TELEFOT: FIRST RESULTS IN ASSESSING THE IMPACTS OF AFTERMARKET AND NOMADIC DEVICES

Serena Fruttaldo *[1], Ruth Welsh[2], Stig E.R. Franzén[3], Petri Mononen [4], Katia Pagle [5]

Serena Fruttaldo [1]
Research Fellowship and Senior Research Scientist, University of Modena and Reggio Emilia
Via Amendola, 2 (padiglione Morselli) - 42122 Reggio Emilia (Italy)
Tel. +39–0-522–52-2663-Fax +39–0-522–52-2164
serena.fruttaldo@unimore.it

Ruth Welsh [2]
Senior Researcher, Loughborough University
Ashby Road, Loughborough, UK
Tel +44 1509 226900 – Fax +44 1509 226960
r.h.welsh@lboro.ac.uk

Stig E.R. Franzén[3]
Professor, Chalmers University of Technology
SE-412 96 Gothenburg, Sweden
Tel: +46317721000, Fax: +46317725858
stigf@chalmers.se

Petri Mononen [4]
Senior Research Scientist, VTT Technical Research Centre of Finland
P.O Box 1100, 90571 Oulu (Finland)
Tel. +358-20-722-2325 – Fax +358-20-722-2090
petri.mononen@vtt.fi

Katia Pagle [5]
Researcher, Institute of Communication and Computer Systems I-SENSE group
9, Iroon Polytechniou str., 15773 Athens, Greece,
Tel: +30 210 772 2398, Fax: +302107722291
katia@iccs.gr

ABSTRACT

This paper presents the status and first results achieved in the European Large Scale Collaborative Project TeleFOT (Field Operational Tests of Aftermarket and Nomadic Devices in vehicles). The paper is structured into three sections.

The Introduction is conceived to show the key issues that TeleFOT deals with and its scenario. Intelligent Transport Systems (ITS) have been the subject of significant research and development in Europe in recent years as they are contributing to a change in the transportation process. The market penetration of portable navigators and smart phones is consistently increasing but no standards directly related to the use of aftermarket and nomadic devices in vehicle exist. To conduct Field Operational Tests (FOTs) based on a large number of drivers using nomadic/mobile devices in their own vehicles and to raise wide awareness of the functions and the potential these devices offer are in the core of TeleFOT.

The section on FOTs provides a description of the trials carried out in TeleFOT. It includes a presentation of the functions tested and of the Research Questions and Hypotheses generation process. The impact areas to be analysed in the project are shown as well. Finally, the section on Indicative results achieved shows the progress made so far in the project, in particular concerning the analysis of data from the pilot tests.

INTRODUCTION

Significant research and development in Europe in recent years has been focused on Intelligent Transport Systems (ITS). Many ITS functions are today made available by portable navigators and smart phones and their market penetration is increasing considerably. Nevertheless no standards directly related to the use of aftermarket and nomadic devices in vehicles exist and almost nothing is known about their impact on the driver behaviour, the user acceptance and on the performance of the traffic and transport systems.

TeleFOT (Field Operational Tests of Aftermarket and Nomadic Devices in Vehicles), a Large Scale Collaborative Project under the Seventh Framework Programme, is a pan-European field trial aiming to assess the impact of functions provided by nomadic devices on the driving task, as well as on the transportation process as whole and on user up-take. Another objective is also to raise wide awareness of the results. A Field Operational Test (FOT) is a relatively new method, in particular in Europe, for studying the impacts of functions on transportation, i.e. on driving, traffic and transport. From a bit more technical and methodological perspective, the FESTA Handbook (1) defines an FOT as “A study undertaken to evaluate a function, or functions, under normal operating conditions in environments typically encountered by the host vehicle(s) using quasi-experimental methods.”

This means that the objective is to compare the impacts that the use of the function has on

traffic with a baseline condition during which the function is not operating. In order to achieve this, the drivers' control over or interaction with the function(s) has to be manipulated by the research team. "Normal operating conditions" implies that the drivers use the vehicles during their daily routines, that data logging works autonomously and that the drivers do not receive special instructions about how and where to drive. Except for some specific occasions, there is no experimenter in the vehicle, and typically the study period extends over several months. In TeleFOT, equal or greater than 1Hz GPS in-vehicle data loggers, which in some case are able to log also events and 3-axis acceleration are used for automated data collection. Subject information management and data security are allowed by an automated system for Machine-to-Machine (M2M) communication from the data loggers of all participating test sites to a central database and from the central database to the individual data user. Web-based questionnaires and travel diaries are used to capture subjective and qualitative data.
FOTs in TeleFOT are organised in three test communities based in Northern (Finland, Sweden), Central (Germany, UK, France) and Southern (Greece, Italy, Spain) Europe.

FIELD OPERATIONAL TESTS IN TELEFOT

The core of TeleFOT, conducting Field Operational Tests, is based on a large number of drivers using functions provided by nomadic devices in their own vehicles. The drivers' interaction with the functions and services provided are studied and data are collected to address related research questions. Up to 3000 drivers will be involved in the project. From these drivers, data on position and speed (via GPS logging) and in some cases acceleration and interaction with the device events are recorded through loggers and transferred to the databank for the analysis. Subjective and qualitative data are also collected.
In very long tests like the ones performed in TeleFOT, the study design chosen is critical and two approaches are possible; between-subject and within-subject design. Due to local circumstances (timing of tests and availability of test subjects) the use of a separate control group was not possible, and as such a between-subject design was not chosen. The way to conduct a within-subject design test was carefully prepared and actions have been taken to minimize the possible negative effects of such an approach (3). The Experimental design to be used in most of the tests was therefore a so called within-subject design. The test persons are first driving under normal conditions without availability of the "function", and then with the functions in operation.
The data are collected in different phases related to the testing period (ideally at least half a year):

- **Pre-test phase**: data about the user are collected, e.g. gender, age, driving experience, experience with driving support systems or similar;

- **During the tests**: the objective data are logged. These data are complemented with additional subjective data. Subjective data are collected by means of diaries, questionnaires, individual interviews and focus group interviews.
- **Post-test phase**: a subjective evaluation of the system by the user will be done.

The TeleFOT project consists of Large scale FOTs **(LFOTs)** and Detailed FOTs **(DFOTs).**

The **LFOTs** are the core of the project and their objective is to investigate normal, everyday, use of one or several functions by the driver; the functions being provided by aftermarket and nomadic devices. The studies concern conditions in which the participants receive, use and react to functions and services provided to them and data are to be collected over a long period of time from a large number of participants. The functions studied are Traffic Information, Speed limit information, Speed alert, Navigation support (static), Navigation support (dynamic), Green driving support, and eCall.

DFOTs investigate the effects under a more controlled environment than the LFOTs, e.g., the participants will be asked to drive certain routes, as well as under certain conditions. A limited number of instrumented vehicles will be used capable of precise recording of driver behaviour – especially in terms of investigating cockpit activities while driving. Data acquisition systems for the DFOTs are for instance the Cockpit Activity Assessment module (CAA) detecting the driver's visual and cognitive distraction. Another is the Environmental Conditions Assessment module (ECA) that calculates in real time the traffic and environmental parameters (such as time to headway/time to collision etc.) and is able to estimate the drivers' intention. The DFOTs will be used to improve and widen the interpretation of the test results from the LFOTs.

Pilot Tests have been carried out before starting the trials to make a final technical and logistic assessment of the test designs and tools to be used, as well as to ensure good-quality dataflow throughout the tests, including. collection, transfer, download and analysis.

FUNCTIONS AND SERVICES AND THEIR IMPACT ON GREENER, SAFER AND MORE EFFICIENT TRANSPORTATION

The increasing role of ICT supporting transportation makes it more and more important to know the impacts of functions provided by aftermarket and nomadic devices on drivers' behaviour and choices. This implies also a deeper consideration of the consequences on Safety and Transportation policies that this use can have. Mobile communication and location based functions and services used in vehicles are expected to have substantial impacts on users and societies.

The objective of TeleFOT is to investigate the impacts of these key functions available today, testing mature systems and technologies. In order to grasp the specific character of the in-vehicle use of the systems to be studied (functions provided by nomadic and aftermarket devices) the approach must cover the wide context of transportation, i.e. travel, transport, and traffic.

The **research hypotheses** to be tested in TeleFOT address the following impact areas:

- Safety
- Mobility
- Efficiency
- Environment
- User up-take

The aforementioned impact areas will be further explained in the following section. The (often real-time) TeleFOT core functions under **impact assessment** in the project are shown in Table 1:

	Efficiency	**Environment**	**Mobility**	**Safety**	**User uptake**
Traffic information	X	X	X	X	X
Speed limit information	X	X	X	X	X
Speed alert	X	X	X	X	X
Navigation support (static)	X	X	X	X	X
Navigation support (dynamic)	X	X	X	X	X
Green driving support	X	X	X	X	X
eCall		X			X

Table 1 – Core functions vs. Impact areas

It should be mentioned that also the ADAS functions Forward Collision Warning (FCW), Lane Departure Warning/Lane Keeping Support (LDW/LKS) and Adaptive Cruise Control (ACC) are addressed in the tests. However, as modern cars are often equipped with these ADAS functions they are included not for the dedicated study of these functions per se, but because they constitute important elements of the driver environment. It is important to understand their possible interference with the use of the TeleFOT core functions (Table 1) under normal driving conditions.

TELEFOT RESEARCH QUESTIONS AND HYPOTHESES – REFINEMENT PROCESS

The analysis undertaken within the TeleFOT project aims to assess the impact of functions provided by after-market and nomadic devices in the five distinct assessment areas mentioned above (Safety, Mobility, Efficiency, Environment and User Uptake). In order to measure the impacts the project developed core research questions and hypotheses for each assessment area that also take into account the functionality of the devices specifically under consideration in TeleFOT.

An **integrated top-down/bottom-up approach** (Figure 1) was used. The top-down approach is driven by the issues of relevance to the impact area irrespective of the system functionality. The bottom-up approach is driven by the functionality, the system design, the use cases and the impact area (i.e. the approach proposed by the FESTA project, (1)).

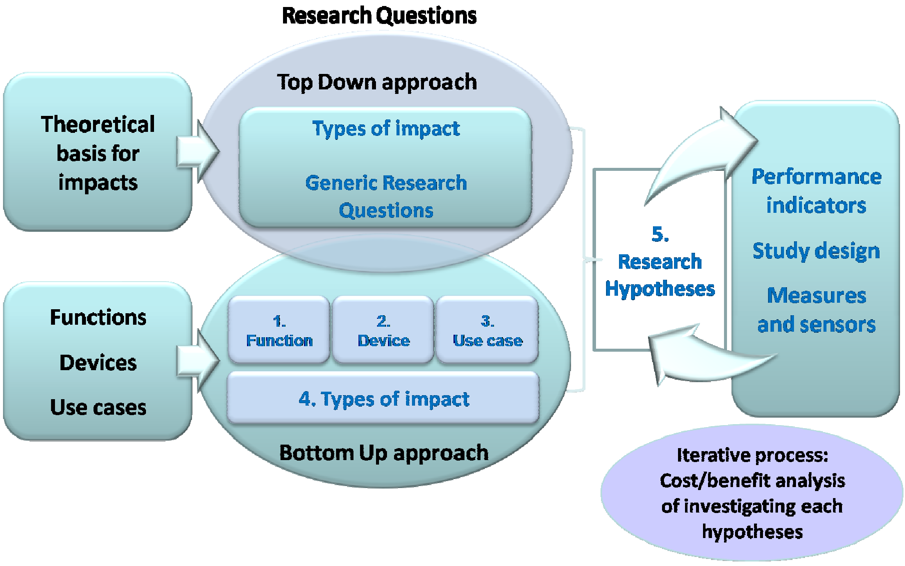

Figure 1 – TeleFOT hypotheses generation

However, because the project developed so many research hypotheses based upon the previous work undertaken, it was necessary to refine these to a number of 'core hypotheses'. The refinement process used to develop these core hypotheses that will be addressed in the FOTs were selected based upon:

- The relevance of each research question to TeleFOT (e.g. the question has a relationship with the functionalities to be assessed),
- The importance of each question (justified by current literature, public perception and the strength of contribution to the impact assessment)
- The feasibility of answering the associated hypotheses, limited by a knowledge of the data to be collected.

The process for developing research questions and associated hypotheses was therefore based on a structured 4-stage approach. This addressed the importance, relevance of each research question in each assessment domain coupled with an appraisal of the feasibility of collecting data in terms of performance indicators that would address each research question. Where it was considered that the research question was not important in the context of after-market and nomadic devices, the research question was not considered further. In cases where the research question was considered important but that there was no feasibility of collecting data without significant effort or expense, the research question was also not considered further.

INDICATIVE RESULTS ACHIEVED

Within the TeleFOT project to date, pilot studies have been carried out prior to commencing the actual FOTs. These have been undertaken in order to test the flow of the data throughout its cycle from collection through transfer, download and analysis. The pilot analyses were undertaken predominantly on LFOT pilot data collected in Sweden, Finland and Greece. A small amount of DFOT data was also available from the UK. In this section some typical analyses are illustrated. It should be noted that these are intended to show the type of analyses planned by the TeleFOT project and should not be seen as conclusive at this stage. An example has been included for each of the data sources available in the project; these being questionnaire, travel dairy and basic logged data in the LFOTs and additional logged data in the DFOTs.

QUESTIONNAIRE DATA

Questionnaire data is typically being used to identify participant's perceptions and the way that these change over a period of time using the TeleFOT function. For example, one question relates to the participants perception of safety offered by the function. Participants were asked in the initial user uptake questionnaires, prior to use of the functions, whether they thought their 'safety' during driving would change following installation of the device to be tested. In particular two functions were assessed – Green Driving (GD) advisory systems and Speed Information (SI) /Speed Alert (SA) systems. The participants were asked to rank the likely changes in perception of safety on a 5-point scale where '1' represents radical decrease in safety and '5' represents radical increase.

Figure 2 shows the initial expectations in terms of perceptions of safety with GD advisory systems. The vast majority of participants reported that they thought the GD advisory system would make no changes to perceived safety (53.8%) or would slightly increase safety (38.7%).

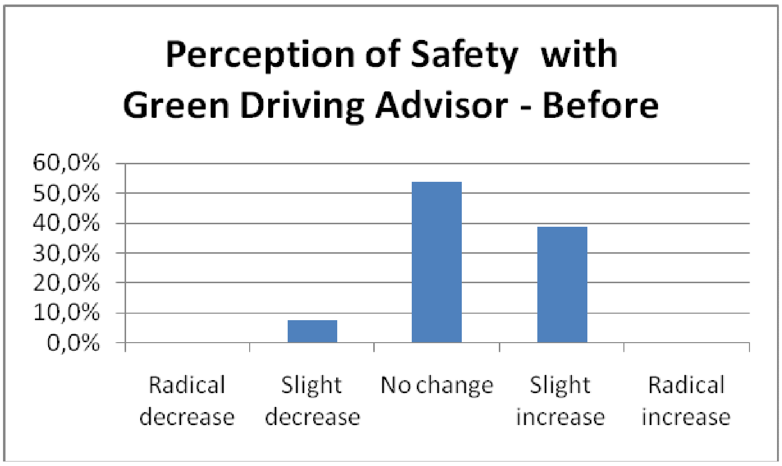

Figure 2 - Perception of change in safety with GD Advisor – Before system use

Similar analysis for SI/SA system is shown in Figure 3. Here the figures are more in favour of a slight increase (52.7%) in subjective safety than for GD. 2.7% respondents actually thought that the system would lead to a radical increase in perceptions of safety.

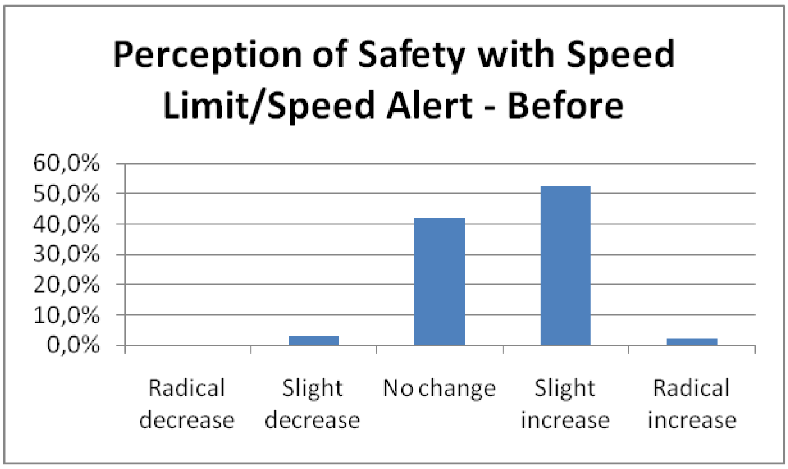

Figure 3 - Perception of change in safety with SI/SA system – Before

Regardless of what the figures tell us at this stage, in the final analysis it is important to determine whether these perceptions change over the course of time. The final analyses will calculate the difference between the pre-phase use and use in the later phases on the LFOT and test its statistical significance.

TRAVEL DIARY DATA

In this example we consider the mobility research question 'Is there a change in departure time of a commuting journey?' The departure time distribution of the commuting journeys reported in travel diaries had the typical two-peaked curve corresponding to the morning and evening peaks (Figure 4). The distribution of the departure time, using at least one of the functions (Traffic Information, Speed alert, Green Driving Support, Navigation Support) is indicated in red.

For the pilot analysis, no statistical evidence for the discrepancy between the two distributions was tested. It was found that during the less congested day time hours, the functions were not used as much as for commuting during peak hours, especially in the evenings. In the final analysis, the following points will be addressed. The objective is to track evidences of a change of habits at the aggregated level of the fleet of drivers. During the analysis, the impact of each function on the departure time will be taken into account: it is expected that the use of Navigation or Traffic information functions will have – if any – a greater impact than the others. Separated analyses will be generated for each function.

If the data enables it, the final analysis will be performed at the individual level, analysing the change of habits of the single drivers: postponing/anticipating the usual departure times. In this case the evolution of the departure time for single drivers will be analysed and statistically relevant differences will be assessed.

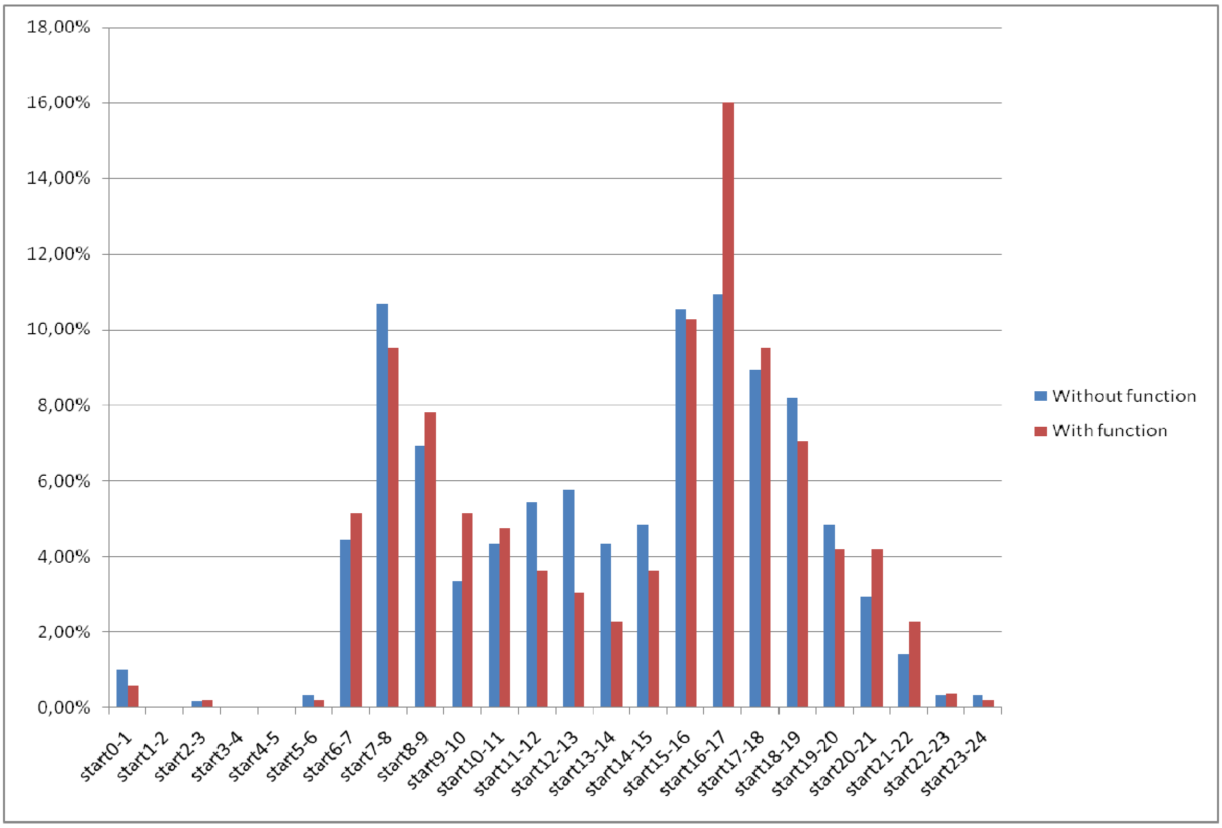

Figure 4- Distributions in the departure time in commuting journeys

Once the data from the full scale LFOTs are available, questions currently piloted using travel diary data will be substantiated using *LFOT Logged Data.* At the time of writing, the central TeleFOT data base was still under construction, and the need for additional variables to be derived from the logged data was identified.

DETAILED FOT DATA

Typically, DFOT data are being collected in order to answer research questions where the level of data being collected in the LFOTs is insufficient due to the need for specialised data collection equipment. Here an example is given showing how, in the context of safety, eye tracking equipment will be used to address the issue of distraction caused by use of the function Navigation support. An eye-tracker has been fitted to the vehicles used for the detailed FOTs at Loughborough University to record head and eye movements. This device operates by processing the images recorded by two cameras mounted on the dashboard in front of the driver in conjunction with the reflection from an infra-red emitter. The influence of the function on the pattern of eye movements will be used as a measure of distraction in later analyses. At this stage some initial data is available and extracts from a single run have been examined.

The capacity of the eye-tracker to lock on the certain facial features, particularly the eyes and mouth, can be affected by a number of factors including physical obstruction (e.g. hand, steering wheel, frame of spectacles), reflection (e.g. spectacle lens), sudden changes of light intensity (e.g. sunlight and shadow), movement of the head out of range of the cameras' field of view, rotation of the head (e.g. from left to right) and closing of the eyes. Furthermore, measurement of the direction of the eyes is based on the direction of the face, and measurement of the direction of the face is based upon location of the head. Recording at 60 Hz, a single driving trial produced almost 200,000 readings, for most of which the eye-tracker was locked on to the head (150,000 readings).

The co-ordinates of the direction of the face can be illustrated by a density plot (a three dimensional surface plot), as shown in Figure 5. It can be seen that the main focus is in the upper left quadrant of the 'screen'. The exact meaning of this will be elaborated in future work; it is provisionally understood to reflect looking over the dashboard towards the centre of the vehicle's travel lane (which in Britain lies slightly to the left of the driver).

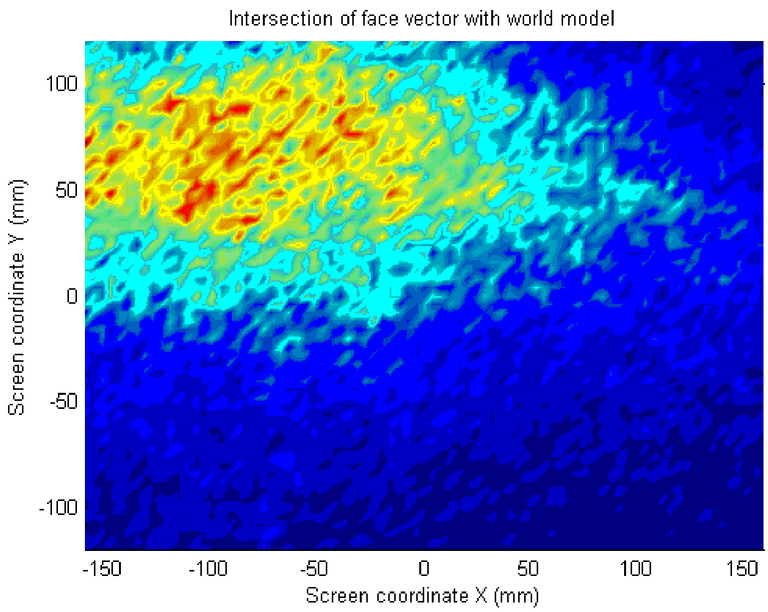

Figure 5 - Direction of gaze—surface plot (overhead view)

The eye-tracker allows a 'world model' to be constructed over the driver's measurable field of view. This in effect means that areas of the 'screen' are associated with components of the vehicle interior, including of course the windscreen. Initial sample results are presented in Table 2:

Component	Readings
Outside	25483
Instrument panel	6217
Navigation system	74
External mirror—right	4
Total	31778

Table 2 - Intersection of eye gaze with components of world model (N=31,778)

This table is useful for identifying relatively small numbers of glances to significant components that are not clearly visible in spatial plots of the X-Y co-ordinates as above. The absolute number of eye glances to both the instrument panel (6217) and navigation system (74) is greater than the number of times the face was turned directly to these components (2593 and 70 respectively) despite the lower number of eye gaze readings. This is consistent with use of the eyes to check the speedometer, for example, while holding the head in position. The data presented here for only one run of the detailed FOT is intended to illustrate one aspect of the capacity of the instrumented vehicle to collect relevant data. In later work, emphasis will be placed on differences in driving behaviour that correlate with use of functions available by means of nomadic devices.

ACKNOWLEDGEMENTS

TeleFOT is a Large Scale Collaborative Project under the Seventh Framework Programme, co-funded by the European Commission DG Information Society and Media within the strategic objective "ICT for Cooperative Systems". The total cost of the project is EUR 14.5 million and it is co-funded by the European Commission for EUR 9.7 million.

The authors would like to thank all colleagues and project partners who contributed to this work. In particular they would like to thank the following people for valuable commentaries and contributions since the earliest drafts of the paper: Roberto Montanari (University of Modena and Reggio Emilia), Andrew Morris (Loughborough University), MariAnne Karlsson (Chalmers University of Technology) and Angelos Amditis (ICCS).

REFERENCES

(1) EU project FESTA (2008). ‘Deliverable n. 6.4: FESTA Handbook’, p. 1.
(2) EU project FOT-Net (2009), available on project website: www.fot-net.eu.
(3) EU project TeleFOT (2009), Deliverable n. 2.2.1: Testing and Evaluation Strategy
(4) EU project Prologue (2010), Deliverable n. 2.2: Methodological and organizational issues and requirements for ND studies
(5) EU-project euroFOT; www. eurofot-ip.eu