: the observer had an overall view of the traffic situation in each case and was able to pick the critical situations as defined in section 4.5.1. However, surroundings of the car that are not captured by the cameras (see figure 5), which capture the scenery, could not be analyzed. Especially on the sides of the car there is no information about the interactions with other road users. This lack is taken in consideration in the recommendations for different camera positions (see figure 14.).

This process was, however, very laborious. For one hour of video, we spent about 2.5 hours watching it on average. This time, however, depended on several factors: quality of the recording, number of critical situations and incidents found, etc. We mentioned previously that the software we used was not optimal for the task and it slowed down the whole process.

## 5 Results

This chapter will provide results for the data collected in the Spanish trial. We will start with a general description of the data collected and then we will continue with the description of incidents identified including tests for specific research questions related with the use of nomadic devices.

Table 2 Descriptive statistics for drivers

Subject	Km driven	Speed Average (km/h)	Time (minutes)	Fuel Consumption (liters)	Fuel Consumption/distance (liters/Kms)
1	216	30	434	31	0.14
2	162	24	411	38	0.23
3	248	33	451	39	0.15
4	195	28	413	42	0.21
5	220	25	536	32	0.14
<b>Mean</b>	<b>208.3</b>	<b>27.9</b>	<b>448.8</b>	<b>36.4</b>	
<b>Total</b>	<b>1041</b>		<b>2244</b>		

There were about one thousand kilometres driven in our trial, mainly by urban roads. Consequently, our drivers had low speed averages: 27.9 km/h was the average for the drivers with low values of 24 km/h. It is interesting to see the variability in the fuel consumption. It would be interesting to explore factors related with this variability and to investigate the extent and modality of ecological driving among drivers.

### 5.1 Description of Incidents

Table 3 shows the number of incidents in the 5 different categories listed in section 4.5.1. As can be seen, we did not observe any incident in the two most dangerous categories, namely, crashes and near crashes. In total, we observed 16 incidents in the other three categories, mainly in the illegal manoeuvre and crash relevant conflict categories.

Table 3 Incidents observed at the field trial in Valencia

	Frequency
Crash	0
Near Crash	0
Crash relevant conflict	6
Unintentional Lane Deviation	1
Illegal Manoeuvre	9
<b>Total</b>	<b>16</b>

Notice that we had approximately 40 hours of recording. Assuming a homogeneous distribution of the incidents along the time, we can expect an incident every 2:30 hour. Given this value, an estimation of the number of hours of testing in order to collect about 100 incidents in the three non empty categories is 250 hours.

Table 4 shows the split of the number of incidents as function of pedestrian involvement.

Table 4 Incidents with pedestrians or other vehicles

Type/Driver	Pedestrians	Other Vehicles	Total
Crash relevant conflict	2	4	6
Unintentional lane deviation	0	1	1
Illegal manoeuvre	8	1	9
<b>Total</b>	<b>10</b>	<b>6</b>	<b>16</b>

Table 4 displays that there is possibly an association between the type of incident illegal manoeuvre and pedestrian involvement. This association might be a consequence of drivers not stopping for pedestrians who legally pass at pedestrian crossings.

Table 5 Cross tabulation of type of incident by driver

Type/Driver	1	2	3	4	5	Total
Crash relevant conflict	2	4	0	0	0	6
Unintentional Lane Deviation	1	0	0	0	0	1
Illegal Manoeuvre	2	2	5	0	0	9
<b>Total</b>	<b>5</b>	<b>6</b>	<b>5</b>	<b>0</b>	<b>0</b>	<b>16</b>

Table 5 displays the cross tabulation of the type of incident versus subject. Notice that many of the cells are empty because of the low number of incidents collected. Perhaps the most interesting observation to draw from this table was that only 3 out of 5 drivers had incidents in our trial.

### 5.1.1 Are there more incidents when the drivers use IVIS in the car?

The first hypothesis explores the effect of using IVIS in the car (in our case, the navigator) on incidents. If the navigator in the car causes a problem for driving, you might expect that a larger number of incidents might occur when the navigator is used. Examination of Table 6, however, does not provide support for this hypothesis. 11 out of 16 incidents happened in the No IVIS condition and only 5 of them in the IVIS condition. Therefore, the hypothesis of more accidents with the IVIS device is not backed up for our results. This result is not expected and will be discussed in section 6.2.

Table 6 Incidents by use of IVIS

Subject/Day	No	Yes	Total
1	5	0	5
2	2	4	6
3	4	1	5
<b>Total</b>	<b>11</b>	<b>5</b>	<b>16</b>

### **5.1.2 Do drivers look at the IVIS when they have incidents?**

None of the incidents showed evidence of drivers looking at the IVIS whilst driving the car. As mentioned before, drivers stopped the car for introducing directions and used audio for following the directions given from the device. This behaviour will be discussed in section 6.2.

### **5.1.3 Are incidents associated with high or low values of certain parameters of the vehicle?**

The cameras in the car provide visual information about the driver and the main parts of the surrounding environment (see figure 5) when there is an incident. The cameras are the clearest signal for investigating the incidents of driving, the behaviour of the driver and the risks involved. At the present moment, there is no appropriate substitute of visual information for studying driver behaviour in the vehicle.

However, the numerical parameters recorded in the car are a complement of such incidents that also deserve attention. Thus, for example, if specific values of these parameters could be related to the incidents, new advanced driver assistance systems (ADAS) could be developed that anticipated an incident or helped to diminish its consequences. Also, new explanations or concepts might arise in connection with this data that could help to develop new explanations/taxonomies for the causes of traffic accidents.

Despite its potential, analyzing the numerical data recorded by an instrumented car has many obstacles, namely:

- Summarizing the values of long series of data may be difficult because of missing, out of range, incorrect or non-applicable values.
- Summaries of specific moments (such as in incidents) are very idiosyncratic because the environment surrounding and the conditions may be a strong determinant of the values recorded.
- A summary is often insufficient. The whole sequence of events is necessary to evaluate the data. However, it is not clear what length of data need to be examined: seconds, minutes or longer.
- The level of aggregation. Typically, data are recorded in milliseconds or similar (in our case every ten milliseconds). However, depending on the events of interest, this level of aggregation is excessive because they happen in the order of minutes or several minutes. On other occasions, things do happen in a few milliseconds and therefore we should find a way of recording very specific periods of time. At this moment, however, there are not clear guidelines on what is the correct level of aggregation.
- The baseline for comparing the numerical data. Values associated with certain variables may stand out only if compared with “normal” values. However, the variation associated with these normal values is high and depends on several factors such as the traffic, the infrastructure, etc. Two candidates for these comparisons are the data immediately preceding and following the incident, or random segments (or averaged) taken from the rest of driving.
- There are many variables that need to be considered simultaneously as they carry complementary information. Actually, the videos need to be examined at the same time in order to clarify what is conveyed by the data only.

The rest of this section shows a number of graphics displaying the data related with the 6 incidents we have considered as Crash relevant conflicts. These graphics show the information about the parameters in a coordinated way, allowing for comparisons be-

tween the incidents and within the incidents. As we will show, these graphics complement the video information with elements that would be invisible using other methods and help to rebuild the whole sequence of events around an incident. We believe that these descriptions are useful for understanding each incident in detail, but, unfortunately, generalizations of what we see in each case are still not possible. We are exploring methods for statistical analysis of this numerical data that might help in such generalizations.

**Fout! Verwijzingsbron niet gevonden.** displays the information about the six Crash relevant incidents that we found in our trial. Each incident corresponds to a column of plots. For each incident, ten measures are displayed, namely:

- Angle of the steering
- Speed of the steering
- Speed
- Accelerator pedal pressure
- Acceleration (vertical, transverse, longitudinal)
- Revolutions per minute
- Distance to the car in front
- Brake pressure

These measures are described in Section 2.2. Notice that the plots use a common scale, so it is possible to compare the plots along the rows. For example, incident 2 (second column) does not feature any swerving at all (cells 2-1 and 2-2 for wheel angle and wheel speed), relatively high speed (cell 2-3 with speeds reaching 60 km/h) and low braking active (last row of column 2)

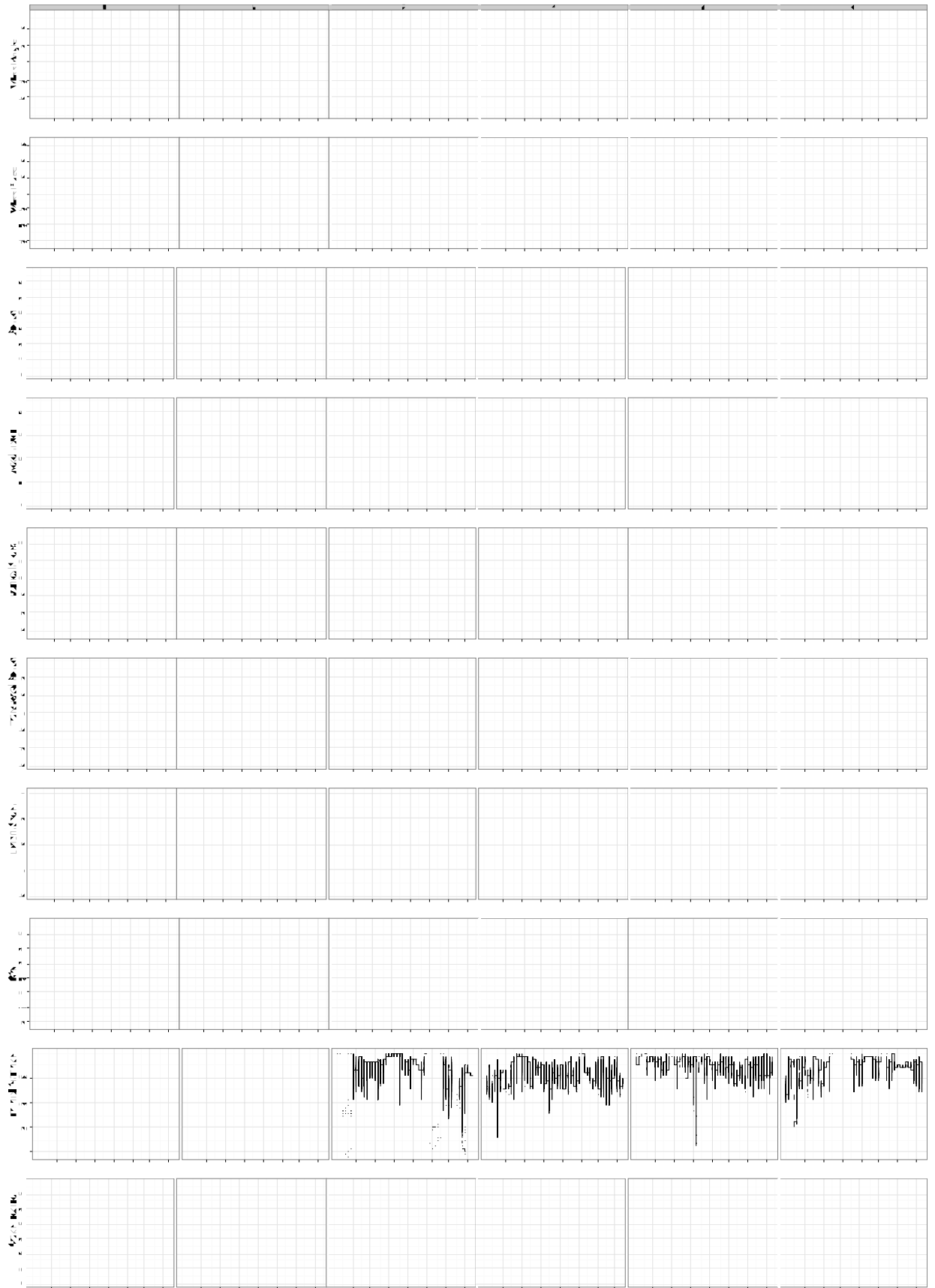


Figure 11 Numerical data for six Crash Relevant Incidents. Each column displays six minutes of ten numerical parameters for each incident. The incident happens in the middle of each graph.

These graphics display the events surrounding an incident, hereby complementing the visualization of the videos used for identifying it. Events such as swerving, brake pressings, accelerator use, can be spotted in these graphics and interpreted. As an example of the kind of interpretations that are possible with them, Figure 12 displays the first incident and the sequence of events around it step by step. The red line is located at the point when the crash-relevant conflict happened. The description shows how the driver stops or swerves several times at traffic lights, pedestrian crossings, cars parked or moving slowly, cyclists, etc. In this context, the driver probably felt the urge to go on without stopping at a pedestrian crossing (incident in red line) even though a pedestrian is on it at that moment. This behaviour, not stopping at pedestrian crossing in congested areas, is possibly very common if cars are moving at very low speeds and the flow of pedestrians makes very difficult to find adequate gaps for pulling out.



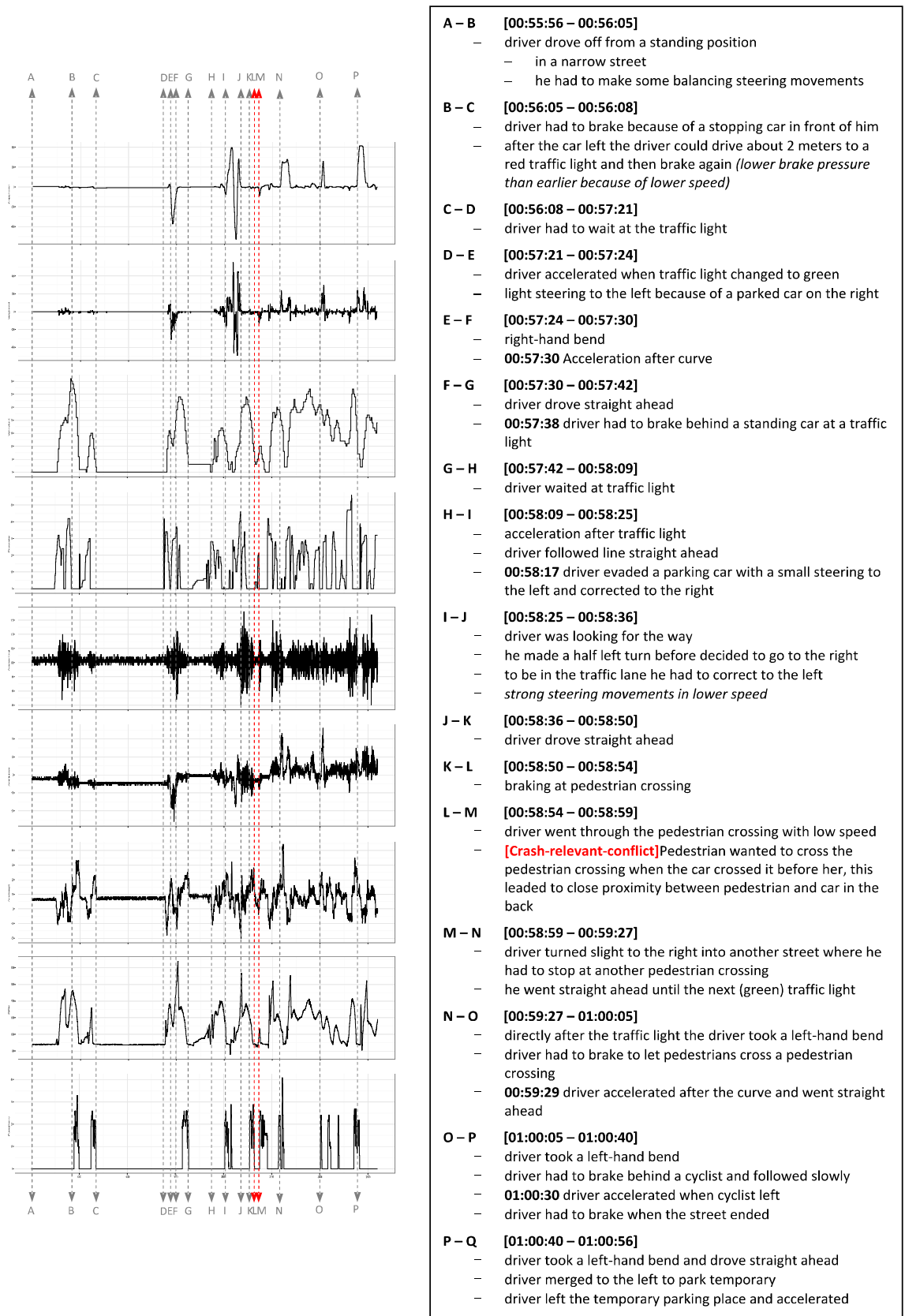


Figure 12 Description of a Crash relevant incident step by step

## 6 Summary and Discussion

The PROLOGUE project has a number of objectives related to technical, methodological and organizational possibilities and requirements needed for performing naturalistic studies. Therefore, an important part of the project is the realization of on-road driving trials in order to gain concrete experience of this methodology of research. Thus, in our case, the Spanish field trial has been an excellent opportunity for testing the ARGOS instrumented car: a very sophisticated research tool with a large potential but that previously has remained largely untested. Therefore, despite setting as objective of our trial to explore the consequences of using in-vehicle information systems in the car (specifically, a navigator), the primary aim of our trial has been learning about the mechanics of conducting a trial with it. Research on nomadic devices must be regarded a secondary goal of this project. In this respect, we consider the trial as very useful, as we have learnt a number of important lessons to consider in future studies.

In this chapter, we will discuss firstly the problems experienced using the ARGOS car in a number of categories, namely, legal issues, technical problems, logistic, subjects, and data analysis; secondly, we will discuss the results found with regard to the use of nomadic devices in the ARGOS car; and finally, we will analyze the strengths and weaknesses of using the ARGOS car for ND research.

### 6.1 Problems experienced

In this section we will discuss the problems we have found in order to use the ARGOS car in our trial. We will use the following categories: legal issues, technical problems, logistic, subjects, and data analysis. Many of these problems have been solved successfully so using the ARGOS car in the future for similar projects is expected to be easier.

- Legal/ethical issues

On the one hand, although we anticipated that issues related to privacy, informed consent, and insurance might be possibly problematic for carrying out experiments with the ARGOS car, these issues were solved satisfactorily without difficulty. On the other hand, one issue that we had not anticipated, the contract lending the car to the UVEG was more difficult to solve than expected and was the cause of some delays. Fortunately, we believe that this is a one off problem and that it will not happen in future trials.

- Technical problems

The ARGOS car is a complex piece of equipment that before this trial remained almost untested. Therefore, it was expected to find a number of technical problems during our trial. Some of the problems were detected by our research team before the trials started, but others eluded our tests and turned up during the trials. Unfortunately, the equipment in the ARGOS car is not as reliable as we wished and these kinds of failures were quite common. Hence, measures must be taken for diminishing the effects of malfunctioning.

The main lesson learnt about technical problems is that the data from the trials must be checked as often as possible. Preferably, data collected during the first half of the day should be examined during the other half. Then, if problems are detected and a subject is appointed for the following day, the trial may be postponed until they are solved. Therefore, it is important that the participants are warned about the possibility of appointments changing at short notice.

- Logistics of the trials

Before the ARGOS car arrived at our facilities, we had planned to lend the car to each of the participants in the experiment for a few days. However, this turned out to be unfeasible because of possible vandalism against it. Therefore, we made participants to set out from our facilities and return every day. Also, technical limitations meant that each trial could last only two or three hours at maximum.

One participant/trial per day was considered a reasonable objective. This allowed examining the data every day.

- Subjects

We have mentioned before that an economical compensation is probably necessary for recruiting participants. In our case, paying the subjects became rather difficult but we found a solution using a company specialized in providing drivers to other companies. While the specifics of this problem are unique, we know that the kind of short contracts needed for rewarding participants are a problem in other places too. Therefore, trials should check the limitations applicable to them in each case.

- Data analysis

Data analysis of the ARGOS car had two aspects: watching the videos and analyzing the numerical data.

The main lesson learned from the analysis of the videos is that it takes long time. In our case, approximately two times the time recorded was needed for watching the videos. The second lesson is about the number and importance of incidents. In our case, we registered 16 incidents in about 40 hours of recording. Therefore, a database of 100 incidents would require about 250 hours of recording and between 100 or 120 days of field trials (6 months). These figures are useful for planning future data collections.

Numerical data are a challenge for analysis. On the one hand, looking at specific values surrounding the incidents is useful for complementing the visual information in the videos. Events such as brake pressures, swerving, etc., may not be apparent in the videos but can be detected by looking at the numbers. However, an interpretation of these values is not straightforward: the values of the numerical parameters surrounding the incidents are often not very remarkable. Also, it is necessary to visualize several parameters at the same time because the important information can be in any of them, or in their combinations. In this report, we have shown a display of the values of many parameters for several incidents that gives a first approximation to the analysis of this data. However, it is important to explore statistical methods that summarize the information for several parameters and that permit identifying categories of incidents according to the observed or latent variables.

- Cameras

As explained in 2.3.1 the ARGOS car is equipped with seven installed cameras. The experiences and recommendations considering these cameras are listed below as well as a recommendation for re-locating/adding cameras (see Figure 14) in order to get as much information about the driver and his surroundings as possible.

Scenario-Camera: The scenario-camera is the most important camera for understanding the traffic situation from the driver's view and for identifying incidents happening in the frontal parts of the car. In the ARGOS car, there are two scenario cameras installed on the roof above the drivers' shoulder. From the position above the shoulder it is possible to capture the whole windshield as well as the upper half of the steering wheel and the centre console. For realizing different camera positions as a function of the information that want to be received it is recommended to install the camera with a small rail on the roof. However, the quality of the image is highly dependent on the sunlight, as high insolation leads to high reflection.

As a result of these experiences with the scenario camera, we recommend to install the scenario camera directly behind the rear window in order to exclude reflection because of the proximity to the windshield and to hide them a bit from the drivers attention. A combination of two cameras is recommended to capture as much of the scenario as possible as well as lateral areas of the car as visualized in Figure 13.

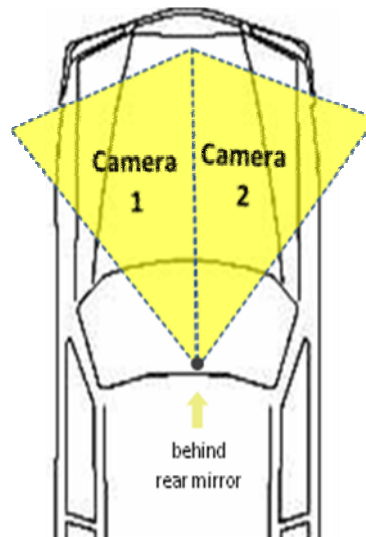


Figure 13 Recommended position for scenario cameras (eye tracking camera is not included here)

**Eye tracking Cameras:** The scenario camera belonging to the remote eye tracking system has to be focused on those parts of the drivers' view, which are most important depending on the research question. According to the different adjustments depending on the research questions, this camera should be adjustable horizontally and vertically. The one installed in Argos is just adjustable horizontally.

**Face-Camera:** The face-camera in the car ARGOS is positioned in the left corner next to the windshield where it captures the head of the driver on eye level and, if essential, the passenger.

If an eye tracking system isn't used, but analyzing the eye glance is planned, a face camera is essential and a recommended position is behind the middle of the steering wheel. Since the dashboard is the separation between the outside view and the in-vehicle view, the eye movement can be comprehended better than from a higher position. Furthermore the camera is not more visible than it is in the left corner at the drivers' eye level, as it is located behind the steering wheel and coloured in black like the dashboard usually is.

**Fog-light-Cameras:** The ARGOS car has two cameras located in the fog-light. They serve for capturing the cars' position on the street. Two thirds of the images are occupied with the street. If the cameras were moved up a bit, they would serve as scenario-cameras as well, as they capture the whole street view and road markings would stay visible. However, as the cameras are located in the front of the car, lateral areas are not captured.

**Rear-view-Camera:** The rear-view camera hangs in the car ARGOS from the roof of the car directly behind the back window. It is helpful for the better understanding and

description of some incidents. However it might be more informative to replace it for two side cameras as explained hereafter.

Side-Cameras: The car ARGOS does not have any cameras that capture lateral parts of the car. We consider them as very useful to have a full view of traffic situations especially in city traffic. In studies with vulnerable road users they are probably indispensable, but in turning situations there is a lot of information missing when just capturing with frontal scenarios.

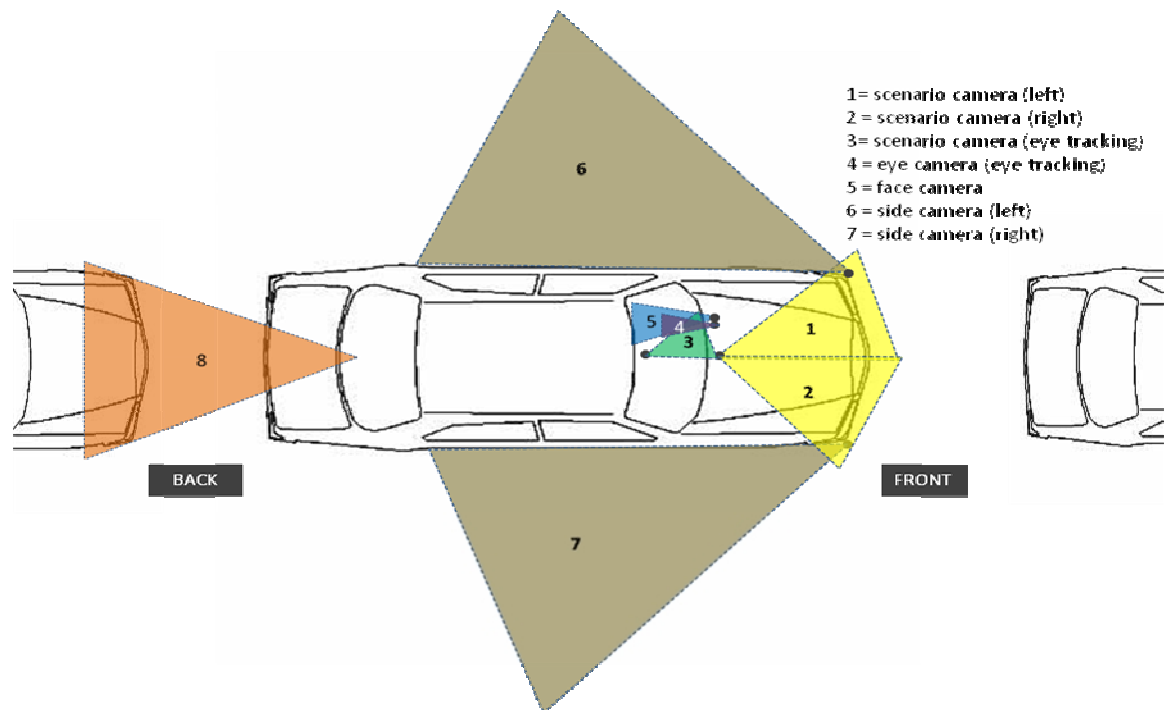


Figure 14 Recommendation for positioning of the cameras

## 6.2 Discussion of results about the use of nomadic devices

We will discuss the results related with what we reckon is the secondary objective of this trial: use of nomadic devices in the vehicle. Note that, as the size of the trial (participants, kilometres and time driven) is not sufficient for stating firm conclusions about this issue, the results discussed here are actually directions for how to get the most out of the ARGOS car in future studies rather than specific statements of the effects of the use of nomadic devices.

1. RQ1: Are there more incidents when the drivers use IVIS in the car?

We have mentioned before that the result obtained in relation with this hypothesis did not back up it. This result can be explained for the following reasons:

- Small sample: Perhaps larger samples of drivers and hours of driving will produce completely different results
- Training effects: We assumed that no training effects will turn up in our trials (the drivers had enough experience as drivers). However, it is possible that there was a problem of adaptation of one of the subjects to the car as he experienced a large number of incidents (5) the first day and none the rest.

Table 6 Incidents by use of IVIS

Subject	No	Yes	Total
1	5	0	5
2	2	4	6
3	4	1	5
<b>Total</b>	<b>11</b>	<b>5</b>	<b>16</b>

- As the task of the drivers consisted in finding addresses in locations in the town, it is possible that the navigator had a positive effect on driving, allowing the drivers to focus on the visual task of driving as they did not need to look at the street names or numbers for finding the addresses they were heading to. What is probably the worst source of distraction from these devices, manipulating them while driving, did not happen at all, as the drivers preferred to stop the car for introducing new addresses. We suspect that they preferred to do this because they found the user interface of the specific navigator in the car too unfriendly, as well as because the experimental situation made them behave extra safely. Besides, the Spanish government had recently passed a law limiting the manipulation of the navigator while driving the car and they had probably been exposed to the campaign in the media associated with it.

In summary, using the ARGOS car or participating in an experiment may have prevented the drivers of behaving naturally.

## 2. RQ2: Do drivers look at the IVIS when they have incidents?

In our study, we did not find any association between looking at the IVIS and the incidents. There are a number of possible interpretations of this result:

- The on-board IVIS was not visually distracting at all.
- Subjects drove carefully in the ARGOS car so they avoided looking at the IVIS as they felt that this might be a source of risk. Besides, they refrained themselves of introducing the directions while they were driving and they only did it while the car was stopped.

Again, the drivers may have opted for not using the nomadic device because of participating in an experiment or driving a special car.

## 3. RQ3: Are incidents associated with high or low values of certain parameters of the vehicle?

The analysis of this hypothesis is probably the most interesting part of our results. Even though we have not arrived to specific conclusions in relation with it, we reckon that the the visualization of the parameters of the car provides a useful first step towards a proper understanding of the circumstances surrounding incidents. However, it is important to remark that paying attention to individual values or parameters will often be of little interest. Pressing the brake or swerving are for example actions that may be related with incidents but very often they are not. Trying to draw conclusions only from specific values of the parameters has few prospects of succeeding. The values of the parameters associated with incidents do not necessarily stand out.

Nevertheless, once the incident has been detected, visualizing the values of the parameters is very important. An otherwise not very remarkable action on the brake, for example, can be of critical importance if it is effectuated just at the right moment. Indeed, assessment of an incident can be very different if there is any evidence of braking. The same can be said about any other parameter of the vehicle.

Furthermore, we see some promise in the analysis of the sequences of the data. As an example, we have mentioned before that an incident may have been associated with driving in high density/low speed traffic area, which forced the driver to stop several times consecutively. This could be considered a hypothesis that could be tested using the data we have collected. Thus, sequences of data with similar characteristics might be identified and compared with sequences with different or random characteristics. Finally, functions smoothing the sequences of data could be derived and used as dependent variables of independent variables of relevance (Ramsay and Silverman, 1997).

### 6.3 Strengths and weaknesses of using the ARGOS car for ND research

Deliverable 1.1. of the PROLOGUE project says that “...ND observation includes objectively and unobtrusively observing normal drivers in their normal driving context while driving their own vehicles” (Backer-Grøndahl et al, 2009). In this definition, the concept of obtrusiveness is probably the key element, as the lack of it is an important threat to the validity of ND methodology. Actually, this same deliverable (p. 13) and deliverable D1.3 of the PROLOGUE project (p. 30) express that observer effects cannot be ruled out completely without further research addressing this issue. So, a hypothesis suggested in these documents is that ND is probably not adequate for studying illegal or deviant behaviour, despite the evidence indicating that observer effects diminish in studies conducted over long periods of time.

In the continuum from experimental research to naturalistic studies described by McLaughlin et al. (2008), there are several factors that will determine the position of a specific study in it. The field trial carried out with the ARGOS car has brought up the following threats to the naturalistic approach:

- **Tasks:** Due to technical issues, the subjects had to pick up the ARGOS car at the Institute’s facilities and could not keep it longer than about 3 hours. During this time they had to look for several destinations that we gave them as a route plan. This contradicts the concept of a naturalistic study as this would require that the driver has the car available whenever he needs it and can go for any self-selected destination. Given that our drivers were professional drivers which usually are hired to go for a predetermined destination, we feel that this specific factor did not affect excessively the validity of the experiment. However, generalization of the results to normal drivers is probably very limited, as finding several addresses in the same day is not typical for them. Therefore, this trial could be regarded as ND for professional drivers, rather than for normal drivers.
- **Car:** The study could not be carried out with the drivers’ own cars which additionally contradicts the ND definition. But the professional drivers are used to drive with unfamiliar cars, so we regard this as acceptable. However, what makes the driving less naturalistic is the instrumentation installed in the car as the ventilation is audible and the cameras in the front as well as some instruments on the dashboard are visible.
- **Participating in an experiment:** Our participants probably did not perform any type of unsafe behaviour whilst driving. On the contrary, the subjects seemed to drive very carefully most of the time. This is probably a consequence of using the ARGOS car and of working for a Traffic Safety Institute. Although you may dismiss some of these elements as not very relevant (people rent cars or forget that they participate in an experiment), taking all together, we may expect a behaviour that is probably not totally naturalistic in many cases. In our trial, for example, none of the drivers manipulated the navigator in the car whilst driving. On the contrary, they only manipulated it when the car was stopped. Hence, finding an association between the navigator and driving is probably out of the question in this case.

In summary, the field trial we have carried out is not on the extreme of naturalistic driving, but it is not on the other extreme either. Although our drivers possibly behaved more carefully than they would do in normal conditions, they were still managing a car in real roads, and independently of how careful they tried to drive, there were many external factors that were not under their control. So, the research setting and the ARGOS car can be a useful source of information for learning about the effects of factors that are not under control of drivers and that can jeopardize even careful drivers. In fact, it is for the analysis of these incidents, as we have shown before, that the ARGOS car is very appropriate. The rich information provided for all the sensors, cameras, and car measures are very useful for analyzing scenarios (incidents, near-crashes, etc.) that are part of daily driving of even careful drivers. Some examples of these scenarios are:

- Errors associated with elements of the infrastructure
- Analysis of incidents
- Interaction with other types of road users

Instrumented cars provide very rich information that can be used for addressing different research questions, but certain experimental settings are not realistic in practice.

#### **6.4 Summary and recommendation for large-scale studies**

The main goal of this small-scale field trial has been the learning about using a highly instrumented car for conducting a long-scale naturalistic driving study. While conducting the study, some technical processes were optimized, several unexpected issues were solved, methods for data reduction and analysis were tested and in consequence a number of lessons were learned that will be useful for large-scale studies.

One important result is that the naturalistic character of studies with the ARGOS or similar cars requires some improvements for further studies. Thus, the driver should be less aware of all the instruments and systems around him in the car. It should be considered to make them less visible and audible for the drivers, what could be obtained by installing some kind of darkened partition that divides the drivers and co-drivers area from the rest of the car. According to the definition of naturalistic driving, drivers should be able to use the car for their daily routine without any instructions neither restrictions. To enable these requirements, cars equipped in the dimensions like ARGOS would require a self-starting system, a very powerful battery, a high capacity hard-disk and a high level of reliability of the systems. However, it is doubtful whether an independent use can be obtained without abandoning some measurements as for example the eye tracking system, which requires often a process of recalibration while using it.

Hence, it might not ever be feasible to reach the highest possible level of naturalistic driving when using a highly instrumented car like the ARGOS. These kinds of cars are possibly more suitable for conducting studies where the behaviour of a small number of drivers as well as the environmental surroundings is of specific interest. To give an example, it might be of practical use to investigate black spots letting several drivers passing it with a highly instrumented car to study their behaviour and their environment. Whereas lower equipped, but driver-owned, cars seem to be more suitable for conducting studies where data is captured continuously in a longer period of time.



## List of abbreviations

- ADAS = Advanced Driver Assistance Systems
- ALASCA = Automotive LAsErSCAnner
- CO = Confidential Deliverable
- DGT = Directorate General of Traffic: the authority in Spain in charge of in-surface traffic management
- ETS-PC = Eye-tracking system
- HCI = Human Computer Interface
- IR = Infrared
- INTRAS = Reserach Institute on Traffic and Road Safety
- IVIS = In Vehicle Information System
- ND = Naturalistic Driving
- NOD = Nomadic Devices
- PU = Public Deliverable
- QA = Quality Assurance
- RE = Restricted Deliverable
- UPM = Universidad Politécnica de Madrid
- UVEG = Universitat de Valencia-Estudio General
- WP = Work Package

## References

- Backer-Grøndahl, A., Phillips, R., Sagberg, F., Toulou, K., Gatscha, M. (2009). *Naturalistic driving observation: Topics and applications of previous and current naturalistic studies*. PROLOGUE Deliverable D1.1. TØI Institute of Transport Economics, Oslo, Norway.
- Barr, L.C., Yang, C.Y.D., Ranney, T. A. (2003). *An exploratory analysis of truck driver distraction using naturalistic driving data*. In: TRB 2003 Annual Meeting DC-ROM. Washington D.C.
- Brusque, C., Alauzet, A. (2006). L'utilisation du téléphone mobile au volant en France : entre déni durisque et autorégulation du comportement (Mobile phone use while driving in France: between risk denial and self-regulation behaviour). *Recherche Transport et Sécurité*, 91, 75-94.
- Brusque, C., Kaufmann, C., Turetescheck, C., Risser, R., Rehnová, V., Macku, I. Vasek, J., Zehnalova, V., Schmeideler, K., Bruyas, M. P., Gelau, C., Simonova, Z., Cozzolino, M. Vaa, T., Simoes, A., Pereira, M., Carvalhais, J.(2006). COST 352: *Influence of Modern In-vehicle Information Systems on Road Safety Requirements-Existing knowledge inventory*. Les collections de l'Inrets, France.
- Brusque et al (2009) COST 352: *Influence of Modern In-vehicle Information Systems on Road Safety Requirements-Final Report*. Les collections de l'Inrets, France.
- Dingus, T. A., Klauer, S. G., Neale, V. L., Petersen, A., Lee, S. E., Sudweeks, J., Perez, M. A., Hankey, J., Ramsey, D., Gupta, S., Bucher, C., Doerzaph, Z. R., Jermeland, J., and Knippling, R.R. (2005). *The 100-Car Naturalistic Driving Study: Phase II –Results of the 100-Car Field Experiment*. Interim Project Report for DTNH22-00-C-07007, Task Order 6; Report No. TBD), National Highway Traffic Safety Administration, Washington, D.C
- European Commission (2006). Commission Recommendation on safe and efficient in-vehicle information and communication systems: update of the European Statement of Principles on human machine interface. *Official Journal of the European Union*, Brussels.
- Green, P., (2004) *Driver distraction, telematics design and workload managers: safety issues and solutions*, Society of Automotive Engineers, Paper No. 2004-21-0022.
- Groenewoud, C., Schoen, E., Malone, K., Jonkers, E., Hoedemaeker, M., Hogema, J. (2010). *Methodological and organizational issues and requirements for ND studies*. Deliverable D2.2. PROLOGUE project
- Hickman, J. S., Knippling, R. R., Olson, R. L., Fumero, M. C., Blanco, M., & Hanowski, R. J. (2005). *Heavy vehicle-light vehicle interaction data collection and countermeasure research project: Phase I – Preliminary analysis of data collected in the Drowsy Driver Warning System Field Operational Test*. DTNH22-00-C-07007, Task Order #21. Federal Motor Carrier Safety Administration, Washington, DC.
- ISO (2003) Road vehicles — Ergonomic aspects of transport information and control systems — Procedure for assessing suitability for use while driving. Report number 17287.
- Jeanne Breen Consulting (2009). *Car telephone use and road safety. Final report. An overview prepared for the European Commission*. Available at [http://ec.europa.eu/transport/road\\_safety/specialist/knowledge/mobile/car\\_telephone\\_use\\_and\\_road\\_safety.pdf](http://ec.europa.eu/transport/road_safety/specialist/knowledge/mobile/car_telephone_use_and_road_safety.pdf) [07.12.2010]
- Klauer, S.G., Dingus, T.A., Neale, V.L., Sudweeks, J.D., and Ramsey, D.J. (2006). *The impact of driver inattention on near-crash/crash risk: an analysis using the 100-car naturalistic driving study data*. Contract No. DTNH22-00-C-07007. Virginia Tech Transportation Institute, Blacksburg, VA.

- McLaughlin, S. B., Hankey, J. M., Dingus, T. A. (2008). A method for evaluating avoidance systems using naturalistic driving data. *Accident Analysis and Prevention*, 40, 8-16.
- Nowakowski, C., Utsui, Y., Green, P. (2000). *Navigation System Destination Entry: The effect of driver workload and input devices, and implication for SAE recommended practice*. (UMTRI-2000-20): The University of Michigan Transportation Research Institute, Michigan, USA.
- Olson, R. L., Hanowski, R. J., Hickman, J. S., Bocanegra, J. (2009). *Driver distraction in commercial vehicle operations*. Report No: FMCSA-RRR-09-042. U.S. Department of Transportation, Federal Motor Carrier Safety Administration. Washington D. C.
- Pöysti, L., Rajalin, S., Summala, H. (2005). Factors influencing the use of cellular (mobile) phone during driving and hazards while using it. *Accident Analysis and Prevention*, 37 (1), 47-51.
- Ramsay, J. O. and Silverman, B. W. (2002). *Applied Functional Data Analysis*. Springer-Verlag, New York.
- Redelmeier, D. A., Tibshirani, R. J. (1997) Association between cellular-telephone calls and motor vehicle collisions. *The New England Journal of Medicine*, 336(7) 453-458.
- Ripley, B. D. (1996). *Pattern Recognition and Neural Networks*. Cambridge University Press. Cambridge.
- Stevens, A., Minton, R. (2001) In-vehicle distraction and fatal accidents in England and Wales. *Accident Analysis and Prevention*, 33, 539-545.
- Stutts, J., Feaganes, J., Reinfurt, D., Rodgman, E., Hamlett, C. Kenneth, G., Loren, S. (2005). Driver's exposure to distractions in their natural driving environment. *Accident Analysis and Prevention*, 37, 1093-1101.
- Sullman, M. J.M., Baas, P. H. (2004). Mobile phone use amongst New Zealand drivers. *Transportation Research Part F*, 7, 95-105.
- Tsimhoni, O., Smith, D., Green, P. (2002). *Destination Entry While Driving: Speech Recognition versus a Touch-Screen Keyboard*. (UMTRI-2001-24). The University of Michigan Transportation Research Institute. Michigan, USA.
- Violant, J. M. (1998) Cellular phones and fatal traffic collisions. *Accident Analysis and Prevention*, 30, 519-524.

## Appendix I: Informed Consent

# Contrato de consentimiento para los conductores de las pruebas de campo del PROLOGUE

### *Consentimiento de los participantes a las pruebas de campo para el proyecto PROLOGUE*

Título del proyecto:	PROLOGUE (Promoting real life observations for gaining understanding of road user behaviour in Europe – Promover las observaciones en condiciones reales para conseguir entender el comportamiento del usuario de la carretera en Europa)
Investigación realizada por:	Grupo de investigación SINTEC del INTRAS-UEVG
Investigación cofinanciada por:	Dirección General de Investigación de la Comisión Europea
Investigadores:	Pedro Valero-Mora, Jaime Sanmartín, Ignacio Pareja, Mar Sánchez, Jean-François Pace, Anita Tontsch

#### I. Propósito del proyecto PROLOGUE

El objetivo principal del PROLOGUE es demostrar la viabilidad y utilidad de un estudio de observación naturalista Europea a gran escala. El proyecto está dirigido a investigadores en seguridad vial y a otras partes interesadas como la industria del automóvil, las compañías de seguros, las organizaciones de aprendizaje y de certificación, y las autoridades y gobiernos. Mientras que la seguridad vial es el principal motivo, el proyecto también se fijará en los temas medioambientales, por ejemplo las emisiones de CO<sub>2</sub>, y en la gestión del tráfico.

Basado en estudios inventariados, una serie de pruebas de campo a pequeña escala, así como una implicación de los grupos de usuarios y de las partes interesadas, PROLOGUE llegará a unas recomendaciones y un esquema para llevar a cabo un estudio naturalista a gran escala, tratando preguntas de investigación, metodología y tecnología para la recogida, el almacenamiento, la comprensión, la extracción y el análisis de datos. La comunicación y la diseminación hacia las posibles partes interesadas son fundamentales para adquirir su apoyo e implicación en un estudio Europea a gran escala.

#### II. Propósito de la prueba de campo

#### III. Procedimientos y responsabilidades del sujeto

A continuación, se describen los procedimientos para el estudio y las responsabilidades del participante:

##### Preparación para el estudio:

Leer detenidamente este contrato, apuntar cualquier pregunta. Puede llamar a 686143258 (Ignacio Pareja) para aclarar cualquier duda.

Firmar y fechar este contrato.

Antes de empezar la prueba de campo: traer el contrato firmado y un permiso de conducir válido.

Escuchar las explicaciones de las características del vehículo.

Revisar el protocolo del seguro del vehículo instrumentado.

Recogida de datos durante la conducción:

Conducir el vehículo normalmente.

Mientras conduce el vehículo, no está permitido llevar ningún pasajero.

Usted debe de ser la única persona que conduzca el vehículo.

Conducción:

Tal y como ya se ha mencionado, tiene que conducir el vehículo como lo haría normalmente. Eso implica respetando las normas de circulación.

En caso de infracción a las normas de circulación durante el experimento, el conductor será el responsable.

Descarga de los datos:

Cada día, para proceder a la descarga de los datos, deberá entregar el vehículo al Instituto de Tráfico y Seguridad Vial de la Universitat de València, situado en la Calle Serpis, 29 – 46022 Valencia.

Mantenimiento del equipo y del vehículo:

En caso de fallo o daño del equipo, avisar a Ignacio Pareja (686143258) lo antes posible.

Las revisiones de seguridad han sido realizadas: presión de los neumáticos, amortiguadores, frenos y nivel del aceite. Dado que el vehículo se tendrá que devolver cada día, el depósito será llenado por el equipo de investigación.

En caso de accidente: Procedimientos del estudio (se aplica para todo tipo de colisión, independientemente de la severidad):

Contactar con Ignacio Pareja (686143258) lo antes posible después del accidente.

En caso de informe policial, pedir una copia al agente para entregársela al equipo de investigación. El equipo de investigación eliminará todos los identificadores personales para asegurar la confidencialidad. Los “identificadores personales” incluyen los nombres y apellidos, la dirección y los números de teléfono.

Pedir y entregar copias de los informes médicos relacionados con las heridas provocadas por el accidente y el tratamiento.

Devolución del vehículo:

El vehículo deberá de ser devuelto todos los días antes de las 19.00 al Instituto de Tráfico y Seguridad Vial de la Universitat de València, situado en la Calle Serpis, 29 – 46022 Valencia.

Equipo y recogida de datos:

Se le ruega conducir el coche instrumentado durante aproximadamente un mes. Los datos serán recogidos cada día al final del día. Una vez descargado los datos, serán almacenados en un servidor específico que sólo podrán consultar los miembros del equipo de investigación asignado para este proyecto.

La recogida de datos está diseñada para no necesitar ningún tipo de mantenimiento y no deberá de encargarse de cualquier tipo de mantenimiento.

Seguro del vehículo:

Una copia de la póliza se adjunta como anexo a este documento.

#### Seguro médico:

Los participantes a un estudio están considerados como voluntarios, independientemente de si reciben una remuneración por participar. Por lo tanto, si no ocurre dentro del vehículo, en caso de lesión, los participantes tendrán que recurrir a sus propios seguros privados/médicos. Un seguro médico adecuado está recomendado para cubrir ese tipo de gastos.

En caso de lesión en un accidente, sea dentro o fuera del vehículo, el tratamiento médico que recibirá será el que se proporciona a cada individuo por los servicios de emergencias de la zona donde el accidente ha tenido lugar.

#### IV Riesgos

El riesgo es idéntico al que está sometido cuando conduce su propio vehículo. Todo el equipo de recogida de datos está instalado de manera que, en mayor medida, no representa ningún peligro. Ningún equipo dificultará su campo de visión normal. La instalación de los sistemas de recogida de datos en el vehículo no afectará en absoluto el manejo del vehículo.

#### V Extensión del anonimato y de la confidencialidad

El proceso de recogida de datos incluye información de video. Los datos recogidos en este experimento serán tratados con confidencialidad. Los nombres de los conductores serán separados de los datos recogidos. Un sistema de codificación se utilizará para identificar los datos por número del sujeto únicamente (por ejemplo conductor nº 2).

Mientras conduce el vehículo, una cámara grabará su rostro así como la parte izquierda exterior del vehículo, la parte derecha exterior del vehículo, la vista hacia adelante, la vista hacia atrás y la vista del tablero. Ningún otro pasajero dentro del vehículo será grabado por las cámaras.

Varios sensores instalados en el vehículo también recogerán datos.

Los datos de este estudio serán almacenados en una zona segura del INTRAS-UEVG. El acceso a dichos datos se realizará bajo la supervisión del Prof. Valero-Mora. Durante el estudio, los videos no podrán ser visionados por personas que no pertenecen al proyecto sin su consentimiento por escrito.

#### VI Compensación

Se ha firmado un contrato con la empresa "SOLUCHOFER" en el cual se han acordado unos recorridos en un tiempo determinado. Si esos recorridos se hacen en menos tiempo, la compensación económica no se verá afectada dado que la parte más importante es cumplir con los recorridos.

#### VII Libertad para retirarse

Está libre de retirarse cuando lo desee sin ninguna penalización. Sin embargo, sólo se vería compensado por la parte proporcional al tiempo que ha participado (ver VI.). El INTRAS-UEVG tiene el derecho de poner fin a su participación en el estudio en cualquier momento. Por ejemplo, el INTRAS-UEVG podría poner fin a su participación en caso de que la cantidad y calidad de los datos recogidos sean insuficientes para los objetivos del proyecto o bien porque representa una amenaza para usted o los demás

usuarios de la vía. Los sujetos cuya participación sea finalizada anticipadamente recibirán una compensación prorrateada.

#### VIII Responsabilidades del conductor

Por voluntad propia, acepto participar en este estudio. Entiendo los procedimientos y las responsabilidades descritas anteriormente y doy voluntariamente mi consentimiento para la recogida y el procesamiento de datos para este estudio.

#### IX Autorización del conductor

He leído y entendido este contrato de consentimiento y las condiciones del proyecto. Todas mis preguntas han sido contestadas. Por la presente, acepto lo antedicho y doy voluntariamente mi consentimiento.

Nombre del conductor: \_\_\_\_\_

Firma del conductor: \_\_\_\_\_

Fecha: \_\_\_\_\_

En el caso de tener cualquier duda o pregunta sobre este estudio, puedo contactar con:

Jean-François Pace (jean.pace@uv.es)

Tel: +34 9633 93880

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