THE SAFETY OF INTELLIGENT DRIVER SUPPORT SYSTEMS
Human Factors in Road and Rail Transport

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Today’s society must confront major land transport problems. The human and financial costs of vehicle accidents are increasing, with road traffic accidents predicted to become the third largest cause of death and injury across the world by 2020. Several social trends pose threats to safety, including increasing car ownership and traffic congestion, the increased complexity of the human-vehicle interface, the ageing of populations in the developed world, and a possible influx of young vehicle operators in the developing world.

Ashgate’s ‘Human Factors in Road and Rail Transport’ series aims to make a timely contribution to these issues by focusing on the driver as a contributing causal agent in road and rail accidents. The series seeks to reflect the increasing demand for safe, efficient and economical land-based transport by reporting on the state-of-the-art science that may be applied to reduce vehicle collisions, improve the usability of vehicles and enhance the operator’s wellbeing and satisfaction. It will do so by disseminating new theoretical and empirical research from specialists in the behavioural and allied disciplines, including traffic psychology, human factors and ergonomics.

The series captures topics such as driver behaviour, driver training, in-vehicle technology, driver health and driver assessment. Specially commissioned works from internationally recognised experts in the field will provide authoritative accounts of the leading approaches to this significant real-world problem.
The Safety of Intelligent Driver Support Systems
Design, Evaluation and Social Perspectives

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<td>Automotive Collision Avoidance System</td>
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<td>ACC</td>
<td>Adaptive/ Autonomous Cruise Control</td>
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<td>ACEA</td>
<td>Association des Constructeurs Européens d’Automobiles (European Automobile Manufacturers Association)</td>
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<td>ADAS</td>
<td>Advanced Driver Assistance System</td>
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<td>Action for Advanced Driver Assistance and Vehicle Control Systems Implementation, Standardisation, Optimum Use of the Road Network and Safety</td>
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<td>AIDE</td>
<td>Adaptive Integrated Driver-Vehicle Interface</td>
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<td>ALC</td>
<td>Alcohol Interlock</td>
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<td>AM</td>
<td>Average Mean</td>
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<td>AR</td>
<td>Augmented Reality</td>
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<td>ATIS</td>
<td>Advanced Traveller Information System</td>
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<td>ATM</td>
<td>Air Traffic Management</td>
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<td>AUTOS</td>
<td>Artefact, User, Task, Organisation and Situation</td>
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<td>BAC</td>
<td>Blood Alcohol Concentration</td>
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<td>BASt</td>
<td>Bundesanstalt für Strassenwesen (Federal Highway Research Institute, Germany)</td>
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<td>BMW</td>
<td>Bayerische Motoren Werke</td>
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<td>C3</td>
<td>Command, Control and Communication</td>
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<td>CAN</td>
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<td>Cognitive Complexity Theory</td>
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<td>CD</td>
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<td>CD-ROM</td>
<td>Compact Disc Read-Only Memory</td>
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<td>CEC</td>
<td>Commission of the European Communities</td>
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<td>CEN</td>
<td>Comité Européen de Normalisation (European Committee for Standardization)</td>
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<td>Cognitive Human-Machine System</td>
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<td>Capacity Maturity Model</td>
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<td>Contextual Control Model</td>
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<td>DAB</td>
<td>Digital Audio Broadcasting</td>
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<td>DG</td>
<td>Directorate General</td>
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<td>DMRG</td>
<td>Dual-Mode Route-Guidance</td>
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<td>DUI</td>
<td>Driving Under the Influence</td>
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<td>DVD</td>
<td>Digital Versatile Disc</td>
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<td>e-call</td>
<td>Emergency Call</td>
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<td>ECG</td>
<td>Electro-Cardiogram</td>
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<td>EEG</td>
<td>Electro-Encephalogram</td>
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<td>Electronic Fee Collection</td>
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<td>ERP</td>
<td>Event-Related Potential</td>
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<td>ESoP</td>
<td>European Statement of Principles</td>
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<td>ETP</td>
<td>Experimental Test Pilot</td>
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<td>EU</td>
<td>European Union</td>
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<td>EURISCO</td>
<td>European Institute of Cognitive Sciences and Engineering</td>
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<td>FCW</td>
<td>Forward Collision Warning</td>
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<td>Following Distance Warning</td>
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<td>FESTA</td>
<td>Field Operational Test Support Action</td>
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<td>FFT</td>
<td>Fast Fourier Transformation</td>
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<td>fMRI</td>
<td>Functional Magnetic Resonance Imaging</td>
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<td>FOT</td>
<td>Field Operational Test</td>
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<td>Fatigue Warning System</td>
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<td>GOMS</td>
<td>Goals, Operators, Methods and Selection Rules</td>
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<td>GPRS</td>
<td>General Packet Radio Service</td>
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<td>GSM</td>
<td>Global System for Mobile Communications</td>
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<td>HCD</td>
<td>Human-Centered Design</td>
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<td>Heavy Goods Vehicle</td>
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<td>Human Machine Interaction</td>
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<td>IBI</td>
<td>Inter-Beat-Interval</td>
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<td>Intelligent Cruise Control</td>
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<td>ISA</td>
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<td>ISO</td>
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<td>IVIS</td>
<td>In-Vehicle Information (and Communication) System</td>
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List of Abbreviations

IVSS  Intelligent Vehicle Safety Systems
KLM  Keystroke-Level Model
LCI  Lane Change Initiation
LCT  Lane Change Test/Task
LDW  Lane Departure Warning
LED  Light-Emitting Diode
LIC  Electronic License
MARA  Mobile Augmented Reality Application
MASTER  Managing Speed in Traffic on European Roads
MDEV  Mean Deviation (as a Lane Change Task Measure)
MP3  MPEG-1 Audio Layer 3
NASA  National Aeronautics and Space Administration
NASA-(R)TLX  NASA (Raw) Task Load Index
ND  Nomadic Devices
ND  Naturalistic Driving
NHTSA  National Highway Traffic Safety Administration
NoE  Network of Excellence
OEM  Original Equipment Manufacturer
PC  Personal Computer
PCL  Percentage Correct Lane
PDA  Personal Digital Assistant
PDT  Peripheral Detection Task
PET  Positron Emission Tomography
PROMETHEUS  Programme for European Traffic of Highest Efficiency and Unprecedented Safety
PWI  Preliminary Work Item
QUARTET  Quadrilateral Advanced Research on Telematics for Environment and Transport
RDCW  Road Departure Crash Warning System
RDS  Radio Data System
RTTI  Real Time Traffic (and Travel) Information
SAE  Society of Automotive Engineers
SBR  Seat Belt Reminder
SCS  Socio-Cognitive Stability
SD  Standard Deviation
SDLP  Standard Deviation of Lateral Position
SDS  Standard Deviation of Speed
SHRP2  Second Strategic Highway Research Program
SIZE  Life Quality of Senior Citizens in Relation to Mobility Conditions
SNRA  Swedish National Road Administration
SoP  Statement of Principles
SPAR  Standardized Plant Analysis Risk
SRK  Skills, Rules and Knowledge
STORM  Stuttgart Transportation Operation by Regional Management
TF     Task Force
THERP  Technique for Human Error Rate Prediction
TICS   Transport Information and Control System
TRKC   Transport Research Knowledge Centre
TRL    Transport Research Laboratory
TRS    Thematic Research Summaries
TSOT   Total Shutter Open Time
TTI    Traffic and Travel Information
UAV    Unmanned Aerial Vehicles
UTAUT  Unified Theory of Acceptance and Use of Technology
V2I    Vehicle-to-Infrastructure
V2V    Vehicle-to-Vehicle
VCE    Virtual Centre of Excellence
VTI    Väg- och Transportforskningsinstitut (Swedish National Road and Transport Research Institute)
VTTI   Virginia Tech Transportation Institute
WG     Workgroup
About the Editors

Yvonne Barnard

Has been a senior research fellow at the Institute for Transport Studies of the University of Leeds since 2008. Following her studies of psychology, with a specialisation in artificial intelligence, she has worked since 1984 as a researcher in the field of information technology in education, first at the University of Utrecht in the department of Educational Research, then at the University of Amsterdam in the department of Social Science Informatics. She obtained a PhD at the University of Amsterdam with a thesis on technologically-rich learning environments. From 1995–2000 she worked as a senior researcher at the Dutch TNO Human Factors Research Institute, coordinating a research group on learning processes, and managing applied research projects. From 2000–2007 she worked as a senior research scientist at EURISCO International in Toulouse, France, especially on human factors in the aeronautic sector. Her research has been focussed on human factors in the use of (information) technology. A large part of her work was performed in European research and development projects.

Ralf Risser

Is owner of FACTUM and founding member of INFAR (an association for the testing, training and rehabilitation of car drivers in Austria). He obtained a PhD in psychology & sociology at the University of Vienna, and was an assistant professor and lecturer at both the University and the Technical University of Vienna. From February 2005 he has been a visiting professor at the Technical University of Lund, Sweden. From 1993 to 2003 he was Convenor of the Task Force Traffic Psychology of the EFPA (European Federation of Psychologists’ Associations), and a member of the EFPA Standing Committee Traffic Psychology since 2004, representing the Austrian Psychologists’ Association. His work focuses on attitude and acceptance issues, marketing and motive research, driver diagnostics and rehabilitation. One of the main topics of his work is the development and use of instruments enabling adequate research into human motives as a basis for social management. He is a specialist of qualitative survey techniques, behaviour observation (developer of the Wiener Fahrprobe and derivatives of it), and group-dynamics-based creative and training measures.
Josef Krems

Professor of cognitive and industrial psychology, graduated at the University of Regensburg in 1980. He then joined the cognitive psychology department as a research assistant. He obtained a PhD in psycholinguistics (1984), and a second PhD for work on computer modelling and expert systems (1990). From 1991–1993 he was a visiting assistant professor at Ohio State University, working on computational models of diagnostic reasoning. From 1994–1995 he was assistant professor at the Centre for Studies on Cognitive Complexity at the University of Potsdam. Since 1995 he is a full professor at Chemnitz University of Technology. His current research projects focus on man-machine interaction, safety, in-vehicle information systems, driver assistance, and green driving. Professor Krems is involved in the development and testing of evaluation procedures for new on-board systems for ISO. He has published and/or co-edited nine books and more than 100 papers in books, scientific journals and conference proceedings.
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Preface

This book derives from work in the European Network of Excellence HUMANIST (Human Centred Design for Information Society Technologies) which brought together research in the domain of user-system interactions, and application of its results in road telematics and driver assistance, with the purpose of improving road safety.

The HUMANIST Network of Excellence was, between 2004 and 2008, a network programme, pro-active in structuring the European Research Area; from 2008 on it was transformed into a Virtual Centre of Excellence.

During the Network-of-Excellence phase thematic scientific activities, interaction with stakeholders, and training and education activities were carried out, among other things.

The public deliverables of the Network of Excellence can be found at http://www.humanist-vce.eu.

Following up on the training activities for professional and young scientists, three senior scientists from the former Network of Excellence decided to summarize, as editors, all the scientific knowledge and training and education know-how from HUMANIST, especially concerning methods and methodologies, in an endeavour involving in total fourteen key scientists.

As former co-ordinator of the HUMANIST Network of Excellence and current President of the HUMANIST Virtual Centre of Excellence Association, I welcome this book with great pleasure. I am sure it will be useful to transport professionals, master and PhD students, and will show the importance of the Human-Machine Interaction and Human-Factors theme in the field of Intelligent Driver Support Systems (IDSS), as is recognised by the eSafety Forum.

Jean-Pierre Médevielle

President of HUMANIST Virtual Centre of Excellence
Former Coordinator of HUMANIST Network of Excellence
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Acknowledgements

This book results from the training seminars on the topic of Safety of Intelligent Driver Support Systems: Design, Evaluation and Social Perspectives, organised by the HUMANIST Network of Excellence, and funded by the European Commission Sixth Framework Programme, under grant agreement number 507420. The network brought together 24 partners from 15 European countries. We would like to thank all our colleagues from the HUMANIST network for their collaboration, and the inspiring discussions within the network. We are also grateful for all the feedback we received from the participants of the seminars.

We would like to thank the authors of the different chapters of this book; your contributions are very much appreciated. Thanks also to Jurjen Keessen and Tibor Petzoldt (Chemnitz University of Technology) for their help in the preparation of the manuscript.

Yvonne Barnard, Ralf Risser and Josef Krems
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Chapter 1

Introduction

Yvonne Barnard

The development of new technologies will, in the coming years, radically transform the uses and practices in transport. Current developments in the fields of road telematics and driver assistance systems may constitute real opportunities for assistance in mobility and road safety. They raise, nevertheless, numerous questions about their effectiveness, possible positive and negative modifications of behaviour and attitudes, and about their acceptability for users.

In this book we focus on the new technologies becoming available in cars that support drivers in their driving task. The range of those technologies is very wide, all kinds of systems are already on the market or under development, and being tested by the industry. Examples are adaptive cruise control, supporting the driver in keeping a safe distance to the car in front, and navigation systems that provide the driver with route guidance. Some systems give direct support concerning the driving itself, other systems provide information for drivers, making the journey more comfortable. Some systems were developed to make driving safer, for example, giving a warning when the driver is falling asleep, but other systems may distract the driver from driving safely, such as mobile telephones. There is also a distinction between systems that are integrated in the car, installed by the car manufacturer or a professional, and systems that are brought in by drivers themselves, as for example, a navigation application on a mobile phone. Not only are new technologies in cars becoming available but also outside the car, technological advancement is taking place, for example, information broadcast to cars by traffic management services.

In the next section we will first describe the background from which this book originated, the European Network of Excellence HUMANIST. Next we will provide an introduction on the development of new technologies becoming available in vehicles, aiming to support drivers in their driving task, and providing them with information. This development may lead to opportunities for improving safety and mobility, but may also give rise to new problems. Intelligent Driver Support Systems will be introduced from the perspective of human factors and social aspects. The chapter finishes with an outline of the book’s further chapters.
Background, the European Network of Excellence HUMANIST

This book derives from work in the European Network of Excellence HUMANIST (Human Centred Design for Information Society Technologies) which brought together research in the domain of user/system interactions, and their applications on road telematics and driver assistance, with the purpose of improving road safety. This network brought together 24 partners from 15 European countries and was funded by the DG Information Society of the European Commission. The network organized training courses and workshops for professionals in the area of safety in road transport. This book is the end-result of five training seminars on the topic of Safety of Intelligent Driver Support Systems: Design, Evaluation and Social Perspectives, and it is based on the consolidated course material together with the feedback from seminar participants.

HUMANIST was funded by the European Commission between 2004 and 2008. Since 2009 HUMANIST is organized as a VCE\(^1\) (Virtual Centre of Excellence) under French law. It has been created in order to support research in Human Machine Interaction and Human Factors applied to road transport systems. This issue is important at a time when Human Factors and Cognitive Ergonomics are recognized both by academic research and industry as key concepts for the development of intelligent transport systems. A major objective still is to act as a network of research centres and universities, and provide a platform for collaborative research. Therefore, the core activities centre on exchange on scientific topics and in interaction with stakeholders.

Human Factors and Social Perspectives

Problems related to the design and evaluation of Intelligent Driver Support Systems (IDSS), and social perspectives related to their introduction on a large scale can only be successfully addressed from a multi-disciplinary point of view. People of different backgrounds, from both engineering and social sciences, should be involved in this development. This book aims to provide knowledge originating from human and social factors backgrounds.

This book aims to inform professionals working in the transport area, so that they can use this knowledge in their work. By professionals we mean transportation and traffic professionals, engineers, system designers, researchers and specialists working in automotive and related industries, departments of transport and communication, public bodies related to road transport, public authorities, etc. Also students at a Master and PhD level, performing studies in the road transportation area, will find in this book a rich source of knowledge. Teachers and trainers, both in professional training and academic education, may use the book as a basis for giving a course on the topic addressed.

\(^1\) http://www.humanist-vce.eu
Intelligent Driver Support Systems

In this book we use the term *Intelligent Driver Support Systems (IDSS)* for the new and advanced technologies that are now becoming available in vehicles or that are being developed for introduction in the near future. IDSS provide support to drivers, helping them to make the best of their driving tasks. ‘Intelligent’ is a word that may give rise to discussion, and that is hard to define. What we mean by this word is that a driver support system has some knowledge about the environment and the state of the car (and sometimes of the driver), and is capable of providing support to the driver based on this knowledge. For example, a lane keeping system is capable to collect information about the position of the car in relation to the markers indicating the boundaries of lanes on a motorway. It uses this information to warn drivers when they cross the line, leaving the lane unintentionally. The system may be more advanced, taking over control and not allowing the car to leave the lane. It is not always possible to determine whether a specific system is a driver support system. A mobile telephone is not an IDSS, but if it has an application that provides important information about the traffic situation, for example, warns of an accident ahead and suggests another route, it does become a support system.

Drivers and Safety

All these new technologies in cars may have a profound influence on how people drive, and on their mobility. The effects may be beneficial in terms of safety, comfort and mobility, but also negative, distracting drivers. Different types of drivers have different needs and deal in different ways with technologies. For example, some older drivers may benefit from a system helping them to park their car, catering for difficulties in turning their head, but they may also find these systems hard to use because they have not much experience with new technologies. Professional drivers improve their safety by using a driver monitoring system that alerts them when they fall asleep, but they may also rely too much on such a system and drive for periods longer than recommended. Whether a system enhances safety and is easy to use is not a question that can be simply answered; it depends on the specific needs and characteristics of the user, the system and the interaction between them.

New technologies in cars not only influence the individual driver, but have wider implications. The effects on other road-users, not only other car drivers but also vulnerable road users such as cyclists and pedestrians, have to be considered. What will happen when some cars are equipped with certain systems while others are not? There are also questions concerning a wider societal scale, such as what are the effects on road congestion, pollution, mobility etc.?
Overview

This book is about the safety of IDSS. We will look at the safety of drivers who use the systems, and at the effects on other road-users and society. We will not discuss the technical aspects of the functioning of the systems, but concentrate on a human and societal point of view. We aim to cover a wide range of IDSS, but as the technological developments are advancing rapidly we will not be able to cover all possible systems. Therefore we aim at an approach that is more generic, describing categories of IDSS with a focus on their functions, instead of talking about specific products. For example, there are different navigation systems on the market, but as their function is to provide route information we will discuss navigation support in general and not focus on specific products.

First of all we will discuss the different types of IDSS and their potential influence on safety. Chapter 2 will classify IDSS and describe the functions of a wide range of IDSS. It discusses the potential impact on safety for each category.

As the impact of using a system is different for different types of drivers, the next topic to be addressed are the relations between types of systems and types of drivers: especially young and older drivers, and professional drivers form distinct categories having different needs and problems. Chapter 3 will discuss the differences in potential safety impacts.

Whether an IDSS improves or diminishes safety is first of all determined by the system’s design. Not only the system itself, but the interface between the driver and the system is of importance. For example, the way in which a warning is given (auditory, visual, repetitive, etc.) may greatly influence effectiveness. Designing for safety is a process that encompasses many aspects, and has strong historical roots in the aeronautical domain. Chapter 4 will discuss many of these aspects, using examples from aircraft design.

A method to ensure that the designs of the interfaces of IDSS do not pose safety problems is developing standards and guidelines to which interfaces should answer. Standardization efforts are made on a continuous basis, ensuring that results from research are taken into account and that consensus is reached between the main players in system development, regulation and research. Chapter 5 will describe how the HUMANIST Network of Excellence contributed to the development of guidelines and standards on the interaction between users and systems.

Design of IDSS with a focus on safety and compliance to standards and guidelines is an important step, but it is also necessary to evaluate whether the impact of the use of IDSS on safe driving is indeed a positive one. There is a wide variety of methods available to evaluate how drivers behave while using an IDSS, and how they influence the driving task. Chapter 6 will give an overview of evaluation criteria and evaluation methods.

In the evaluation of IDSS, tools and procedures have been developed in recent years to measure safety-relevant criteria. Some measures are subjective, for example, when asking drivers about their perceived workload, others are objective, for example, measuring driving behaviour such as speed chosen while driving in
a driving simulator. In Chapter 7 several evaluation procedures and tools will be discussed in detail.

In evaluating IDSS it is important to look at how the attention and workload of drivers are influenced by IDSS. Does the IDSS reduce the workload of drivers so that they can focus better on their driving task or does interaction with an IDSS deflect the attention of drivers away from the road? These questions are usually studied by looking at driver behaviour or drivers’ opinions. However, there are ways of measuring workload and attention by looking at the reaction of the driver’s body. Psychophysiological measures focus on reactions of the organs such as the brain, heart and skin of drivers. Chapter 8 will explain these rather complex measures.

Where evaluation usually looks at the impact of IDSS on individual drivers, one should also look at the societal impacts of IDSS becoming available on a large scale. Especially the public impact on drivers whose cars are not equipped with IDSS and the effect on vulnerable road-users such as cyclists and pedestrians should be taken into account. People are not only defined by their roles as road-users. People are also residents and may have different opinions about safety in their neighbourhood, and about how the equipment of cars may influence that safety. For example, drivers may object to systems that do not allow driving a car above a certain speed limit, but parents of young children living in a residential area may find this a very good idea. Sometimes the same people may have different opinions depending on their roles. Chapter 9 will discuss the public impact of IDSS.

Differences between groups of drivers may be caused by their roles in society. For example, young drivers may experience more peer pressure to drink and drive. Gender differences are reflected in the way in which women and men drive. For example, women often drive shorter distances, older women have less driving experience than men, and they have less advanced equipment in their cars. All these differences influence the usefulness and the adoption of IDSS for different groups. Chapter 10 will address the different types of drivers’ social problems in relation to the deployment of IDSS.

Finally, the development and use of IDSS and their interfaces is rapidly and continuously changing. Part of the driving task may become fully automated, changing the role of the driver to more of a supervisory one. Cooperative systems will become available, providing communication between cars, and between roadside systems and cars. Changes in policies, laws, enforcement, and public opinion will take place. New methods of testing IDSS are becoming available; especially instrumentation of cars to monitor what is going on in the car and its environment on a continuous basis. Chapter 11 will discuss these future developments and the impact they will have on safety.
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Introduction: General Definition and Main Purpose of Intelligent Driver Support Systems

In Europe ambitious objectives were clearly stated in the EU White Paper (European Commission 2001) concerning a commitment at the European level to drastically reduce the number of crashes and fatalities on the road, aiming at getting concrete results in middle terms perspective.

The development and spreading of new information and communication technologies in our societies is seen as an opportunity to support reaching this goal. These technologies are usually labelled Intelligent Transport Systems (ITS) when applied to the transport domain, covering a set of applications designed and implemented to improve transport in a broader sense, including infrastructure, private and public transport and freight. As a part of ITS, Intelligent Driver Support Systems (IDSS) are the set of applications specifically devoted to be used by the driver, with the aim of improving safety and comfort of the complex driving task.

In terms of road safety, there is a hope for IDSS functions to compensate human deficiencies in terms of perception, decision making, and emergency reactions, but there is also a concern related to behaviour adaptation and risk compensation while using these functions and potential interference with the main driving task due to attention sharing induced by additional tasks.

The objective of this chapter is to describe the most important functions based upon information and communication technologies developed to support the driver task or, at least, to increase drivers’ comfort. This chapter will provide an overview of the IDSS functions, describing primary characteristics of the systems as well as their impact on road safety. Two main types of systems will be described: In-Vehicle Information Systems (IVIS) and Advanced Driver Assistance Systems (ADAS). The functions of IVIS that are addressed are navigation, traffic and other information, and information coming from other vehicles or from the infrastructure. ADAS provide driver support for lateral (e.g., lane keeping) and longitudinal control (e.g., speed adaptation). Other functions discussed are parking aids, vision enhancement, driver monitoring, and pre-crash systems. As
drivers have to interact with these systems, issues related to the human-machine interaction will be discussed in relation with road safety. The chapter concludes with perspectives on IDSS safety in the future.

IDSS Applications

Several applications have been developed in the automotive area. They have been classified under two categories: IVIS for ‘In-Vehicle Information Systems’, and ADAS for ‘Advanced Driver Assistance Systems’ (Floudas et al. 2004). In the framework of the European project AIDE (Engström et al. 2005), the following definitions are proposed:

In-vehicle Information Systems (IVIS): Systems with the main purpose of providing information to the driver not directly related to the primary driving task, including telematics and communication services, infotainment (radio, CD, DVD, MP3, email). These functions potentially impose a secondary task that may interfere with the primary driving task. An important sub-category of IVIS is constituted by the so-called nomadic systems, i.e., by systems brought into the vehicle by the driver or passengers such as mobile phones.

Advanced Driver Assistance Systems (ADAS): Systems with the main purpose to enhance safety and/or comfort by supporting the driver on performing the primary driving task. Examples include lateral control support, collision warning, safe following, vision enhancement, and driver fatigue monitoring.

Just considering the above definitions, it seems feasible to expect IVIS functions to have a higher probability of impairing the driving activity, with negative consequences for road safety, while ADAS may have an opposite impact. Indeed, except for the navigation function, the primary objective of IVIS is to entertain drivers, and to propose extra activities for their comfort and pleasure, such as listening to music or accomplishing certain professional activities while driving, such as checking email. On the other hand, the primary objective of ADAS is clearly relying on technologies to compensate for human behaviour shortcomings in perceptual, cognitive, and motor abilities. Nevertheless, research has shown that the relationship between the type of function, and its road safety impact is complicated, due to the complexity of road/driver/system relationships (HUMANIST report A.4, 2006): e.g., listening to music when the level of a driver’s vigilance is low can have positive consequences, and relying on sophisticated safety systems can induce an increase of risky behaviour.

In the following section, the main features of some IVIS and ADAS Systems will be reviewed.
In-vehicle Information Systems (IVIS)

In Vehicle Information Systems are the most advanced systems on the market, with several functions already available in cars. These functions are informative for drivers.

In this paragraph, the following IVIS applications are described:

- Navigation functions;
- Traffic and Travel information functions;
- Driver information function through vehicle-to-vehicle and vehicle-to-infrastructure communication.

Navigation Functions

A navigation system provides vehicle location information and route guidance instructions to the driver. It can also provide traffic information related to vehicle location and the route travelled and offer recommendations for optimal routing based on driver preferences. More advanced versions of this service may integrate real-time traffic conditions in the calculation of optimal routes.

This system uses a GPS sensor in combination with digital maps that may contain information on road structures, location databases, etc. They generally consist of a remotely accessible, small display with a colour map with suggested routes marked in a bright colour. The Human Machine Interface of navigation systems is generally composed of an output display and a vocal messaging system. The input systems can be controls included in the dashboard or remote controls managed by joystick or switch. In the future interfaces may involve speech recognition and touch screen.

A navigation system can be integrated in the dashboard, can be implemented as an after-market device or can be available on a nomadic device such as a mobile phone or a Personal Digital Assistant (PDA). This last type of device is an evolution in the fixed on-board navigation systems, giving car drivers the opportunity to be guided through traffic by requesting optimal routes from a service centre using mobile end devices. Advantages of this kind of systems are: low-cost solutions, dynamic routing, turn-by-turn navigation, possibly automatic updates, etc.

Studies conducted in real road environment have shown that drivers following visual and auditory instructions from navigation systems had a better performance, made less driving errors, and maintained lower average speeds than drivers using a classical paper map for finding their route. This result applied for elderly drivers as well (Pauzie and Marin-Lamellet 1989). The data support the hypothesis that a navigation system can have a positive impact on road safety by supporting the strategical level of the driving task, e.g., by simplifying cognitive processes linked to decision making, or by supporting the tactical level, e.g., by simplifying perceptual processes linked to the reading of road signs. Nevertheless, specific care should be devoted to the design of the visual interface in order to avoid
overloading the driver by displaying too complex or not well legible information. Indeed, a poor interface can induce risky behaviour, especially among drivers with presbyopia, and elderly drivers (Pauzié 1996).

Traffic and Travel Information Functions

These functions aim to provide information to assist travellers in reaching a desired destination with a private vehicle, public transport or a combination of the two. This may include information provided before a trip (pre-trip), from web sites or public kiosks, or during travel (on-route), from variable message signs and highway advisory radio. In this paragraph, the focus is on functions devoted to the driver.

In the past, receivers of traffic information were essentially car radios, transmitting general traffic bulletins. But the large amount of specific information needed by drivers, who want detailed information related to precise local areas in relation with their current route, highlighted the necessity for a personalised service able to discard unnecessary information that may annoy or disturb. The RDS (Radio Data System) has allowed the introduction of more personal services to broadcast information about traffic.

The system can provide information on current and forecast traffic situations, and travel information at local, regional, national and international levels, extensive trip information, e.g., prices, fares, routes, incidents, roadwork, forecast and current traffic situations, traffic control, local warnings, special events, weather conditions, hotels, etc.

The consequences for road safety of all these functions depend largely on the type of information transmitted, in addition to the quality of the perceptive modalities. As long as the information displayed has a direct relation with the driving activity, such as traffic jam location, weather conditions, local warnings, such a function is expected to have a positive impact on safety, allowing the driver to anticipate specific conditions that are potentially risky. Other information, such as toll road prices, hotel locations, tourist events, can distract the driver and have the opposite effect. In order to avoid this problem, it is possible to design the system in such a way that the driver cannot access this information while the vehicle is moving.

Traffic and Travel Information (TTI) broadcasting is an important issue in the European transportation system. In fact, real-time traffic information should favour an optimised utilization of public resources, such as roads, public transportation systems, etc., by citizens. The system should be able to influence modal shifts according to a specified transport policy, provide trip information on other modes of transport, e.g., for the spreading of demand or when major events occur such as strikes, cultural or sports events or in relation to weather conditions, etc.
Driver Information Function through Vehicle-to-vehicle and Vehicle-to-infrastructure Communication

Vehicle-to-vehicle communication covers communication between vehicles for various purposes, such as information about fog occurrence, icy roads, etc.

Vehicle-to-infrastructure communication covers information exchange between vehicle and infrastructure. Information transmitted may concern weather conditions, traffic jam situations, risky curves, etc. The communication may be towards a central traffic server, which will then spread the information to all other interested vehicles, or towards a more traditional type of infrastructure, such as traffic lights at a junction which get the information about the vehicle flows passing the intersection.

Through these two modes of communication, more and more relevant information directly linked to road environment and conditions will then be available for the driver. This part of IDSS is still under research and development, and may greatly improve safety in the coming decades by improving the knowledge of drivers of risky conditions concerning their route.

Studies performed within the SAFESPOT project concluded that for a 15 per cent penetration rate, a microscopic simulation indicated a decrease in minimum ‘Time To Collision’ values for a cooperative system providing congestion warning (Fakler et al 2010).

Advanced Driver Assistance Systems (ADAS)

The Advanced Driver Assistance Systems are functions that have been developed with the explicit goal to improve road safety by supporting one or several tasks required while controlling and manoeuvring the vehicle. Once sufficiently tested, these electronic support systems are expected to have an important positive impact on road safety.

Given their role in the driving task, e.g., taking decisions in the place of the driver, these functions will have to demonstrate their reliability before they can be implemented on a large scale. Indeed, it is easy to predict that a lack of robustness could lead to disasters in a risky context. The developers are aware of this issue, and of their responsibility in the case of systems’ failure.

Another issue is dealing with drivers’ behaviour adaptation to automatic functions, in addition to the problem of over-reliance. The issue of risk homeostasis, concerning the characteristic human behaviour of taking more risk when feeling safer, is especially difficult to evaluate in this context. This concept implies that electronic support would not have any positive impact on safety as drivers would systematically take more risk every time they were assisted in their task. Research has still to be conducted to better identify the framework of ergonomic development for these functions in order to fit human needs and requirements, and to avoid this problem.
In this paragraph, the following ADAS applications are described:

- Lateral control;
- Longitudinal control;
- Reversing aids / Parking aids;
- Vision enhancement;
- Driver monitoring;
- Pre-crash systems.

**Lateral Control**

*Lane keeping and warning*  Lane keeping and warning functions aim at helping in the drivers’ lane detection task. In the lane-keeping function, when a significant deviation from the expected vehicle trajectory is detected, the system steers the vehicle back to the centre of the lane applying an appropriate steering wheel force in the appropriate steering direction. The driver is always able to overcome this force. In the lane-warning function, instead of active steering, a warning is given to the driver.

Warning and control assistance are provided to the driver through lane or road edge tracking, and by determining the safe speed for the road configuration in front of the vehicle. These features are under prototyping at this stage. It is intended that these functions will first be used as driver warning systems, and at some time will develop the capability to provide advice concerning the necessary actions for the safe handling of the driving task or will intervene in the control of the vehicle (speed or steering adjustments). The system will warn the driver when the vehicle is (potentially) deviating from the intended lane of travel, and will provide advice on the appropriate driver steering or braking response to correct the problem. More advanced capabilities would include an integrated Intelligent Cruise Control (ICC) function where vehicle speed could be adjusted on the basis of the road configuration according to input from an enhanced map database and navigation system. Furthermore, information from the infrastructure or in-vehicle sensors regarding road surface conditions (wet, icy, etc.) could also serve to adjust vehicle speed. Driver inattention during the driving task will be countered with this system, and would ultimately be supported by the driver condition warning service.

Different warning strategies have been implemented by different manufacturers, such as acoustic warning (beep), smooth vibration in the steering wheel, acoustic warning simulating the sound of driving over ‘rumble strips’, and vibration of the driver’s seat simulating the *kinaesthetic effect of driving over ‘rumble strips’*. The function is independent from the vehicle condition (i.e., it does not matter if the vehicle is running or stationary) but usually the warning is suppressed if the vehicle is running below a certain speed (usually this threshold is around 40 km/h). It is a symmetric function, so the system will use the same measure for left and right lane departure.
Blind spot monitoring  The blind spot monitoring function provides the driver with a warning alarm in case an overtaking vehicle is detected. The system relies on a sensor checking the lateral area of the vehicle. Images from a camera integrated into the lateral rear mirror are processed to determine the presence of an overtaking vehicle.

In general, a blind spot sensor can be situated either on the side or behind the vehicle, when low obstacles cannot be seen in the rear view mirror. For a blind spot on the side of the vehicle a warning is given when turning or changing lanes in the presence of other vehicles, cyclists or pedestrians in the driver’s blind spot. A passive or active infra-red sensor can be used. A flashing LED can warn the driver of the presence of a vehicle in the adjacent lane.

This feature can be also integrated in an electronic rear view mirror. The main advantage of blind spot detection is its combination with normal mirrors. It seems to be very useful to combine the use of blind spot detection with automatic lane keeping.

Lane change and merge collision avoidance  The lane change and merge collision avoidance functions provide various levels of support for detecting and warning the driver of vehicles and objects in adjacent lanes. Later systems would introduce capabilities that will provide merge advice and/or warnings of vehicles in adjacent lanes whose position and relative velocity make a planned lane change unsafe. Later capabilities would potentially include speed and steering control intervention for enhanced collision avoidance. Such functions aim at re-constructing the road scenario. Usually this is realised by two lateral cameras and one radar sensor, installed at the back of the vehicle. The lateral cameras are installed on the left and right lateral rear-view mirrors. When an approaching vehicle enters the lateral lane, a warning signal is given to make the driver aware of a possible risk in case of a lane change.

The function is not affected by the dynamic condition of the vehicle; it does not matter if the vehicle is running or stationary. However, there is a reduction in recognition accuracy and distance when the vehicle is turning or travelling on curving roads. The driver warning is usually implemented by acoustic (beep) or visual (e.g., four aligned spot lights – LEDs on the left/right rear view mirror) means.

In an experiment performed on real roads within the AIDE project (Portouli et al, 2006), it was found that a lane deviation warning system resulted in better lane keeping performance (reduced standard deviation of lane position and smaller number of warnings). Participants used the direction lights more systematically during lane changes. These behavioural changes remained unaffected after long term use of the system.
Longitudinal Control

**Intelligent Speed Adaptation (ISA)**  The Intelligent Speed Adaptation (ISA) function aims at controlling the speed of the car. It can be based on input by the user (i.e., the driver sets the desired speed limit) or according to the legal speed limit. The system controls the car speed so that it does not exceed the given threshold. Speed control covers a wide range of different applications, from external speed recommendations to an automatic speed reduction (limitation) function integrated within traffic control systems. The latter may be imposed directly on all vehicles (or only equipped vehicles, for instance, trucks) within the control area through a Centre to call communication, or indirectly, by managing the local traffic lights. Stop and go functions may be also included in this category, especially when implemented by an infrastructure-based system.

The relevant implementation may be based on:

- Static sensors measuring vehicle speed (located at sign posts and traffic lights) as has been the practice for years.
- An in-car navigation system with speed limit information stored in the CD-ROM. The location of the car is determined by GPS; the speed limit of the road section the car is driving on, is also known, so a feedback system can give the driver a warning or can discourage speeding by a counter force in the accelerator pedal, and lastly can regulate the fuel and braking system to prevent speeding.
- A regional centre transmits up-to-date data to cars in the region for navigation and safety purposes (speed warning during adverse road, traffic, and weather conditions), superimposing the in-car speed limit system.

Previous studies have found that a warning ISA may reduce accidents by 10 per cent, while a system that limits the vehicle speed may reduce accidents up to 40 per cent (Carsten and Fowkes, 2000). However, several studies reveal some unwanted behavioural adaptations when using the system, i.e., driving at shorter distances to other vehicles, accepting smaller gaps for yielding, etc. Research is still going on regarding this issue, especially studying effects after long-term use of the systems.

**Distance keeping – Adaptive Cruise Control**  The aim of the distance keeping function is the regulation of a safety distance to a lead car. The main difference between distance keeping and collision avoidance is that Adaptive Cruise Control (ACC) systems cannot adequately react to stationary objects. The system is activated/deactivated manually, and automatically deactivated when the driver brakes. For liability reasons visual feed-back is provided when the system is in operation.
The Human Machine Interface (HMI) consists of active gas pedals and automatic braking, and a visual output which displays the incoming vehicle, the safety distance and the speed set by the driver.

In general, speed variability reduces when driving with an ACC. Previous research reveals contradictory results regarding impact of ACC on speed and time headway adopted. In some studies the driving speed increases and time headway reduces, while in others speed does not change or decreases (Ward et al. 1995) and the frequency of short time headway is reduced (Stanton et al, 1997).

Adaptive Cruise Control and Curve Management

The ‘Adaptive Cruise Control (ACC) and Curve Management’ is a function able to reduce the speed (chosen by the user) automatically when the vehicle is approaching a dangerous curve, thus enhancing the ACC performance. From this point of view, this function can be regarded as an extension of the ACC system, since it allows keeping the velocity selected when there are no curves, and, when there are curves, to automatically slow down in a comfortable way, which means with limited longitudinal and lateral acceleration. Of course, the basic functionality of the ACC system remains to maintain the selected speed when there is no obstacle, and to slow down automatically, keeping a pre-defined distance, in case a (slower) obstacle is detected in front of the vehicle.

The curve management is performed with the support of dedicated maps, the so-called ADAS maps, properly developed for the ADAS applications, and containing more information (e.g., about landmarks) and more precision (e.g., on road curvature) than standard maps.

The ‘ACC and Curve Management’ function runs through a set of procedures in order to provide the longitudinal control with the information needed for adapting the vehicle speed. These procedures are:

- Identification of the vehicle on the map;
- Reconstruction of the road profile on which the vehicle is travelling;
- Assessment of the curvature profile;
- Computation and evaluation of the velocity fit for travelling a specific curve;
- Computation of the intervention distance;
- Set-up of travelling speed.

The HMI module can be a set of LEDs and warning lights in the instrument panel and a set of commands on the steering wheel.

Curve warning

The aim of curve warning is to warn the driver in case he/she is approaching a curve too fast. In order to understand if a dangerous situation may occur, the road curvature is computed with the data contained in the maps, and then the maximum speed at which it is possible to travel in that particular curve is
computed. Comparing this value with the vehicle velocity, the system will or will not alert and warn the driver.

This function is very similar to the one described before, but in this specific case no intervention is provided. This means that the vehicle control is completely left to the user, and the system performs no intervention on the vehicle mechanics.

**Collision warning and avoidance systems** Collision warning and avoidance systems aim to avoid the risk represented by an obstacle in the vehicle path. The system is composed of a sensor to measure distance, angular position, and relative speed of obstacles. An elaboration unit identifies the obstacles on the trajectory. Commonly used technologies involve laser and microwave radars, which are more suitable for adverse weather conditions (e.g., fog) than other technology.

There are two different approaches in order to manage the user interaction. The first one is limited to warning messages issued by the system; the second adds to this an automatic braking intervention in case the driver fails to react.

A forward collision warning system operates, generally in the following manner: a sensor installed at the front of a vehicle constantly scans the road ahead for vehicles or other obstacles. When an obstacle is found, the system determines whether the vehicle is in imminent danger of crashing into it, and if so, a collision warning is given to the driver. Most systems are non-co-operative, i.e., detection is independent of whether other vehicles on the road are equipped with collision avoidance devices or not. An alternative technology relies on vehicle-to-vehicle communication to exchange information on vehicles’ presence, location, lane of travel, and speed, among other factors. In addition to the front-end sensor, in this case vehicles require a rear-end transponder as well, since communication, and therefore detection, only occurs among equipped vehicles.

In an experiment performed on real roads within the AIDE project (Portouli et al, 2006), it was found that a forward collision warning system reduced the frequency of short headways (<1s) at the initial period of system use. This result was however not found after long-term use of the system.

**Intersection collision avoidance** The intersection collision avoidance function provides a warning to the driver when a potential for collision exists at an intersection. Due to the complexity of the intersection collision problem, it is anticipated that a cooperative vehicle-infrastructure solution will be necessary. Complexities include detecting vehicles on intersecting roadways, and determining the intent of these vehicles in terms of slowing down, turning and potentials for violations of traffic control devices.

Research efforts so far have used two different technologies: either a camera placed at the side of the frontal part of the vehicle, able to ‘see’ oncoming vehicles when they are 25–20m away from the junction, or a short range car-to-car communication system. Apart from the difficulty of solving the oncoming vehicle location problem, the driver warning issue is still open. Current prototypes transfer the intersection image inside the car and project it to the driver by means of an in-
vehicle screen. However, this has been reported to be far from optimal and it has been suggested that a sufficient degree of post-processing of the data is required to warn the driver vocally as well, but only in case of converging vehicles.

**Stop & Go** The Stop & Go function provides automatic distance keeping control at speeds below 70 km/h. It is an extension of the ACC for not-free-flowing traffic conditions, like in the urban scenario. These conditions include lower traffic speeds, stop and go traffic, light controlled intersections, and emergency braking situations. The implementation of the Stop & Go system involves two operative modes: fully automatic manoeuvre, and semi-automatic manoeuvre. The first approach guarantees the vehicle’s stopping and departure without the driver’s intervention. The second guarantees the vehicle stops, but not its departure, for which the driver needs to press a button. In the case of a free traffic flow the vehicle maintains a 70 km/h speed until a new driver intervention.

**Pedestrian or obstacle detection** The pedestrian or obstacle detection function aims at detecting pedestrians, and warning the driver whenever an obstacle enters the vehicle’s predicted path, improving the safety of vulnerable road users (pedestrians, cyclists, and motorcyclists) in urban and rural areas.

These systems warn the driver when pedestrians, vehicles or obstacles are in close proximity to the driver’s intended route. This could be accomplished with on-board sensors or infrastructure-based sensors communicating with vehicles. It is also possible that obstacles and pedestrians are provided with a ‘bar-code’ for presence recognition and identification purposes.

Use is also made of a video system, with the system learning from examples: the object model is derived from a set of training images of pedestrians. To enable the architecture to detect a different class of objects, the training set of object examples may be changed.

**Reversing aids/parking aids** Parking aids are devices aimed at detecting obstacles at low speeds. The parking aid is activated by the reverse gear or on demand of the driver. Sensors used involve cameras and ultrasonic technology. The systems differ mainly in the modality of providing distance information to the driver.

The HMI of these systems is composed of a visual display and/or an acoustical output system. The display can show different types of information according to the different solutions adopted. For instance, a real image of the parking scenario can be displayed by a camera, or a set of different colours can be shown varying with the distance from the obstacles around. This feature provides information and warning to the driver by short-range obstacle detection and tracking. It helps the driver to see areas that are currently out of sight, and warns the driver of obstacles in the vicinity, leaving sufficient time to avoid collisions. Such a system can be fitted as a rear end system (for reversing operations) or as a combined front and rear system for more complex parking operations.
Vision enhancement systems  For several years, both car manufacturers and automotive suppliers have been working on the development of assistance systems for driver support in conditions of reduced visibility. The basic drivers’ task under these conditions, including hazardous conditions such as fog, rain, snow or darkness, is to adapt his/her speed. With vision enhancement the driver can drive faster than without it.

Different technological approaches have been pursued during the last few years:

- Use of ultraviolet light headlamps;
- Near infra-red illuminator;
- Far infrared sensor, capable of detecting clear images in complete darkness as it relies on the thermal map of the scenario.

The images acquired by the camera can be presented to the driver on a Head-up Display. This human machine interface solution would allow images to be presented to the driver without causing him/her any distraction, discomfort or fatigue. Images can be projected in the lower part of the vehicle windscreen, not obstructing the external field of view, but keeping the images in the driver’s peripheral field of view. So in this case, the aim is to allow the driver to use this driving support as a ‘fourth mirror’ when the external visibility is reduced to some extent.

Vision enhancement systems are roughly divided into two categories:

- Active vision enhancement systems use additional sensors, information sources like digital maps and special installations to concentrate the headlights on that part of the road ahead which is of significant interest to the driver.
- Passive vision enhancement systems employ non-visible sources of illumination, which have a broader or deeper range ahead.

A subcategory of vision enhancement system is the electronic mirror device. This feature replaces conventional door and interior mirrors with an electronic rear vision system based on multiple video sensors. More advanced applications work with digital image processing, merging the images into a single homogeneous view displayed on a central screen. Such a system would provide the driver with a better field of view without being obstructed by pillars, passengers, etc. However, camera images present their own problems for the human eye: e.g., the camera doesn’t provide the depth of focus a mirror gives, and forces the driver to determine distances by the relative size of the objects viewed.
Driver Monitoring

Driver monitoring systems monitor the driver’s physiological status, for instance, drowsiness, lack of attention by monitoring eye-movement and heart rate variability, and identify possible risks that might emerge because of an abnormal status. This feature provides warning capability to alert the driver in cases of problems such as drowsiness and other types of impairments. The term ‘driver impairment’ encompasses all the situations in which the driver’s alertness is diminished, as a consequence of stress, fatigue, alcohol abuse, medication, inattention or the effects of various diseases, causing an inability to perform the driving task adequately.

Driver vigilance monitoring  The current driver vigilance monitoring systems encompass three strategic levels: detection, diagnostic, and decision making/information. Detection level trends are to fuse information provided by several sensors (primarily information related to the vehicle’s lateral position, steering wheel position, driver behaviour, and the driver’s eyelid movements). Use of new sensor technologies, such as video sensors, is also fairly widespread. The most promising techniques for a diagnostic purpose are those based on neural networks techniques.

Pre-crash Systems

A pre-crash system is a system that can detect an unavoidable accident. This information can then be used for ‘pre-activation’ of the on-board vehicle restraint system (i.e., seat-belts, air-bags).

Smart restraints  New concepts for smart restraint systems deal with several aspects. One objective is to impose and to distribute the energy of occupant restraints according to the severity of the impact. Another objective is pre-crash detection that provides advance warning of impending (forward or side) crashes, and pre-deploys the appropriate air bag(s) in a vehicle prior to the impact to obtain maximum protection for the vehicle occupants. If these systems were reliable in all potential impact situations they might permit slower deployment speeds for the air bags, and ultimately, more protection for the occupants. Finally, vehicle inner space monitoring adapts air bag inflation to the current cockpit situation, e.g., no inflation in case of unoccupied seat or baby seat, partial inflation in case of out-of-position situations.

The development of a new generation of restraint systems is related to the introduction of new sensors and data processing concepts. Beside the well-known accelerometers, proximity radar sensors can be used for pre-crash detection; concerning vehicle inner space monitoring, several more or less sophisticated technologies are currently being developed or explored: weight sensors, capacitive sensors, but also very promising techniques based on video detection and associated three dimensional (3D) reconstruction techniques. Furthermore, classification
techniques are applied to determine seat occupant nature. Two research directions are currently being explored: conventional stereoscopic vision using two cameras, and active vision using one video sensor and a light module.

**IVIS versus ADAS**

As defined earlier, ADAS have the role of supporting the driving task, while, by contrast, IVIS impose other tasks that may interfere with driving. According to other definitions ADAS functions cover only systems with more or less automated properties, while IVIS functions cover systems that transmit information to the driver who, however, stays in charge of the final control of the vehicle.

Following the first definitions, a technology, such as ‘identification of vehicle speed’, e.g., will be identified as an ADAS function, as speed is linked to the driving task. Following the second type of definitions, this technology can transmit only ‘alert’ messages to the driver, having then the status of IVIS, or can take the control of the vehicle and automatically slow it down, becoming an ADAS. Whatever the final decision and agreement about the adequate vocabulary, the various functions lead to rather different Human Machine Interaction requirements, and evaluation criteria – and hence to different challenges for HMI design.

**Human Machine Interaction and Road Safety**

Effective achievement of the expected benefits will depend on conditions of systems design and implementation; in particular, the extent to which the system answers to drivers’ needs, is compatible with their functional capacities whatever their age, and satisfies the criteria of relevance, usability and acceptability.

This is true for informative systems, requiring additional attention from the driver, where the benefit of this cognitive load has to be put in balance with the potential interference with the driving task they create.

This is also true in the case of automation technologies, where assistance systems are able to take care of some of the control tasks traditionally assigned to the driver, which poses the problem of the division of tasks between human and machine, as well as the choice of the logic used for the management of this control sharing: substitute or co-operation (Wilde 1982).

**Needs and requirements of the heterogeneous drivers population for IVIS and ADAS functions** In order to process a human-centred design, it is necessary to investigate in depth the drivers’ needs and requirements in relation to the various stages of the driving task: operational (basic vehicle-control processes), tactical (choices of vehicle manoeuvres according to rules and road environment), and strategic (decisions at a high level, such as routes to follow) in addition to the drivers’ functional abilities (visual, auditory and cognitive capacities) according to age and experience in driving. Identification of drivers’ needs according to new
technological development requires several types of investigation as the population varies widely in terms of functional abilities and requirements.

For example, elderly drivers reported more navigation problems, such as way finding, with increasing old age. Elderly drivers were often found to be searching for a street, address or road signs when collisions occurred. Furthermore, the elderly have more difficulties with manoeuvres related to gap acceptance for crossing non-limited access highways, and high-speed lane changes on limited-access highways. So, even if this population has some difficulties in attention sharing between several informative sources, the benefit of an easy access to clear guidance instructions induced a benefit higher than the load caused by using the navigation system; this was shown in a real road driving context (Pauzié and Alauzet 1991).

Novice drivers have difficulties of self-calibration, hazard and risk perception. For example, reaction times and accuracy in detecting hazardous situations are significantly higher for novices than for experienced and expert drivers. An adequate design of functions supporting the novice driver can bring positive consequences in terms of road safety. Issues of setting up training programmes for these innovative functions are also raised.

One specific group to take into account is the group of professional drivers. These drivers need communication systems while driving, more often than private drivers do, as it can be highly important for the purpose of their job. Nevertheless, a French survey showed that the same work constraint can lead to various strategies for companies in terms of in-vehicle design and implementation (Pauzié 2004, 2005).

Several researches devoted to the identification of drivers’ needs have already been conducted for functions such as navigation and guidance, Advanced Adaptive Cruise Control, Intelligent Speed Adaptation, Lane Change Assistance (see HUMANIST report Del A.4c 2006, for an overview).

Design and Evaluation of IVIS and for ADAS Functions

In-vehicle devices have to be intuitive, self-explanatory and non-intrusive. In order to reach this goal, the human-centred design approach is relevant at each step of development: setting up the concept, development of the mock-up and the prototype, implementation of the system, with a series of iterations to improve the final result (Pauzié 2002).

The Network of Excellence HUMANIST (HUMAN centred design for Information Society Technologies), funded by the European Commission DG InfSo, gathers research activities directly linked to this issue: identification of the driver needs in relation to ITS, evaluation of ITS’s potential benefits, joint cognitive models of driver-vehicle-environment for user centred design, impact analysis of ITS on driving behaviour, development of innovative methodologies
to evaluate ITS safety and usability, driver education and training for ITS use, use of ITS to train and to educate drivers.\(^1\)

Generally, the ergonomic approach for design and evaluation processes aims at:

- Assisting designers to allow quicker and more efficient design processes by setting up ergonomic criteria, taking into account the wide heterogeneity of drivers’ needs and requirements;
- Evaluating safety for drivers using these devices.

**Perspectives of IDSS Safety**

IDSS has brought a strong hope for the improvement of road safety, mobility, quality of transport environment, etc., through traffic optimisation, as they allow an electronic support for human functional abilities, and for road management. Several functions are already available, dealing with drivers’ perceptive, cognitive and motor abilities such as preparation for unexpected events, decision making under time constraint, reaction time in emergency situations. Nevertheless, the driving task is a complex activity, and the system functions have to match the drivers’ expectations, needs, requirements, and capacities. This is really a challenge when one considers the wide heterogeneity of the drivers population, meaning that the same product has to fit an important range of contexts and users. This is true for any product, but it is even more challenging in the context of the driving task, due to the real time constraint, and the severity of the issue in terms of road safety.

Finally, the question of the designers’ responsibility concerning these systems is also an important aspect to consider. All these parameters lead to conducting investigations on Human Centred Design processes in order to avoid as much as possible misconceptions, and in order to ensure reliability and acceptability of the proposed functions for a wide range of environments and types of drivers.

The various in-vehicle functions proposed by these systems to the driver have diverse purposes, linked to safety and to comfort. Some of them are clearly aimed at facilitating the driving task, and improving the safety of travel. For example, the access to navigation information allows a lowering of the attention level involved in the orientation process of the driving situation, even for elderly drivers. The transmission of traffic information in real time can allow the avoidance of critical situations. Alert messages, concerning road infrastructure or weather events arising downstream, and displayed as quickly as possible to the driver, allow the activation of anticipation processes. Adaptive cruise control, while maintaining a safe headway to the car ahead, decreases the drivers’ stress and mental workload. Directly connected to the objectives of road safety, the active assistance systems conceived specifically to take effect in critical situations can balance some reaction

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\(^1\) www.noehumanist.org
delay and uncertainty of decision inherent in the human functioning in different driving situations.

Some other functions have more to do with entertaining the driver, such as mobile phone use, or can be developed in the context of professional use, such as connecting to electronic mail. As they are irrelevant for the driving task itself, experimental investigations have shown that these types of functions are prone to have a negative impact on road safety, requiring additional attention in comparison to a reference driving situation where no system would be available (Bruyas and Taffin 2009). This argues for an active participation of the Human Sciences in the various stages of systems conception, and for a concept of technological development determinedly centred on the human in which assistance is designed according to the needs and the capabilities of the human being, and not driven by the technological offer.

Due to the novelty of the topic, several European research projects are active in this area, with the objective of gathering data to support the human centred design of these innovative functions, including elderly characteristics (Amditis et al. 2001, Bekiaris, Widlroither and Amditis 2002). Further research will in any case be needed regarding the emergent human driving tasks of system supervision, system status awareness, and system response representation, particularly in the case of co-operative assistance.

Successful deployment of these new products, beyond technological research efforts, needs strong and continuous action in the scientific research area of human factors and ergonomics, in order to bring knowledge about appropriate design in terms of usability and acceptability of these systems, and consequently a real improvement of safety and mobility.

References


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Chapter 3
Safety According to IDSS Functions and to Different Driver Types
Ralf Risser and Ioanna Spyropoulou

Introduction

Intelligent Driver Support Systems (IDSS) could contribute to mitigating or solving problems that different types of drivers have. There might be different types of support for different types of groups, hence there should be a discussion about what types of functions could theoretically, or have proved to be able to, solve different target groups’ traffic safety problems. In this chapter mainly individual problems related to the ‘will vs skill’ perspective are discussed. The discussion also addresses the types of accidents that certain people or groups of people are involved in. This is related to the question ‘what possible measures (in our case: IDSS-based) could help to mitigate or to solve the problems of different groups?’ Three types of drivers are looked at specifically:

1. Older drivers (over 64 years old);
2. Young/novice drivers; and
3. Professional drivers.

According to the literature, older drivers tend to prefer to behave according to traffic rules (e.g., yielding right of way, obeying speed limits, etc.). The rules they disrespect tend to be rules on the meta-level which are not written down in detail in traffic codes. For example, they might overestimate their own capability, ‘feel younger’ than they are, and so on. However, this seems to be the exception rather than the rule, as the problems noted are mostly due to reduced skills.

Novice drivers are discussed with respect to two elements which elicit different driver behaviour, and hence request different types of measures. The first element involves age, and the second experience. Usually, novice drivers are also young drivers (up to 24 years old) and vice versa. Young drivers’ behaviour tends to be induced by extra motives, i.e., motives that are not directly related to the transport function when driving a car, such as showing off. For example, young drivers tend to drive fast. Their focus is not on rules and the abidance of them. In respect to inexperience in driving, actions in connection with driving a car are quickly learned. However, interpersonal communication in traffic is more difficult to learn.
Experience shows that when novice drivers become efficient in handling a car, there remain significant, or even greater, safety problems.

Professional drivers, including HGV (heavy goods vehicle) drivers, bus drivers and taxi drivers, are often confronted with time pressure and high workload. It is known, more from practical experience than from systematic study, that compensation for such disadvantages of the job may be looked for. For example, drivers may try to get home earlier by breaking rules (including speed limit violation, reduction of the number/duration of breaks), eventually to the disadvantage of other road users. ‘Professional arrogance’ may be considered another problem: Being a better driver than other ‘amateur’ drivers may result in the idea of not necessarily having to respect ‘all those rules’.

Several studies have investigated the typical problems of older drivers and novice/young drivers in respect to driving. On the other hand, the driving behaviour of professional drivers has been studied to a lesser degree than that of other driver categories.

Aspects to be Considered

Will vs Skill

The discussion undertaken in this chapter is based on the axis will vs. skill. The question of whether someone wants to do everything according to rules but fails, or if he/she wilfully disrespects rules, is of central significance when it comes to traffic safety measures, to equipment or implemented system types, to the goals one wants to reach with any equipment, etc. (Wegman and Arts 2006).

Typical Safety Problems

This refers to the question of what types of accidents certain people or groups of people are involved in. This is strongly related to the question of what possible measures (in our case: IDSS-based) could help mitigate or solve the problems of different groups. Will vs. skill aspects have to be considered in this context as well (UNECE 2006; non-accident-based studies of older, novice, and professional drivers).

Driver types

In this chapter, three types of drivers are considered: 1. Older drivers, 2. Young/Novice drivers, and 3. Professional drivers.

Older Drivers

Risk Factors

Will vs skill

According to what is known from literature, older drivers prefer to behave according to traffic rules (like yielding right of way, keeping the speed
limits etc.). Older drivers are prone to lapses and errors rather than violations – the latter describing a situation where the driver deliberately violates a rule (Reason et al. 1990, Parker et al. 1995a,b, Parker et al. 2000). Older drivers sometimes disrespect rules that are more on a meta-level and do not involve the traffic rules of the highway-code; usually such cases are about overestimation of capacities and abilities, and ‘feeling younger’ than they really are (Holland and Rabbitt 1992), which affects their decisions about driving; e.g., driving long distances disregarding fatigue problems. But even this seems to be more the exception than the rule, as often older drivers adopt regulatory behaviour to compensate for their declining skills by reducing their exposure, and by avoiding adverse driving conditions such as driving in the dark, in heavy traffic or under adverse weather conditions (Benekohal et al. 1994, Ball et al. 1998, Hakamies-Blomqvist 2004, Charlton et al. 2006).

Typical problems of the persons in this group tend to be skill related, i.e., they are not able to cope with certain situations due to their reduced psychophysical capacity. In particular, such problems involve visual and perceptual, cognitive and physical abilities, including reduction in vision and peripheral vision, decline in cognitive capacity and functions, difficulty in performing certain movements such as turning the head, decline in information processing capacities, and impairment of physical condition, the latter also potentially due to medication (Sivak et al. 1995, Holland 2001). As a result older drivers tend to have a reduced attention and alertness, cognitive overload in dealing with complex situations, and a diminished ability to deal with new situations and problems (Hakamies-Blomqvist 1994, Schlag 2008). Complex situations are those where more variables have to be kept under control simultaneously: scenarios including intersection, motorway or urban (comprising different types of other users and heavy flow) traffic situations. Older drivers are over-represented in intersection accidents, and especially in incidents involving turning movements with vehicles in the on-coming traffic on main roads, and in accidents involving more than one road user (Stamatiadis and Deacon 1995, Ryan et al. 1998, McGwin and Brown 1999, FHWA 2003).

Vulnerability Another problematic factor in older driver safety involves the high severity rates of older drivers’ accidents, which are due to their physical vulnerability (ERSO 2007). Hence, an older driver is more likely to be injured or injured severely than a younger one in an accident of the same dimensions (Massie and Campbell 1993).

IDSS Measures

The aim of system implementation should not be to facilitate one aspect of driving without considering whether it will obstruct others; the overall contribution of a system should be beneficial for the drivers. Hence, the balance between the actual aid that IDSS provide and the impact of the additional workload they incur should be explored in great detail for this particular driver group. In principle,
any IDSS-interference may be seen as a new variable that has to be considered as additional workload instead of an aid. Hence, suitable ways towards implementing IDSS in many cases would be to de-dynamise traffic, e.g., with the help of lower speed limits and their enforcement, and to control traffic, especially in intersection areas. There could also be help available by IDSS providing infrastructure-based electronic assistance, when approaching intersections, for moving into motorway lanes, for performing lane changes before turning points, etc.

Technical assistance supporting the intake of information can be helpful. One such technology is head-up display. This brings together information on several variables, and displays it more in the focus of vision at the same time. Information that could be provided in this way includes possible obstacles, the prevailing speed limit, and so on. However, attention should be paid to the danger of overloading the driver with information, especially if trivial.

Route guidance systems which include replacing the driver in specific tasks (on a strategic driving level) may have the potential of increasing his or her cognitive and workload capacity for the other elements of the driving task (at a tactical and operational driving level), and the awareness of the traffic environment including road infrastructure and other road users. In general, specific systems that assist the driver in performing specific tasks could help, such as: collision warning, intersection warning, lane departure warning, and vision enhancement systems. Another type of system that could improve older drivers’ road safety is video-supported rear view to facilitate checks of traffic at the rear that are of essential importance when changing lanes, parking, etc. Vigilance monitoring systems could be advantageous as well, as these systems monitor driver performance to assess the driver’s condition, and provide warnings in case of a poor condition. Furthermore, emergency call (e-call) systems are expected to reduce older-driver accidents’ severity rates as quicker and more efficient emergency services will be provided to the injured driver. These are systems that operate following an accident and reduce severity rates rather than accident rates, targeting the older driver’s higher physical vulnerability levels.

Last but not least, and in addition to all other measures, driver training is of essential importance as older drivers cannot quickly familiarise themselves with new technologies, and any interference with their normal driving tasks might prove not to be beneficial. Older drivers need to be accustomed with the new systems and their operation mainly in terms of the nature of the warnings, and also with the system’s capabilities and limitations, to achieve optimal implementation. HMI (Human Machine Interaction) issues have to be dealt with especially for this group because of their potentially deteriorating information-processing capacity.

**Young/Novice Drivers**

Young drivers are not necessarily identical to novice drivers. Novice drivers are considered those who have up to three years’ driving experience – usually
defined as from the date they obtained their driving licence, while young drivers are considered those who are up to 24 years old. Usually young drivers are also novice drivers (assuming that the legal age for obtaining a driving licence is 18 years) whereas novice drivers are not always young ones. These two driver groups often overlap, but also demonstrate different problems related to safe driving, as these result from immaturity for young drivers, and inexperience for novices. In this section we will first deal with young drivers.

Young Drivers, Risk Factors

Will Peer group dependence is the most relevant structural problem in the group of young drivers, and from the perspective of road safety can be defined as a will problem. According to studies (Chaloupka et al. 1998), young drivers, when together with peers, tend to do things that they would never dare to do as individuals. Group pressure sometimes enforces ‘incorrect’ and risky behaviour in order to try to impress peers or the other sex, to be respected, attractive, etc. Thus, for young drivers, traffic rules as defined by the highway code, or by the logic of safe traffic behaviour, and their abidance do not seem to be in central focus, as their driving behaviour tends to be steered by extra motives that are not directly related to the transport function (Rothe 1987). Young drivers use their driving as a means of pretence and prestige, and of indicating their disregard for society (Preusser et al. 1998). In particular, young drivers tend to disrespect traffic rules more than other road users (Reason et al. 1991, Aberg and Rimmö 1998). Another feature to be found especially within the male young drivers population is ‘sensation seeking’ (Jonah 1997). Such behaviour is encountered in experienced young drivers – especially male ones – rather than inexperienced ones (Rimmö and Aberg 1999), and has been proven to constitute a stable predictor of accidents. In addition, the ‘it will not happen to me’ mentality is also evident in young drivers, increasing their risky driving style (Finn and Bragg 1986). By and large, will related indicators for traffic accidents of young drivers involve driving fast, and generally disobeying traffic rules. Youngsters’ lifestyles also imply a higher risk of driving under the influence (DUI) of alcohol or other illegal substances. In particular, alcohol/drug involvement in accidents is highly related to driver characteristics, mainly age and gender (Abdel-Aty and Abdelwahab 2000, Finnish Motor Insurers’ Centre 2006), with young and male drivers being more prone to such accidents. In general, alcohol involvement in accidents declines with age (Mason et al. 1992).

Skill Specific physical cognitive procedures, such as peripheral vision and cognitive reflexes, are not fully developed in young people (Hale and Glendon 1987). For example, it has been found that perceptual skills also including peripheral vision develop only slowly, and are still improving even up to the age of 22 (Chapman et al. 1982). In addition, cognitive functions that are crucial determinants for drivers’ expectations have been found to increase with age (McDonald 1994). Therefore,
young drivers are less capable of anticipating developing traffic situations that might contain risks. It is assumed that these findings are related to young age and not to lack of experience. But in addition, young drivers also demonstrate the skill related issues that are a result of driver inexperience, and which will be discussed in the section of novice drivers.

**Young Drivers, IDSS Measures**

*Will* It would seem that, in order to deal with will related behaviour, only equipment or measures that inhibit risky behaviour can help to avoid or to mitigate these problems. The main elements of will-induced misbehaviour include fast driving (and usually exceeding the speed limit), disrespecting the traffic rules and DUI (driving under the influence). There is a wide range of available systems targeting speeding, such as, Intelligent Speed Adaptation systems (ISA) (ETSC 2005, 2006). The warning or the intervening/mandatory variants of the system could mitigate or even eliminate speeding. The informative variant would not be suitable for this driver group as it targets unintentional rather than intentional speeding, and has not been established to be effective (Spyropoulou and Karlaftis 2008). Certain types of Autonomous Cruise Control (ACC) also have the potential to reduce young drivers’ road accident risks, as they assist the driver to keep the appropriate distance to the car in front in relation to speed driven. At present there are no systems targeting traffic-rules disobedience explicitly, although systems like alco-lock (also referred to as alcohol interlock, a system that monitors the blood alcohol concentration (BAC) and does not allow the driver to drive when exceeding the threshold limit; (ICADTS 2001, 2005), and ISA target specific traffic violations.

Also, co-operative systems allowing for the communication between vehicle/driving characteristics (e.g., location, speed), road infrastructure and other vehicles’ characteristics are expected to be developed in the future and could reduce young driver risks. One such application could involve a driver approaching an intersection where the conflicting arm has right of way, but the driver is not willing to yield this right of way. The system could warn the driver or even stop the vehicle if a potential conflict was detected, taking into account the position and speed of the vehicle, the existence of a ‘stop’ sign at the intersection and the position and speed of the first vehicle approaching the conflicting arm of the intersection (FHWA 1999). Another example would be a system warning or stopping the driver when the traffic signal at the intersection approach is red. The new approach in these cases, and the reason why they are able to affect the will component, is that they would interfere in case drivers are not willing to respect certain rules.

Generally speaking, one may assume that systems providing information will not have any effect (or only a slight effect) on young drivers’ behaviour, as young drivers are aware of their misbehaviour. Warning systems that transmit irritating warnings – hence auditory rather than visual or haptic – are expected to improve driver behaviour (Kaufmann et al. 2008). Intervening/mandatory systems that take
over the driving task whenever incorrect behaviour is detected are expected to be the most effective ones.

However, in all cases, the possibility that young drivers will try to fiddle around with equipment that inhibits them in certain actions that they ‘have to do’ has to be taken into account. This also raises the issue of whether to provide the driver with the possibility to switch off the operation of the systems. If this possibility exists it is expected that young drivers prone to incorrect behaviour will have the system switched off. On the other hand if this possibility is not provided specific risky situations might evolve, such as situations in which, in order to avoid an accident with on-coming traffic, one has to speed. Hence, there should be a way to allow, but also to manage, the possibility of switching off the system.

In addition, there is the possibility of drivers misusing the system. Young drivers might be even more prone to misuse than other road users by means of exploring the limits of the systems and their capabilities, and treating them as gadgets rather than driving aids.

In the case of young drivers where the main problem involves will rather than skill, motives that would increase system implementation and use should be sought, as drivers are not expected to use systems that would interfere with their driving style. These may range from voluntary implementation by providing financial motives such as reduced rates for vehicle insurance for users of intelligent speed adaptation or other systems, to enforced implementation such as the obligatory use of the systems for DUI or speeding offenders.

**Skill** As the main risks induced by skill-related behaviour for young drivers are a result of driver inexperience, most of the suggested systems will be discussed in the novice-drivers sections. However, since peripheral vision and cognitive reflexes are not as developed in young drivers, systems that would warn of possible collisions (i.e., collision avoidance systems with a focus on interaction at intersections), may have the potential of mitigating young drivers’ risks. Such systems include collision avoidance with other vehicles, pedestrians and obstacles (Moriya et al. 2002).

**Novice Drivers, Risk Factors**

**Will** Novice drivers, as beginners in other areas of life, are rather willing to obey the traffic rules and to drive safely. This is also true for young novice drivers, though only for a rather short time. After that, will-related issues arise from immaturity in those cases where the novice drivers are also young, which is usually the case. Hence, will-related problems in novice drivers are described in the young drivers section.

**Skill** Although the actions in connection with driving a car are quickly learned, it takes time for driving procedures to become automated. Hence, novice drivers need more concentration in driving tasks and procedures to perform a driving task.
than experienced drivers. The complexity of driving can lead to cognitive overload and hence to erroneous reactions to specific stimuli or events (Milech et al. 1989). In contrast to handling a car, interpersonal communication in traffic is relatively difficult to learn. Novice drivers frequently encounter complex traffic situations which they are not capable of handling due to their limited understanding of the situation (Fuller 1988). Experience shows that when novice drivers are competent in handling the car, there remain problems with communication in traffic. In fact, due to the self-perception of one’s competency in handling the car, severe problems can arise when this self-perception leads to risky behaviour. Skill overestimation, to be found mainly in young novice drivers, is an additional factor increasing novice drivers’ risks (Twisk 1996). Driving behaviour of novice drivers also includes several of the following elements: reduced use of mirrors (Mourant and Rockwell 1972), reduced detection of prevailing traffic conditions (Williams 1997) and reduced attention to risks resulting from other vehicle movements (Benda and Hoyos 1983).

**Novice Drivers, IDSS Measures**

Novice drivers experience driving as a relatively complex task, hence attention should be paid to avoiding or mitigating the addition of extra tasks, i.e., workload connected to system operation, which would be the case with information systems. Warning systems transmitting subtle, but unmistakable warnings (the latter aspect can be tested and trained very nicely) might provide an effective solution.

**Will** In the case of inexperienced drivers, the incorrect behaviour is mostly unintentional. Will-induced risky types of behaviour of novice drivers, as we understand it, are related mainly to young novice drivers (and therefore discussed in the young drivers section).

**Skill** As skill problems frequently consist of communication problems, IDSS equipment that supports non-verbal interpersonal communication would be needed. It is difficult to think of such systems at the moment. One would tend to exclude, e.g., walkie-talkie type systems: they would probably be used more for communicating about issues that are not related to traffic (joking, where to meet in the evening, etc.) than for tackling traffic-safety related tasks. Of course, this is only an assumption and appropriate research concerning this issue is needed. The same is valid for co-operative systems, anticipated to be developed in the future, that are based on the communication of the equipped vehicle with other vehicles and road infrastructure; such systems, that do not give drivers a possibility to interfere, might provide solutions for novice drivers. They could assist drivers by providing information about other road users’ needs, possibilities, and restraints, allowing for the design of automated procedures towards more efficient driving. Systems that detect and/or remind of the presence of other road users could be recommended. Such systems make aware of the potential presence of other road users.
Safety According to IDSS Functions and to Different Driver Types

users, and of the fact that a continuous preparedness to communicate with other road users is necessary. Novice drivers have to internalise that one is hardly ever alone in the public space, in the frame of the social system that is called traffic. Examples of appropriate IDSS include, among others, collision avoidance systems, in particular in respect to other vehicles, and lane departure warning systems.

It should be noted, that although intervening systems might prove to be a good solution, reducing risk for novice drivers, they raise the danger of novice drivers relying on the system to a high degree, leading to their not learning to react appropriately to traffic situations, and hence never really stopping being ‘novices’. For example, a parking aid system that would instruct the driver how to park might lead to drivers never enhancing their parking abilities. This risk should be taken into account when suggesting IDSS for novice drivers.

The efficient incorporation of the use of equipment into novice driving behaviour can be accomplished by means of driver training. Novice drivers could adapt to the operation of IDSS if this is part of their driver licence training at driving schools or of training courses on later occasions.

Professional Drivers

Risk Factors

Many professional drivers are confronted with time pressure and high workloads. Time pressure, e.g., for truck drivers results from the aim of delivering goods at the earliest possible or at specific times, which may in some cases result in illegal behaviour, potentially induced by employers. For other categories of professional drivers, time pressure – although present to a lower degree – is connected to transferring passengers quickly (taxi drivers) or arriving at specific stops on time (bus drivers). Also, high workload affects professional drivers, as they are often required to drive long hours to reach their destinations, respond to passengers’ requests, etc. As a result, road safety of professional drivers – mainly those who perform long trips – is endangered by fatigue, which is considered to be an important risk factor.

Will ‘Professional arrogance’ may be considered as an important contributor to will problems. This is expressed as a conviction that professional drivers are more competent than non-professional ones, which generates a belief that they do not have to respect ‘all those rules’. Especially for the category of truck drivers, a tendency is known to exist (more from practical experience than from systematic study) to compensate for disadvantages of the job (like time pressure and high workload). Drivers may try to get home earlier by breaking certain rules like exceeding the speed limit, and not allowing for the appropriate number or duration of breaks, to drive alone for some time in spite of the rule that there should be two persons on a truck, giving the other driver a possibility to have an extra rest, etc.
**Skill**  It is not obvious to envisage skill problems in connection with professional drivers. However, newcomers to the driving profession could still have problems with certain specific skills, due to lack of experience, and most probably these would be found on the communication level (e.g., communication in foreign countries, etc.). However, one may expect experienced professional drivers not to show many skill problems. One may assume that skill problems will primarily arise when many tasks have to be carried out under time pressure and/or for longer time periods, and also in conditions of monotony, leading to reduced fitness and vigilance because of fatigue.

**IDSS Measures**

A crucial problem concerning the implementation of IDSS for professional drivers is driver acceptance. The drivers are not expected to accept these easily, especially systems that may interfere with their driving style and habits. Hence, system implementation can only be achieved in co-operation with both the owners and the operators of the vehicles. It can be argued that, although these devices might prove to reduce the efficiency of logistics, in respect to the duration of travel and times of delivery, they can potentially increase it in terms of cost reduction through accident reduction. It would therefore be possible to design regulation enforcing the use of such equipment in trucks or buses; the latter being quite important considering the safety of passengers. For specific professional driver categories, such as taxi drivers, the implementation of systems like intelligent speed adaptation could be perceived as an additional advantage as it could give the customer a heightened sense of security, which might lead to better publicity and increased demand. This could serve as a motive for companies or taxi owners to install such equipment. Acceptability and acceptance problems in connection with this type of equipment should, of course, be discussed in further detail (see also Chapter 10 of this book).

**Will**  Working conditions have the potential to trigger incorrect driving behaviour, like exceeding the speed limit, breaking the rules for the number and duration of breaks, etc. Reasonable working conditions could help reduce risk. At the same time, equipment to control drivers’ behaviour may prevent them from adopting risky behaviour. Intelligent speed adaptation systems could mitigate or even prevent speeding. Driver monitoring systems, including fatigue/vigilance monitoring, could reduce fatigue-related accidents, by alerting the driver when driver fatigue is detected and possibly by imposing on him/her to take a break. In addition, black-box-like devices have a similar potential impact. A black-box that registers travel data is already common practice with European companies, and could be useful to ensure cautious driving. However, this exists mainly on a voluntary basis as there is no regulation enforcing the implementation of such equipment yet.
Furthermore, all kinds of organising assistance, like route guidance assistance, general logistic help (e.g., ‘travelling salesman’ support etc.) and similar equipment could be useful by optimising routes and reducing travel duration.

**Skill** If speed is under control, and driving when tired etc. is avoided, there will hardly be any ‘skill’ problems with this group. However, any type of equipment that makes professional drivers’ jobs easier from a skill perspective, but without making their work more monotonous, should be considered as positive.

**Summary of Problems and Measures**

Table 3.1 gives an overview of will and skill problems in older drivers, young drivers, novice drivers, and professional drivers, and it suggests some types of IDSS equipment that may have the potential to mitigate or to solve certain problems.

In addition to proposing systems targeting the specific problems that the distinct groups demonstrate, we should also consider other peripheral, yet crucial, issues describing elements of the different groups, which have been discussed in this chapter.

In particular, the systems proposed for older drivers should operate in such ways that the additional workload they impose is minimal, as they could otherwise further diminish these drivers’ capacities. In addition, it must be taken into account that older drivers are less familiar with new technologies.

Where young drivers are concerned, as their higher risk level is mainly a problem of will rather than skill, supporting systems (providing information or transmitting warnings) may not prove to be as effective. Intervening systems are expected to be more beneficial. In addition, the possibility of drivers treating the systems as gadgets rather than driving aids, misusing them and testing their limits, imposes a further threat that needs to be tackled. Finally, motivation for installing such systems, and operating them, should be sought.

Systems intended for novice drivers should also not significantly increase the driver workload, and should focus mainly on solving traffic communication problems. Driver training – also in respect to system use – is essential, and should be carefully developed.

Finally, obstruction of the learning procedures for driving by systems should be avoided. For this reason intervening systems that replace the driver in performing driving tasks are considered the least beneficial.

The main problem concerning the implementation of IDSS with the professional driver population is driver acceptance. Hence, system operation should be imposed by government or company regulation, and in addition extra motivation for system use should be looked for.
<table>
<thead>
<tr>
<th>Group</th>
<th>Will problems</th>
<th>Possible aids</th>
<th>Skill problems</th>
<th>Possible aids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Older drivers</td>
<td>Not accepting deterioration of abilities as a consequence of age.</td>
<td>No aids directly involving will problems.</td>
<td>Problems of a psychophysical nature due to age including:</td>
<td>• Collision warning</td>
</tr>
<tr>
<td></td>
<td>Consequently, overestimation of own capability.</td>
<td>Aids involving consequences (i.e., accident types) which are directly targeting skill problems.</td>
<td>• Stochastic decline of perceptual, cognitive and physical abilities</td>
<td>• Intersection warning</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Reduction in vision and peripheral vision</td>
<td>• Lane departure warning</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Difficulties in performing certain movements such as turning the head</td>
<td>• Systems providing video-supported rear view (e.g., vision enhancement system)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Processing information could become more difficult</td>
<td>• Vigilance monitoring systems</td>
</tr>
<tr>
<td>Young drivers</td>
<td>Sensation-seeking driving as a means to gain respect or impress peers.</td>
<td>Alco-lock</td>
<td>Reduced peripheral vision and cognitive reflexes.</td>
<td>Driver vulnerability</td>
</tr>
<tr>
<td></td>
<td>Demonstrating illegal behaviour.</td>
<td>Intelligent Speed Adaptation</td>
<td></td>
<td>Emergency call (e-call)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cooperative Systems.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Novice drivers</td>
<td>For novice drivers that are also young: same issues as for young drivers.</td>
<td>As above</td>
<td>Communication skills (event anticipation, risk perception).</td>
<td>Collision avoidance systems.</td>
</tr>
<tr>
<td></td>
<td>Otherwise: no evident will problems.</td>
<td></td>
<td>Skill overestimation once handling has been learnt.</td>
<td>Pedestrian registration systems.</td>
</tr>
<tr>
<td>drivers</td>
<td></td>
<td>Black-box driver monitoring.</td>
<td></td>
<td>Route guidance.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Logistic support.</td>
</tr>
</tbody>
</table>
Conclusion

The types of problems that older drivers, young/novice drivers and professional drivers experience have partly been studied quite extensively (older drivers being a group that has been extensively studied), but partly knowledge and know-how are scarce: professional drivers have only been studied on a surprisingly limited scale as far as behavioural problems and the related risks in traffic are concerned. As for IDSS support, not many studies have been carried out focusing on the different driver groups and their distinctive needs. Thus, the question of what types of equipment can be used to solve or mitigate certain problems is very much an heuristic topic here. This implies that discussion is possible and legitimate in this respect.

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Introduction

Design for safety has become a key process in industry producing systems that involve risks. They are known as safety-critical systems, e.g., nuclear systems, aircraft, spacecraft and automobile. What do we mean by safety? A tremendous amount of work has been done in the field of system safety, reliability, availability and dependability (Johnson and Malek 1988, Laprie 1992, 1994, Prasad et al. 1996, Nilsen and Aven 2003). There are methods that were developed to assess human reliability as extension of probabilistic methods addressing system reliability such as Human Error Rate Prediction (THERP) (Swain and Guttman 1983) or Standardized Plant Analysis Risk (SPAR) (Gertman et al. 2005). The main issue is that probability barely works for predicting human errors and more generally human behavior. What is the probability of pilot incapacitation in an aircraft cockpit? For that matter, there was a need for starting deeper work on the human side of safety-critical human-machine systems. Consequently, Human Reliability Analysis (HRA) must be developed from various perspectives, including physiological, cognitive and social. Dejohn et al. (2005) reported the results of a study carried out on the 1993–98 period on in-flight medical incapacitation and impairment of US airline pilots. According to these results, there were two nonfatal aircraft accidents due to the in-flight medical impairment of the pilots. One was caused by pilot’s visual impairment due to the use of mono-vision contact lenses during an approach. The other was caused by flight crew fatigue. Authors concluded that the probability that an in-flight medical event would be associated with an accident was two out of 50 events, or 0.04. There were 54,295,899 flights and 217 accidents involving US Federal Aviation Regulation Part 121 scheduled and non-scheduled airlines between 1993 and 1998. The probability of an aircraft accident for a pilot experiencing an in-flight medical event is summarized in Table 4.1. This kind of medical event seems to be predictable and unrecoverable onboard.
Even if physiology is an important source of safety issues, problems induced by cognition motivated a lot of research efforts during the last decades to the point of creating a new field of research called cognitive engineering. The cognitive community promoted ‘human reliability’ through the investigation of human errors, associated risks and recovery strategies. Everybody knows that ‘errare humanum est’, i.e., to err is human. But if people commit errors all the time they recover most of them almost immediately. The main problem comes from the fact that there are errors that may lead to undesirable and even catastrophic situations. For that matter, cognitive engineering introduced a new set of conceptual tools such as the Contextual Control Model (COCOM) and the Cognitive Reliability and Error Analysis Method (CREAM) (Hollnagel 1993, 1998). The concept of human error dominates this kind of cognitive approach (Reason 1990, Hollnagel 1991). Reason emphasizes the systemic approach of human error management that concentrates on the conditions under which individuals work and tries to build defenses to avert errors or mitigate their effects, instead of blaming these individuals for forgetfulness, inattention, or moral weakness. But cognition is not involved in the vacuum, human operators evolve in a social environment. Socially speaking, human reliability is related to the distribution of appropriate roles or functions among agents. This is related to authority delegation among agents (Boy and Grote 2011). The way information is shared among agents is crucial to insure safety, as well as the way functions are allocated among agents. Agents require using contracts to support their cooperation and coordination when one delegates responsibility to the other. In addition, they need to trade authority in a dynamic way. These processes of authority distribution, sharing, delegation and trading are likely to generate reliability problems in the overall human-machine system. This view is reinforced by the fact that levels of automation and software tremendously increase providing machines with sophisticated cognitive functions (Boy 1998).

Consequently, experience feedback and sharing among human agents are mandatory processes. However, it is crucial to make sure that the data elaborated from such experience feedback would not prohibit human agents’ actions over-using the precaution principle. Indeed, in safety-critical environments, human

| Flight Event | Accident | | | | |
|-------------|----------|---|---|---|
|              | Yes | No | Total |
| Yes          | 2   | 48 | 50    |
| No           | 215 | 54,295,634 | 54,295,849 |
| Total        | 217 | 54,295,682 | 54,295,899 |

Source: Civil Aerospace Medical Institute (CAMI), US Federal Aviation Administration (FAA)
agents need to know risk and what entails risk taking. In other words, the practice of risk-taking is an important part of the anticipation of risks in such environments, and the development of procedures and automation should be carefully done to enable human operators to be in the control loop.

Therefore, even if we would like to rationalize safety and safety-critical technology and organization in a systemic sense, the field remains a matter of people. These people are called human agents in this chapter. They are of course human operators (i.e., users of safety-critical technology), but also designers, manufacturers, maintainers, certifiers, trainers and (not to forget) managers. Human-Centered Design (HCD) is not only a matter of taking into account human factors into design, but also human-centered organization that produces technology from design to obsolescence, i.e., over the whole life cycle (Boy 1998). HCD cannot be thought locally on small pieces that will be put together later, but holistically taking into account five entities and their interrelations:

- The artifact being designed (i.e., technology that is being designed);
- Possible users (i.e., a categorization of user profiles is necessary);
- The various tasks that are anticipated (i.e., inputs of the various cognitive functions that the various agents will have to use);
- The organization in which users will perform tasks using the artifact (i.e., typically a set of human and machine agents); and
- The various situations (i.e., various kinds of context patterns that characterize the environment).

This is summarized in a new perspective of the AUTOS pyramid framework (Boy 2008). This chapter first tries to answer the questions of what is a safe human-machine system and how human-centered should be the design. It is based on a thirty-year experience in the aerospace domain, but attempts to extend several important concepts to safety-critical systems in general. It also provides a rationalizing distinction between exceptional and routine use. Design for safety is a matter of both expertise and shared common sense. The targeted population is very important and should be clearly understood. In addition, we cannot design a safe artifact in one shot, it has to be matured and improved during its whole life cycle, i.e., 'constant' evaluations should be performed. Finally, this contribution is a departure towards a safety culture for design.

This chapter presents an experience-based approach to design for safety. Aerospace, and automotive systems in general, are often qualified as safety-critical where risk management is a crucial issue. Therefore, we need to better understand

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1 EURISCO organized a summer school in 2001 on the topic that gathered most recognized contributors such as René Amalberti, Saadi Lahlou, Edwin Hutchins and Kim Vicente. Several references to their work are taken in this paper. In addition, I gave several tutorials organized by the HUMANIST European network of excellence. These tutorials enabled me to synthesize distributed knowledge and experience on design for safety.
what the main facets of safety that should be taken into account during design and development processes are. There are many factors that contribute to design for safety. I propose some of these factors and an articulation of them from requirement gathering and synthesis to formative evaluations to summative evaluations. Among these factors, we will analyze complexity, stability, redundancy, support, training, experience and test. However, a product and its various uses become progressively mature. We will see that product maturity is both a matter of high-level requirements quality and appropriate incremental formative human-centered evaluations. But this is only possible when we know well the practice features and the various human factors that are involved in the use of the product. When we deal with new products, main difficulties come from the fact that practice features emerge from the use of the product and are difficult, even impossible, to predict ahead of time. This is why design for safety is not possible without anticipatory simulations and a period of tests in the real world, such as flight tests in aeronautics. In addition, the design-for-safety process does not end when the product is delivered, experience feedback is an important part of an overall global design process. Experience feedback not only provides useful information for redesign for safety, but also for the next related products.

What is a Safe Human-machine System?

It is crucial to understand and master major attributes of design for safety in order to improve them. Safety can be seen as the resilience of a system to failure (Hollnagel et al. 2006). When the system is an artifact, we talk about fault. When the system is a human, we talk about error or erroneous action. We will use the term ‘failure’ for both artifacts and human beings. We would like to be able to avoid, detect, remove, tolerate or resist to failures. However, it is never possible to anticipate all probable failures at design time. This is due to ignorance, uncertainty and imprecision. In particular, we cannot anticipate all possible practices, i.e., even if designers try to anticipate possible uses, users always find peculiar ways of using a system that cannot be anticipated. Of course, system engineering has already developed methods to take care of safety in the sense of insuring that a system would work as well as possible. Disciplines such as reliability engineering or quality management have brought their shares, and most industries use resulting methods. Standards such as ISO 14001 are now routinely used in industries that produce safety-critical systems. Procedural application of such standards is supposed to guarantee the safety of products that will be delivered. In practice, system reliability is certified with extremely high level of safety, such as probability of failure per hour of flight of $10^{-9}$. Ultra-safe systems, to take the terminology used by René Amalberti (2001), such as aerospace systems, are the result of the highest level of expertise, experience feedback and a systematic habit of testing. The paradox today is that

the level of expertise of the local actors is much higher than before, but these actors are barely coordinated even if industry spends a lot of money developing quality and organizational procedures and reporting systems. The world has been cut into small pieces, transferring expertise at the ‘atomic level’, and assuming that well-designed procedures and organization will contribute to the quality of the overall product. Note that when this product is a large commercial airplane, a piece of equipment may be designed and built by people who do not have the knowledge of how it will be used and maintained, and conversely the people who will use it may not have enough knowledge of the way it was designed and built. Safety-critical systems are therefore a matter of participatory design, development, maintenance, use and transformation.

**Complexity**

First, let’s try to understand human-machine system complexity. A distinction is made between internal complexity of an artifact and perceived complexity induced by the use of it (Boy 2008). Of course, the former is likely to induce the latter, but even if internal complexity is mastered, people may however perceive complexity in the interaction. Since our technology-intensive, and especially software-intensive, world increases the distance between people and the graspable real world, perceived complexity is a central issue in human-centered design, of safety-critical systems specifically. Systems that we develop are more complex because they are more interconnected. As already introduced, the paradox here is that quality forces design and development organizations to divide work into processes in order to be able to control them, from a financial viewpoint especially. In other words, we have a positivist approach to design and development instead of a holistic one and we produce artifacts that are often used in a holistic manner because of the great number of interconnections. This increasing interconnectivity makes current software-intensive systems look like biological systems where we need to elicit emerging properties. Therefore, reliability, availability and maturity of these artifacts need to be tested in all possible critical situations. In practice, this is difficult, and sometimes impossible, because human operators use them in many ways that were not anticipated by designers. We usually talk about surprises. The design of a safety-critical system requires that such surprises are anticipated before they are delivered.

Design for safety can be seen as design for simplicity. Therefore, it is important to assess the complexity of a safety-critical system being designed. There were several attempts to assess artifact complexity. Pylyshyn (1985) referred to the equivalence between cognitive complexity and computational complexity. He compared programs as instances of generic algorithms. The choice of an algorithm is often made under contradictory requirements. Understandability, transferability and modifiability of an algorithm are generally contradictory to its efficiency. The measure of computational complexity of an algorithm was studied extensively in theoretical computer science (Karp 1986). Pedersen (1990) dissociated
computational complexity into algorithmic and informational complexity, and provided several complexity attributes such as objective and subjective, system, representational and agent-related. The HCI field introduced other methods such as the Keystroke-Level Model (KLM) (Card et al., 1980), Goals, Operators, Methods and Selection rules (GOMS) (Card et al. 1983) and Cognitive Complexity Theory (CCT) (Kieras and Polson 1985). They proposed several measures of interaction complexity such as the number of necessary production rules and the learning time, as well as the number of items momentarily kept in the working memory in order to predict the probability of errors. In cognitive engineering, Rasmussen (1983) proposed the SRK (i.e., skills, rules and knowledge) model to capture three types of behavior. He also developed an ecological approach based on five levels of abstraction hierarchy. Vicente (1999) used this approach to develop the Cognitive Work Analysis (CWA) approach. Norman (1986) proposed a generic model that takes into account human actions, learning, usability and possibility of errors. Amalberti (1996) related interaction complexity to action reversibility and effect predictability, the dynamics of underlying processes, time pressure, the number of systems to be managed at the same time, resource management when the execution of a task requires several actors, artifacts representation, risk, factors coming from the insertion of safety-critical systems in cooperative macro-systems and factors related to the human-machine interface, users’ expertise and situation awareness.

In the MESSAGE approach (Boy and Tessier 1985), interaction complexity was assessed as information-processing difficulty in early glass-cockpit developments. Several difficulty indices were developed including visibility, observability, accessibility, operability and monitorability. These indices were combined with tolerance functions, which were expressed as possibility distributions of relevant user-interface parameters. Subsequent work led to the development of interaction-blocks to model interaction chains between agents in order to better analyze and understand the emerging interaction complexity of underlying operations. Interaction-block development requires the elicitation and specification of various interaction contexts, and therefore structuring various relevant situations. Five generic interaction-block structures were proposed including sequence, parallel blocks, loop, deviation, hierarchy and blocks leading to either weak or strong abnormal conditions (Boy 1998). More recently, we developed an approach to novelty complexity analysis (Boy 2008).

Cognitive Stability

Design for safety can also be seen as design for stability. The concept of stability has been studied in mechanics and physics. There are systems that are stable by themselves and others that are unstable. The pendulum, e.g., is a stable system. When one pulls the mass at the bottom of a pendulum, it returns to its stable state by itself. We usually talk about passive stability. This model works for a Cognitive Human-Machine System (CHMS) where a human agent interacts with
a machine agent. Whether a human agent or a machine agent fails, the overall system returns to a stable state by itself (passive cognitive stability) or requires additional actions (active cognitive stability). For example, let’s take a CHMS where there are human operators managing and controlling Unmanned Aerial Vehicles (UAVs). An UAV is a semi-autonomous system that is able to fly without human intervention for a limited period of time and in a limited airspace. Human operators manage to change their trajectories and speed. They also can act on their onboard systems such as video recorders. It may happen that an UAV has a failure, e.g., a wing was damaged during take-off. This injury has a direct impact on UAV trajectory. Imagine that the UAV is equipped with a GPS and an automaton that is able to automatically fix the actual trajectory to reach the target. In this case, the trajectory of the UAV is passively stable for the human operator. This is because there is an onboard software agent that takes into account the actual location of the UAV and computes the next point according to the target location. From the perspective of this software agent, stability is active. And if this kind of software agent is not installed onboard, the human operator has to take care of the active stability effort. In addition, disturbing events may not come from the human agent only, here the UAV. They may also come from the human operators in the form of human errors, from the environment in the form of unexpected weather changes, from the organization in the form of enemy attacks or from the task in the form of mandatory re-planning.

It is useful to extend the concept of cognitive stability, i.e., a human agent interacting with a machine agent, to a multi-agent environment. Therefore, it would be more appropriate to talk about socio-cognitive stability (SCS) even if we will use the term ‘cognitive stability’ for both individual agents and groups of agents. Consequently, interaction between human and software agents can be modeled as a network of cognitive functions (Boy 1998) where cognition is distributed among humans and machines (Hutchins 1995).

A measure of socio-cognitive stability was recently proposed by distinguishing between local and global stability (Boy and Grote 2011). The former is related to agent’s workload, situation awareness, ability to make appropriate decisions and, finally, correct action execution. Local stability can be supported by appropriate redundancies and various kinds of cognitive support such as trends, relevant situational information and possible actions. The latter is concerned with the appropriateness of functions allocated to agents, pace of information flows and related coordination. Globally, socio-cognitive support could be found in a safety net that would take into account the evolution of interacting agents and propose a constraining safety envelope in real time.

In addition, there are unexpected or unplanned events that oblige the revision of agents’ tasks in order to ensure an acceptable level of safety. Socio-cognitive stability is then related to the resilience of the socio-cognitive system, e.g., ATM. Passive SCS refers to a multi-agent system that returns by itself to a stable state after a disturbance. Active SCS refers to a multi-agent system that requires external intervention to make it return to a stable state. Obviously, there is a continuum
between passive and active socio-cognitive stability where several levels of difficulty can be defined to stabilize a multi-agent system, as well as several levels of resilience of that system. We proposed that this difficulty be assessed using three kinds of metrics: time pressure criticality; complexity; and flexibility (Boy and Grote 2011).

**Flexibility**

Safety nets, barriers and all kinds of protections will not remove the possibility of failure either from humans who may no longer be self immune from danger because of the lack of exposure to risks, or from safety systems themselves. This is why expertise and experience are still crucial assets in the management of safety-critical systems. Consequently, human operators need to have both appropriate skills and tools to handle unpredictable or infrequent events. Therefore, design for safety can also be seen as design for flexibility. What do we mean by flexibility? Flexibility is related to adaptation and resilience, i.e., capacity to appropriately act in response to a disturbance. Flexibility deals with the ability to diagnose, solve problems and act in the right context. A paradox comes from the fact that we develop (rigid) procedures to help people in abnormal and emergency situations, but they do not use them when they do not fully understand their effects. This is specifically true in highly safety-critical situations. In these cases, people rely on their skills and knowledge, and require enough flexibility to diagnose, solve problems and ultimately act. Flexibility needs to be considered in relation to stability and complexity.

When an unpredicted event occurs, agents in charge should be able to make the system return to its stable state. Such agents could be either automata or human operators. The latter require redundancy in the control of a safety-critical system. A human operator requires cognitive stability to act safely and therefore appropriate cognitive support that could be provided in the form of redundant states useful for cross-checking for example. Other kinds of redundancy are also useful, i.e., *Why* the system is doing what it does? *How* to obtain a system state with respect to an action using control devices? *With what* other display or device the current input/output should be associated? Such redundancies provide more flexibility to human operators.

Safety assurance is also a matter of intimate connectivity between the various appropriate agents; this is where complexity enters into play. This implies that each agent has good awareness of the relevant states of the other agents of the organization and the environment. The more awareness, the better in safety-critical situations, but such awareness should be completed by appropriate situated action patterns; indeed, improvisation is not flexibility. In order to ensure situation awareness, there are two requirements: good human operator’s attention and vigilance; and good affordances of the software agent. Attention and vigilance depend on training, fatigue and other physiological, psychological and social factors (Wickens and Hollands 2000). Affordances (Gibson 1979) need to
be elicited from the use of a software agent. This is why simulations should be performed in order to situate the various interactions between agents. Affordances emerge from these interactions; without them affordances cannot be elicited.

This chapter claims that a human-machine system is safer when it is stable either passively or actively. This means that its constituting human and software agents are able to interact to maintain both local and global socio-cognitive stability. This requires appropriate automation and human operator training that provide enough flexibility in the case of unpredicted or rare events. This means that both technology and human practice are incrementally co-designed, i.e., end-users and designers/developers should work cooperatively during the whole life cycle of the safety-critical system. This is the way aircraft have been built up to now involving the participation of pilots and aerospace engineers. Even if the nature of design is iterative, we will see in the following of this chapter that starting right is the most important.

**How Human-centered Should be the Design?**

HCD motivated a large amount of research efforts for the last two decades where the participation of potential users in the design process is strongly advocated (Boy 2003). I developed the concept of cognitive function in order to capture both concepts of task, i.e., what is prescribed to be done, and activity, i.e., what is actually done. Activity is also called situated work or performance. A cognitive function transforms a task into an activity. Most HCD approaches are based on task analysis. Norman (2004) recently made the point that activity-centered design is superior. This is not new however, since there is a long tradition of the Francophone school of ergonomics to advocate and use activity analysis to support HCD (Leplat 1997, De Keyser 1991). This approach needs to be put in perspective with the Russian activity theory (Leontiev 1978). The main problem is the availability of appropriate end-users. In the following of this chapter, several examples coming from operational experience will be presented to illustrate needs for the development of an integrated approach to human-centered design for safety.

**Various Kinds of Design Situations**

It may happen that potential users of an artifact that is being designed do not exist a priori. This is the case of a drastically new product or technology, such as the design of the Apollo 11 system that enabled Neil Armstrong and Edwin Aldrin to land on the Moon on July 20, 1969. The job of these astronauts needed to be defined without any possibility to verify its efficiency, safety and comfort before the actual implementation of the Apollo 11 mission. So, why did it work out so well? First, there was a need for a great decision maker and leadership. It started by President John F. Kennedy’s famous speech in 1961: ‘I believe that
this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth.’ Who could have known at this time who would be the best candidates to accomplish this mission and with what kind of supporting technology? Nobody did that before. Risks needed to be taken to reach Kennedy’s goal. What were the ‘ingredients’ for success? The first one was motivation. The entire US nation was behind NASA. NASA employees were extremely motivated and honored to be involved in such as an innovative endeavor. Trust and confidence were crucial assets for success. Technically speaking, various kinds of scenarios were imagined and implemented in simulation environments. Simulation is a key design support tool that enables the anticipation of possible operational issues. Another solution was to select and train exceptional people who would be able to solve problems better than anyone else in limited periods of time, under pressure, and with maximum safety. It seems that expertise is always a requirement when there is no experience available, i.e., any time a drastically new instrument is validated without appropriate end-users. It should also be said that a fair amount of money was provided to NASA to implement Kennedy’s vision. In addition, end-users, i.e., astronauts, were incrementally ‘fabricated’, i.e., incrementally selected and trained for such specific missions. NASA incrementally discovered astronauts’ tasks, behavior, functions, skills, knowledge, and so on. They also incrementally discovered and implemented organizational setups and appropriate technology that would support efficiently the astronauts and ground personnel during a space mission. Everything was thought, designed and constructed from scratch! Of course, this HCD process led to many evaluation and validation tests. I would talk about a highly structured process cross-fertilized with a genius large-scale ‘bricolage’. The term ‘bricolage’ denotes the process of ‘fixing things’ that requires constant motivation and appropriate skills until a successful result is reached.

A second example I would take is the experience I got from a research and development effort I was involved in more than twenty years ago when we tried to develop the HERMES space plane in Europe. The topic of this research was the operations assistance in tele-robotic missions. The HERMES space plane was designed to carry a robotic arm installed in the cargo bay. The problem was that this robot was not directly tractable and required remote manipulation. The astronaut in charge of this manipulation was sitting in the HERMES cockpit. Another problem came from the fact that the robotic arm was standing at the back of the astronaut, therefore it was not directly visible. The manipulation was handled through two screens displaying the views from three cameras and two joysticks to handle both position and attitude of the robot gripper. Our goal was to anticipate possible joint limit dangerous states and several kinds of issues that may result from possible system failures and human errors. We developed an operations assistance system based on our research group’s knowledge in space technology, robotics and human-computer interaction. We developed a knowledge-based system for assisting an astronaut in the task of grasping a satellite in flight. We had a one-quarter scale simulation environment with a tele-robotic arm and a satellite
moving in three dimensions. After one year of development effort, came the day of the first experimentation with an astronaut. We trained this person during a few hours and started the tests. Our surprise came from the fact this astronaut never had to use our operations assistance system; he always succeeded directly to grasp a satellite in flight with no problem. This was very disappointing for us since we did not find any situation where this astronaut could need the help of our operations assistance system. There were two main flaws in our design approach. First, we did not spend enough time to develop appropriate scenarios. Second, we developed the operations assistance system and scenarios based on our own knowledge and know-how. We quickly understood that we should have involved astronauts from the beginning of the design process as well as in the development of the scenarios. The concept of participatory design came up much in the 1990s in the HCD community.

Satisfying the Product Maturity Requirement

The issue of maturity was taken seriously by Curtis and his team at Carnegie Mellon University through the development of the Capacity Maturity Model (CMM) for software development (Paulk et al. 1995). This technique is extensively used in industry worldwide today. However, it emphasizes the maturity of development processes, and it assumes that if these processes are mature then the product will be mature. This is an assumption that barely works. We developed an alternative approach to product maturity that takes into account a human-centered definition of high-level requirements, as well as usability and usefulness tests of the product being developed (Boy 2005). Product maturity is a matter of time and extensive tests that involve end-users. It can be seen as incorporating user experience in the definition and implementation of the product. For that matter, user experience is crucially needed during design and development processes.

Experimental Test Pilots (ETPs) are involved in this product maturity process from the early stages of the design to the delivery of an aircraft. Therefore, the aeronautical industry has a long experience of such maturity processes. An aircraft is tested during the whole design and development cycle, i.e., from early prototypes to the first flying vehicle. Of course, ETPs do not have the same profile as airline pilots. They are usually more skilled and have more knowledge on the systems of the aircraft from an engineering viewpoint. However, they are required to fly in an airline periodically. Can the design of a commercial aircraft qualify as HCD? I would say it used to qualify. This may seem paradoxical because the science of HCD and cognitive engineering made a lot of progress during the last twenty years. The main problem is that only 15 years ago, test pilots were the bosses of the aircraft industry. Therefore, HCD was coming from the top and was very well managed even if it was done implicitly, i.e., not using current HCD formal methods and principles. Of course, one could argue that design and development are more user-centered today because HCD methods are taken into account, but,
as already said, the main issue is the coordination between the various processes and people.

Management is intended to support technical work. However, the complexity and uncertainty of economical industrial environments have led to the necessity to justify almost all activities and control costs. Therefore, industrial organization and management setups have been very mechanized. In particular, structured reporting has been installed. The main problem comes from the related human factors induced by the application. Even if quality processes are implemented, product quality and maturity is still an issue because they are attributes that must be mastered by people. The technological glue that the former technical and operational managers were constantly bringing into product design and development is often somehow remote nowadays to the benefit of very accurate control of money. Now, we have the Capacity Maturity Model and quality assurance processes that contribute to the generation of huge quantities of cost information both electronically and on paper, but it fails at providing meaningful socio-technical information on product usability and usefulness. Related authority has been transferred from ETPs to managers whose main task is to decrease costs and increase benefits. The goal is no longer the beauty of technology and satisfaction of end-users, but the happiness of the shareholders. Issues are not based on long-term visions, but on short-term benefits. Consequently, even if it is very fashionable to take into account human factors, this is done in a way that barely involves end-users, just because it is too costly for a short-term benefit.

Well, what could this very sad analysis bring to the practice of HCD? Since the issue is about money, we need to find solutions that take this parameter into account. In many cases, the voice of the users is of little interest because they do not know about the product. We should then listen to the voice of science. Getting to product maturity is a matter of a well-balanced mix of systematic tests that involve real users all along the design and development process, as well as engineering competence and leadership.

*Inventing Human-centered Design Solutions*

A recent study brought an important issue of end-user participation in the design process. The problem was to get information, knowledge and know-how from UAV operators to design new work places for the management of UAVs in a military environment. These operators were identified, but were not available. Our approach was based on interviews and GEM sessions involving these UAV operators. The problem was not that these people did not want to participate. It was a problem of culture and organization complexity. Access was extremely difficult for several reasons that include confidentiality, distance between research money providers and end-users (i.e., UAV operators), and difficulty in convincing management that user requirement gathering was important.

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3 Group Elicitation Method (Boy 1996).
A first solution is to communicate and even train top managers to make them sensitive to participatory design. Top managers are key. End-users should be involved in the design process from the beginning to the end. This is not only an issue of organization, but also a cultural issue. So, what does socio-cognitive science say? Human-centered design needs to be anticipated both organizationally and personally by all stakeholders who will have to deal with the product being designed and developed, i.e., managers, end-users, trainers, maintainers, certifiers, suppliers, and so on.

As already said, a distinction must be made between an evolutionary product and a revolutionary product. An evolutionary product involves small modifications on an existing product. Users will have to adapt to these modifications. Job changes need to be anticipated, for social reasons first. With a revolutionary product, their job will certainly change and will have to be redefined. In both cases, it is crucial that users are involved in such definitions. Users are the best to tell if the product prototype is usable and useful. It may take some time to understand the co-adaptation between users and technology.

Here is a second solution. Since this section of the chapter emphasizes solutions to compensate the lack of access to real users, freshly retired experts and/or end-users could provide effective help in the design process. Usually, experts who are still on duty do not have time, or are commercially or legally constrained with their organization and cannot commit for HCD purposes. Freshly retired experts and/or end-users can! This is a solution that was used by consulting firms to extend the technical memory of an organization in order to make personnel turnover more continuous.

We should make a difference between products for public or common sense use, and expert use. Common sense use does not require any training, e.g., typical users are everyone who uses an automated teller machine to get cash. Instead, expert use requires a fair amount of training, e.g., typical users are airline pilots. Of course, there are systems that may require common sense from experts. In abnormal situations, in particular, everything should be simple enough to handle risky situations. In any case, it is quite important to get current activity patterns from users. Of course, we know from the start that these patterns will be modified when the users will use the product; this is why simulators are great help for getting appropriate activity patterns. Nevertheless, it is important to elicit such activity patterns from users through interviews or GEM sessions.

A third solution is to use domain experts who are not necessarily users, but who have enough knowledge of the operational domain. However, this could be a dangerous solution because domain experts may not know the right activity patterns because they never practiced them and even worse they may have totally different patterns due to their lack of use expertise. This was the case of the HERMES robotic study described earlier. Nevertheless, this could be considered as a starting solution that must be complemented by a real user-centered validation when convincing results are produced. This complementation should not be done too late.
A fourth solution is to *take expert users from an analogous domain*. For example, in some specific cases, an automotive HCD problem could be handled using aviation knowledge or conversely. If the problem is, e.g., to study attention while flying in a single pilot configuration, there are other domains where attention was extensively studied such as truck driving. Making analogies could be extremely useful and efficient, but we need to be clearly aware of the limitations and discrepancies that may result from these limitations.

Of course, the choice of any of these solutions requires expertise and appropriate common sense. It also depends on the domain and the problem to be solved.

**Rationalization and Expertise for Safety**

People learn to preserve themselves from the early days of their lives and do not stop improving their defenses against external aggressions. For that matter, they try to keep an acceptable cognitive stability in their environment. Indeed, cognitive stability is context-dependent. The more human beings are familiar with their environment, the more they are cognitively stable, i.e., they know how to interact within this environment. They learn the various appropriate patterns that are mandatory to maintain high cognitive stability.

**Anticipation, Interaction and Recovery**

In a safety-critical environment, people learn how to anticipate, interact and recover from failures. Anticipation is certainly one of the most important skills or cognitive functions that a human operator needs to have in order to maintain a reasonable level of safety. Pilots learn how to ‘be ahead’ of their plane. Anticipation is a matter of situation awareness that entails both perception and understanding of what is currently going on and what should happen next (Endsley 1996). A pilot typically takes the risk to act according to assumptions made on the evolution of his/her environment including plane, weather, traffic and so on. From this perspective, anticipation is not only perception but also action. We usually talk about situated action (Suchman 1987). Anticipation is therefore linked to abduction. Abduction is one of the three types of inference, in addition to the most well known that are deduction and induction. If $A \rightarrow B$ represents an inference, abduction makes the assumption of $B$ and proves $A \rightarrow B$. Postulating $B$ is based on heuristics usually based on intuition, expertise and competence. Abduction is crucial in safety-critical actions. Charles Peirce (1903) defines abduction as a construction process of an explicative hypothesis, and claims that this is the only logical operation that introduces a new idea. *Fly-by-wire* technology, first introduced by Airbus, was a revolution in flying commercial airplanes. Its designers implemented an abduction process. Of course, their choice led to a number of deductive processes that contributed to rationalize and demonstrate its relevance and viability. For example, they tried to (deductively) demonstrate how to reduce aircraft weight,
facilitate operator training, protect against external events or human errors. Initial abductive processes, and the following rationalizing deductive processes, are guided by general objectives related, e.g., to the economy of operations, safety, performance, comfort and training. At this point, the state of the art supports choices and implementation of these processes. The final choice of fly-by-wire technology resulted from the rational and deductive choice relying on specific objectives such as weight reduction, simplicity, flight envelope protection and training homogeneity.

Interaction with a safety-critical system is strongly grounded into action skills. A good pilot is intimately ‘integrated’ into his/her aircraft, i.e., aircraft controls and observable parameters are harmonious extensions of his/her cognition, the same as his/her arms or legs. It takes long training and experience, as well as affordant aircraft devices. Unfortunately, there are failures coming from both sides, aircraft and pilots. Therefore, recovery is also an important asset that needs to be mastered. Failure recovery is a matter of diagnostic and problem solving. The aeronautical industry learnt how to categorize failures and appropriate recovery strategies and actions. This is the basis of pilot training and flying documentation.

Automation Maturity Management

HCD of a safety-critical system involves the consideration of various situations that could be normal or abnormal. In normal situations, human operators either have jobs that require routine operations that can be proceduralized. Procedures work in any situations that can be anticipated. They are built from experience and technical knowledge. There are abnormal situations that lead to abnormal procedures because they are very well known. The same holds for emergency situations. The main issue comes from situations that are not persistent enough or constantly requiring problem solving for enabling the elicitation of appropriate procedures. For example, a pilot uses procedures because his/her work is very well anticipated most of the time, but in some situations he/she has to solve problems using his/her airmanship. Such procedures were developed for two main reasons: experience feedback and regulations; and high-level automation. Conversely, air traffic controllers do not use procedures as much because their job is to solve problems at each instant, i.e., action patterns cannot be proceduralized because situations are not prototypical like in the cockpit. The automation of air traffic management (ATM) will transform the controllers’ job to a more procedural work.

Automation tends to promote management skills. The main reason is that previous active stability maintenance is replaced by a more passive stability assurance that needs to be managed. Human operators go from a high-stress problem-solving job to a hypo-vigilance monitoring work. There are two main problems that emerge from automation regarding the change in the nature of socio-cognitive stability. The first type of problem is the maturity of the new automated system, i.e., reliability, availability and robustness. The second problem is the
maturity of use of this new automated system, i.e., adaptation of current practice to a new one. After the introduction of glass cockpits, it took a while to stabilize flight management, i.e., pilots had to shift to a managerial way of controlling automated systems. Instead of controlling flight parameters directly, they had to manage artificial agents that controlled these parameters.

The first French computers were introduced in the early seventies. Mitra 15 and Mitra 125 were very advanced computers, but they were used by very educated computer-scientists. It was necessary to know about computer architecture and how to program them. Very simple programs were generated at that time but high-level skills were required to develop them. It was the same for the automobile industry. At the beginning of the automotive development, in the first part of the twentieth century, car drivers were also mechanics, i.e., they knew how an engine worked. Very skilled people were able to drive with very low performance compared to nowadays’ car performance. Today, almost everyone can drive a very fast and comfortable car.

How about safety? In the car domain, early cars were less safe than those that we drive today. They had less protection either for passive safety or for active safety. However, we still have safety issues today, and accidents could be more terrible than before. This is because of the number of cars and consequently drivers, as well as the extended possibilities that modern cars and trucks provide. This is also because drivers do not have all capacities that are required to handle such safety-critical systems.

Exploiting Expertise and Creativity

As previously mentioned, this chapter advocates the use of expertise to handle difficult design problems that require user experience gathering. It focuses on the cases where there is a lack of user experience whether because no user profile exists (revolutionary case) or actual existing users are not available or not easy to access (evolutionary case). Expertise should be used in conjunction with creativity. Here is a method that may be used for successful solutions.

There are three kinds of tasks that should be carried out concurrently:

- User requirement gathering (using the solutions that are provided earlier in the chapter);
- Systematic use of ergonomic rules and usability heuristics; and
- Creative design and prototype development.

The result of this mixed approach should be validated by a set of experts that includes end-users, domain engineers and human factors specialists. Of course, it is even better when these three tasks can be iterated several times.

Involving users is not only good for the design and development of the product, but also for the acceptability of the product when delivered, i.e., when involved in the design of something it is easier to accept it in the end.
In the case of UAV operators, there is an additional task, which is to define their profiles. For example, should they be pilots, aeromodelism operators, air traffic controllers or new profile to be defined. For some missions, there is no need for flying knowledge and know-how since UAVs are already autonomous and do not need any flying qualities handling. Besides, strategies may be more important and the UAV operator profile should include this kind of capacity. For that matter, it is always important to specifically define the goal of product use, i.e., what kind of task will be at stake. This will help selecting the kind of expertise required to be elicited.

Conclusion and Perspectives

Design for safety is a real issue that deserves extreme attention, reflection and practice. The current answer to protect people from failing safety-critical systems is grounded in the development of software-intensive systems. It is an easy way to generate protections but it may introduce a vicious circle. Indeed, the accumulation of software layers increases system complexity and consequently perceived complexity that in turn generate new types of safety issues. This is due to the fact that software-intensive system maturity is almost never reached. Software is always evolving and used as patches instead of an integrated solution. Safety-critical systems deserve clean and understandable solutions. Why?

We saw that ultra-safe systems work most of the time with a very good passive stability. However, human operator’s vigilance tends to decrease when he or she does not have much to do. This is why it is important that they keep human operators in the control loop one way or another. It is interesting to note that a driver may stay in a hypo-vigilance state for a long period of time on an empty road and suddenly realize it when an external event ‘wakes him/her up’, inducing adrenaline production. For example, it may happen that a truck driver stays in a hypo-vigilant state. What does it mean to design for driver’s safety? First, the artificial agent to be designed should anticipate the truck driver falling asleep and act accordingly! This is a very important high-level requirement for the technology to be developed. Conversely, it would not be the same for pilots since we know that they may get a sleep during the cruise phase without causing any harm to the flight. The main difference between driving and flying lies in required reaction times that are typically slower on the flight deck than in the car or truck. Therefore, HCD should be based on high-level requirements that would provide the appropriate answer to the pilot waking up! The rest is technology development.

I would like to insist on the importance of having ‘the right’ high-level requirements in the early stages of design. This is a very important attribute of maturity. A series of endless modifications are always necessary to fix a wrong design. This is why formative evaluations are so important to be carried out during all the various design and development processes. Both concept and practice were
introduced in software development in order to improve programs. In contrast, summative evaluation is performed at the end of the development of a product. Both types of evaluation may use the same kind of techniques such as interviews, brainstorming, data collection, and user-in-the-loop experiments.

We need to make a distinction between the maturity of a product concept and a product that is not finished. Once a mature concept is found, it needs to be developed and finished, i.e., matured in the sense of the CMM. This does not remove the importance of user-centered continuous testing. Sometimes, a concept is not mature because the technology is not ready. Leonardo Da Vinci designed a flying machine, but he did not have any powerful propulsion mechanism to make it fly. It took several centuries to get this kind of means that enabled Clement Ader to sustain 50 meters high in his Eole flying machine in 1890. Propulsion was there to stay. The same happened when Douglas Engelbart invented the mouse and the concept of an interactive computer in 1957 at NASA Ames Research Center. We had to wait until the beginning of the eighties to deliver usable interactive computers designed at Xerox Palo Alto Research Center and finally developed by Apple. Engelbart’s concept was mature, but the technology was not ready. Consequently, maturity and readiness must go together. Why is all this so important in safety-critical systems?

This is related to risk taking. Developing a new nuclear power plant concept involves a long life-cycle that is important to anticipate. Having the right high-level requirements is crucial. In this case, we are talking about safety of the nuclear process during energy production as well as after, when the waste needs to be treated. In the same way, we will go to Mars as we went to the Moon. Such an undertaking is safety-critical. There will be people who will take the risk to go to Mars. For that matter, the design of both the spacecraft and the mission should be done jointly between the astronauts, engineers, and all kinds of specialists who know about astrophysics and life in close environment. A trip to Mars is expected to last at least three years. What would be the profile of the people who will jump onboard? How should we design their environment and life? What should be anticipated in the case of a death onboard?

These examples seem to be extreme. However, they illustrate the need for constructing new job and life profiles. Design for safety takes efforts in the definition of appropriate levels of system automation and human expertise. Technology and societies are constantly evolving, putting us in transient states with no hope to reach a steady state as it used to be. Therefore, anywhere passive socio-cognitive stability cannot be reached by design or organizational set-up, safety has to be thought as active stability where people are accountable and in control. Nevertheless, safety needs to be thought and handled by both people and technology. People means individuals and organizations.
References


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Introduction

Due to the progressive development and availability of In-Vehicle Information and Communication Systems (IVIS) and Advanced Driver Assistance Systems (ADAS) issues concerning the design of the in-vehicle Human Machine Interface (HMI) have received considerable interest in recent years. Although there is no doubt that from the implementation of these systems benefits for road traffic safety can be expected, several questions are left open, principally, how drivers will interact with these systems while driving, how drivers’ behaviour in general will be affected, and what consequences for traffic safety in particular are to be expected. Irrespective of the available systems there is a consensus that the user-oriented design of in-vehicle HMI is especially important (e.g., Gelau 2004, Young, Regan and Hammer 2003).

It is obvious that the design of the in-vehicle HMI of IVIS and ADAS is not only crucial for usability and safety but also for acceptance on the part of the customer, and may therefore be considered as a key factor in competition (cf. Gail et al. 2002). HMI-Guidelines and Standards are developed in order to promote safe and usable products, and to ensure transparency in competition. A Guideline is a practice that should be followed. In this sense the ‘European Statement of Principles on HMI’ (ESoP) will hereafter be discussed as a Guideline. However, the official status of this document is that of an EC-Recommendation, which means, put simply, that non-compliance will not be punished but should at least be justified in order to avoid other more mandatory legislative measures. Standards describe procedures, processes or features of products which should be followed, although standardisation organisations like, e.g., ISO, CEN or SAE do not have the possibility to enforce compliance. This is usually done by authorities who refer to standards in regulations which are mandatory (cf. Green 2001). But standards are also important, e.g., in cases of negotiations between Original Equipment Manufacturers (OEM) and suppliers. Moreover, the compliance with the requirements and recommendations defined by standards is critical in terms of product liability, i.e., in the case a manufacturer has a ‘burden of proof’ and must
convincingly explain that he came up with the requirements resulting from the ‘duty of care’, as they can be considered to represent the state-of-the-art regarding science and technology. Therefore the standards also require a certain level of maturity of the products to which they are intended to be applied.

Right from the beginning the NoE HUMANIST (HUMAN centred design for Information Society Technologies)\(^1\) was very clear with respect to contributions to be expected from joint research activities by standardisation bodies and regulatory institutions. Regarding International Standardisation on ISO level the NoE HUMANIST Technical Annex (p.14, update November 30 2005) made a very clear point when stating that ‘the work conducted in the framework of the HUMANIST NoE will allow inputs to the work going on within ISO TC 22 SC 13 WG 8’ (see paragraph 3 for further explanation). Concerning the ESoP it was stated in the same document (p.14): ‘The research conducted in the HUMANIST NoE will contribute to bring results usable to improve the content of these SoP (author’s comment: ESoP). It will allow to define more precisely some aspects still vague in this version in terms of HMI for in-vehicle-systems.’ This holds true for the HMI of systems integrated by the Original Equipment Manufacturers (OEM) as well as for systems from the so-called ‘after market’, which are fitted into a vehicle after its production, and portable or nomadic systems, which are non-stationary although intended to be used while driving.

For this reason, in the present chapter we start with a brief review of the ESoP and relevant activities in the area of International Standardisation (ISO/TC 22/SC 13/WG 8). This will be followed by a brief review of relevant results achieved by the NoE HUMANIST. Methodologies to arrive at scientifically sound guidelines are described in more detail. Special attention is paid to nomadic devices, providing information and communication to drivers. This chapter will end with some conclusions on utilisation aspects and needs for future research.

The European Statement of Principles on HMI

On 21 December 1999 the Commission of the European Communities (CEC) adopted a Recommendation incorporating the ‘European Statement of Principles’ (ESoP). In addition, the CEC published the ‘Expansions of the Principles’ in 2001 as a supporting document. The ESoP summarises essential safety aspects to be considered for the design of HMI for in-vehicle information and communication systems (IVIS). More precisely, both documents contain three overall design principles on human machine interaction and 32 principles covering the topics of system installation, information presentation, interaction with displays and controls, system behaviour, and information about the system. In order to avoid unnecessary obstacles or constraints to the innovative development of products, the principles are expressed mainly in terms of the generic goals to be reached

\(^1\) See www.noehumanist.org
by proper HMI design (cf. Haller 1999, Stevens et al. 2005, Stevens 2009). The ‘Expansions of the Principles’ can be considered as an elaboration and clarification of the ESoP, supplying definitions, examples and explanations for each of the principles in order to facilitate its application. However, the purpose of the ESoP was to disseminate the principles widely, through the Member States to the main stakeholders in the field. A voluntary agreement of European car manufacturers to fully respect the ESoP was issued in 2001 by ACEA (the European Automobile Manufacturers’ Association).

In 2003 the eSafety Forum was established by the CEC in close collaboration with the industry, industrial associations and public sector stakeholders to address both safety and market issues in the implementation of intelligent information and communication technologies as a contribution to European road safety improvement targets. Following the recommendations of the ‘eSafety Working Group on Road Safety’ (November 2002) the eSafety Steering Group established a ‘Working Group on Human Machine Interaction’ in order to tackle the important issue of driver interaction with on-board devices, so that HMI would not become a barrier to deployment. More precisely the following recommendations referring to HMI were made:

- ‘Assess the reports by the EU Member States on the ESoP and decide on further actions as necessary, taking into account the rapid development in this area.
- The use of portable (nomadic) devices requires urgent assessment of risk.
- Develop workload assessment, testing and certification methodology and procedures for complex in-vehicle environments.’

The ‘eSafety Working Group on Human Machine Interaction’ (eSafety WG HMI) was active during 2004 analysing issues and discussing approaches to promote safe deployment. Following a workshop in mid-2004 specific recommendations were developed and discussed with Member State officials and industry representatives. The application of the ESoP by car manufacturers and suppliers of original equipment was judged positive, but the impact of the ESoP could be improved for other stakeholders, e.g., nomadic device manufacturers and service providers. The report of the eSafety WG HMI was finalised and submitted to the CEC in early 2005. Based on responses and further reflection, the eSafety WG HMI recommended to revise the ESoP based on the ‘Expansions of the Principles’ (2001).

The CEC accepted the report and responded quickly by announcing that a new updated version of the ESoP would be produced during 2005 and become part of a CEC Communication on HMI issues towards the end of the year. The CEC made some funding available through the existing HMI-related projects HUMANIST and AIDE and invited a small group of HMI specialists – the ‘ESoP Development Group’ – to implement the eSafety ‘WG-Human Machine Interaction’ recommendations concerning the ESoP.
The ‘ESoP Development Group’ worked intensively from April to September 2005 and submitted a draft version of the revised ESoP (ESoP II in the following) for further processing by the CEC in October 2005. The CEC adopted the update of the ESoP on 22 December 2006 which was then published in the Official Journal of the European Union on 6 February 2007 (L 32/200).²

As with the ESoP, the principles included in the ESoP II are short generic statements summarising specific and distinct HMI issues (e.g., Interaction principle I: ‘The driver should always be able to keep at least one hand on the steering wheel when interacting with the system.’). Following each statement an explanation is given of the rationale and meaning of the principle, including examples. Where possible, a practical means of verifying that the principle has been followed is provided. Nevertheless, the ‘ESoP Development Group’ was convinced that the current state of scientific development is not sufficient to justify specific or even quantitative compliance criteria relevant for safety to be linked with all of the principles. In contrast to the position of some authors (e.g., Green 2009: 456), who believe that the definition of ‘hard’ numeric performance criteria is a guarantee against unsafe, distracting HMI concepts, formulating ‘simplistic pass/fail criteria’ was carefully avoided, in favour of the formulation of goals in order to support good design.

The ESoP II also applies to IVIS intended for use by the driver while the vehicle is in motion, e.g., navigation systems, telephones and traffic information. It should be stressed that the principles are not specifically intended to apply to systems providing vehicle stabilisation (such as ABS and ESP/ESC) or to Advanced Driver Assistance Systems (ADAS) such as, e.g., ACC because these systems differ from IVIS in some fundamental aspects, and require additional consideration in terms of Human Machine Interaction. Furthermore, the scope of the ESoP II covers all components and aspects of a system that the manufacturer expects the driver to interact with while driving, and also to certain other components and aspects that should not be used while driving. This means that ‘the system’ refers to the functions and parts, such as displays and controls, which constitute the interface and interaction between the system and the driver. Moreover, the scope of the ESoP II explicitly excludes aspects not related to Human Machine Interaction such as electrical characteristics, material properties, system performance and legal considerations.

The ESoP II applies specifically to class M and N vehicles (i.e., motor vehicles with at least four wheels for the carriage of passengers (M) or goods (N)), although some aspects may also be relevant for other vehicle classes. Most important, the principles are valid for both portable and permanently installed systems as well as for OEM systems, and after market systems, and Nomadic Devices (ND). Finally, the principles apply to HMI functionality independent of the degree of integration between systems. In addition to optimising individual system design, the driver

² ESoP II is available in the Internet at http://ec.europa.eu/information_society/activities/esafety/library/index_en.htm
can be supported in the safe operation of IVIS while driving by making other aspects of the context of use as benign as possible.

An eSafety conference was organised which took place on 5–6 June 2007 in Berlin during the German EU Council Presidency. Beside Real Time Traffic Information (RTTI) and legal issues of driver assistance systems, Human Machine Interaction (HMI) was one of the key topics. In the session on HMI six presentations were given by speakers from governmental authorities, industry, and research institutes which all addressed issues concerning the revised ESoP. As a result of these presentations and the following discussions, several conclusions were adopted and sent as an official communication from the German Federal Government to the European Commission, with the request to take them into consideration when taking further action.³

The conclusions on HMI concerned the implementation of the ESoP II, Nomadic Devices, the prevention of manipulation and misuse, and the future development of the ESoP. Of special interest in the context of the present chapter is the recommendation on Nomadic Devices which in summary states that special attention has ‘to be paid to issues relating to the safe integration and use of portable systems’.

### International Standardisation (ISO) Activities on HMI

Due to the progressive development and availability of IVIS and ADAS, issues concerning the design of the in-vehicle Human Machine Interface (HMI) have received considerable interest in recent years. In the field of standardisation this is reflected by the establishment of relevant working-groups operating on an international level. In this paragraph a brief overview is given of finalised and ongoing standardisation projects performed by the experts of ISO/TC 22/SC 13/WG 8 ‘HMI of Transport Information and Control Systems (TICS)’, which can be considered as a potential field of dissemination and application of HUMANIST results.

There is quite a number of standardisation committees concerned with HMI topics. The ISO/TC 22/SC 13/WG 8 with its mirror organisations is the only one that deals exclusively with automotive HMI.⁴ The results of WG 8 activities are very specialised standards that meet the needs of developers of automotive HMI, as the following examples show: Vision provides the primary source of information

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⁴ The work of this expert group is mirrored by CEN/TC 278/WG 10 on a European level. However, as this group consists of the European ISO experts the work of CEN/TC 278/WG 10 is completely integrated in the programme of ISO/TC 22/SC 13/WG 8 in order to ensure efficient networking and to avoid double work.
available to the driver. Information is gathered by looking at objects and events which, in turn, enable control and navigation of the vehicle in the road traffic environment. A Visual Information Standard (ISO 15008) ensures legibility of displays by setting limits for contrast and letter size. The multitude of information needing to be displayed to the driver through TICS may create the need to minimise visual load and make more and better use of the auditory channel. An Auditory Standard (ISO 15007) provides ergonomic specifications for the design and installation of auditory displays presenting speech and tonal information while driving. In a technical specification on Priority (ISO TS 16951) methods are described which enable developers to determine the relevance of warnings, and to control their presentation to the driver accordingly. A technical report on Warnings compiles the present knowledge of the topic, and gives guidance to HMI developers (ISO TR 16352). In view of the importance of this topic, a new Task Force was established to develop guidelines on warnings based on the existing knowledge (ISO/TC 22/SC 13/WG 8 NWI Warnings Integration).

Another approach, rather than fixing certain details of HMI, is an overall testing framework in order to determine the influence of HMI on driving performance. For the overall assessment of in-vehicle systems such a framework is supplied by the Suitability Standard (ISO 17287) based on a structured methodology. In the Dialogue Management Standard (ISO 15005) requirements and recommendations on the design of interactive user interfaces to limit driver distraction are formulated.

The Occlusion Standard (ISO 16673) describes the experimental protocol for the assessment of visual load induced by visual-manual in-vehicle tasks. Another method which is currently under development is the Lane Change Test (LCT) (ISO DIS 26002). The work on the lane change test stimulated the launch of another standardisation project. It is the objective of the Calibration Task project to define reference tasks to ensure comparability of results of LCT or occlusion experiments across laboratories. The status of the calibration task project is currently that of a Preliminary Work Item (PWI), meaning that for the adoption into the work programme of WG 8 according to the ISO rules, agreement by means of an official ballot is still required.

**Overview on Contributions from the NoE HUMANIST**

The NoE HUMANIST produced several results which can in some ways be considered as relevant for ongoing work on guidelines and standards, and which will be briefly reviewed in this paragraph.

**Impact Analysis of ITS on Driving Behaviour**

One of the main objectives of HUMANIST was to exchange the knowledge and experience from projects which have applied or developed methodologies for
the evaluation of IVIS and ADAS, both in terms of safety and usability. Several studies were reviewed where these methods were applied. A main objective was to describe and continuously update the ‘state-of-the-art’ on the impact of IVIS on relevant criteria of driver workload and behaviour by reviewing and exchanging knowledge and experiences. As a first practical step to initiate this exchange of knowledge within the network a joint workshop was held on 9 September 2004 in Toulouse, France. The presentations given addressed the following issues and projects (see Annexes 1–15 in Gelau and Bygrave 2004 for a more complete summary of presentations and results).

The current range of ND on the market both in the UK and across Europe: methods for assessing the visual and cognitive demand imposed by in-vehicle system tasks were discussed, before detailing findings relating to the HMI, and safety concerns about some specific ND:

- Results from the German contribution to a joint project ordered by the Swedish National Road Administration (SNRA) and BASf which contributed to research on promising methods for safety evaluation of IVIS, and which should become part of a more standardised set of evaluation methods. More precisely, two parallel on-road driving studies were undertaken in Linköping, Sweden by VTI and in Chemnitz, Germany by CUT in order to investigate the impacts of route complexity and route guidance systems on driver workload.

- Results from the French project COUNTIC: The main objective of this research was to develop evaluation methods for the distracting effects of various vocal communication activities. A multi-parametric approach was adopted in two experimental contexts: in a driving simulator and on a test track. The experiments on simulator and test track showed concordant results with regard to the common situations and their common parameters (response time and heartbeat). A paper is included in this report.

- Results from the European Project COMUNICAR (COmmunication MUltimedia UNit Inside CAR) and a comparable BASf project which both provided evidence for the beneficial effects of Information Management Systems on driver workload and distraction in multi-tasking situations.

- Results of an Austrian project performed in order to validate the ‘Vienna Driving Test’ (Wiener Fahrprobe) as a tool to analyse the impacts of IVIS on driver behaviour. The ‘Vienna Driving Test’ is an observation method used by one or two persons inside subjects’ cars, in order to assess their driving behaviour. Several behavioural variables are registered both in a standardised and non-standardised way. The total set of variables is assumed to be a reflection of the observed subjects’ driving behaviour or driving style. Considerable emphasis is thus put on aspects of interaction and communication when driving in real traffic.

- A paper on a series of experiments in a Dutch simulator that investigated the effects of different difficulty levels of a secondary task on primary task
performance. Although the experiments were performed in a ship simulator it is shown that the results also have clear implications for the analysis of the impacts of ITS on driving behaviour.

- Results from a German project assessing IVIS using the occlusion method and the peripheral detection task (PDT): twenty-four participants solved a set of twelve tasks in order to validate occlusion and visual detection tasks as methods for assessing the visual demand of IVIS. The results demonstrate that both methods are able to detect tasks with high visual demands. It was concluded that both seem to be suitable to be used as ‘quick and dirty’-screening tests to evaluate the visual demand of prototypes, and design alternatives relatively early in the design cycle.
- Results from a Swedish study of driver performance and safety. The study investigated the effects of using hands-free and hand-held mobile phones while driving in urban and rural road environments of different complexities. When driving in the various environments specifically designed traffic situations occurred. Effects of both conversation over the phone and dialling were investigated. Mobile phone conversation and dialling were found to be demanding tasks. Both PDT reaction time and the proportion of missed signals markedly increased during phone use.
- A literature review and discussion of available methods for IVIS assessment.
- Results from a German project which aimed to assess the reliability of evaluation methods by means of re-analysing data from several recently finalised studies. In these studies the occlusion technique and the Peripheral Detection Task (PDT) were investigated as assessment tools for the in-vehicle HMI of IVIS. Split-half coefficients and Kendall’s W were calculated for data from a total of four occlusion experiments by CUT as subcontractor of BaSt.

The presentations given covered a broad range of themes and issues. In order to integrate the results all participants who presented their research were asked to fill in ‘The Matrix’ (see Gelau and Bygrave 2004: Annex 16) based on what they had demonstrated. This ‘Matrix’ can be considered as a standardised summary description of available methods for the HMI assessment of ADAS/IVIS which should provide assistance for decisions on appropriate procedures. During the final part of the workshop the discussion focused on the future of this tool which will be described in some more detail in the next section.

Methodologies for ITS Safety

One of the tasks defined in the framework of HUMANIST was the development of a matrix approach to indicate the main aspects of applicability of various methods for HMI assessment. As a first step, the ‘Matrix’ focused on methods applicable for the assessment of the HMI of IVIS (Gelau and Bygrave 2004) but has in a
later stage been updated to include ADAS (Cotter et al. 2008). The matrix can be considered as one main element of the so-called ‘Integrated Methodology’. This has been defined as a ‘structured human factors evaluation (of a system or function) that combines evidence from multiple assessments of different aspects of driver-vehicle interaction within a conceptual framework’ (Cotter et al. 2008) and covers a wide range of IVIS/ADAS aspects such as embedded functions, information functions, warning functions, and assistance functions with their different evaluation criteria (technical performance, distraction, understandability, controllability).

As is shown in Figure 5.1 the HUMANIST Integrated Methodology can be considered as a process. It directly refers to the Suitability Standard (ISO 17287) which can be considered as a conceptual framework. Moreover it considers results from European projects RESPONSE III and ADVISORS (see Cotter et al. 2008). However, as can also be concluded from Figure 5.1, the development of this process model has not yet been completely finalised. But as future research will help change the yellow and red boxes to green, it may be expected to provide fruitful input for revisions of the Suitability Standard (ISO 17287) which might become necessary due to the ISO rules.
An Occlusion Experiment

Inspired by work done by ISO/TC 22/SC 13/WG 8 an occlusion project was performed (Horberry et al. 2007) which aimed at supporting a recently published International Standard (ISO 16673). This standard defines the experimental protocol for the occlusion method to assess visual demand due to the use of in-vehicle systems. The occlusion technique is based on the systematic control of the time intervals available for a test subject to look at a scene during the performance of the in-vehicle task (such as entering a destination into a navigation system) to be assessed. The time period during which the relevant piece of information is visible (shutter open time) and the time period during which it is not visible (shutter closed) are the two essential parameters which are technically realised by means of a shutter device, usually the so-called occlusion goggles. Used in this way the occlusion technique simulates the visual demands imposed by the primary driving task on the in-vehicle task. The major aim is then to measure performance on a task while being interrupted in a manner similar to normal driving conditions (see Gelau and Krems 2004 and Chapter 7 of this volume for further explanation).

ISO 16673 does not define the age ranges of subjects participating in an occlusion test but only recommends that 20 per cent of the sample should be 50 years of age or older. However, as the extent of inter-individual variability in performance can be expected to be positively correlated with participants’ age, there were concerns that insufficient control of this variable might lead to inconsistent results and conclusions from different occlusion tests. Thus, it was the primary goal of this project to propose an age range needed for the protocol in order to minimise variability, and thereby also the number of subjects needed in order to establish statistically significant effects.

Empirically an occlusion experiment was performed with 60 subjects (30 males, 30 females) with an overall age range from 17 to 76. Subjects had to perform four different in-vehicle tasks under occluded and non-occluded conditions. The in-vehicle tasks were selected in such a way as to vary with regard to Total Shutter Open Time (TSOT), and the resumption ratio $R$, which is an indicator for the ease with which an interaction can be continued after an interruption (see ISO 16673 for further explanation).

The results showed some differences between the age categories for the two occlusion performance measures TSOT and $R$ for all four IVIS tasks. In particular the older participants showed a greater spread of scores (especially for TSOT). Overall, these results imply that to obtain minimal inter-subject variability an experiment should ideally use younger/middle aged participants. Gender imbalance may be maintained for other reasons (e.g., to reflect a population, such as truck drivers).

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5 The value of the variable TSOT describes total time for which the scene is visible or the sum of all intervals for which the shutter device is open during a run of an occlusion experiment. (cf. Gelau and Krems 2004).
Nomadic Devices (ND) – Use while Driving and Impact on Driving Behaviour

Nomadic Devices (ND) such as mobile telephones and personal digital assistants (PDA) provide users with information access and communication tools. As well as being used at home, in the office or on the train, these systems can be accessed whilst operating vehicles. Many ND are now providing users with applications that offer assistance while driving, such as traffic information and navigation instructions. Although many of these systems have the potential to provide drivers with useful information, there are concerns relating to driver distraction, workload and visual demand imposed, the safety of their installation, and ergonomic factors relating to ease of use and display legibility (e.g., Stevens et al. 2005).

The ESoP (and ESoP II) clearly covers all types of IVIS used in the vehicle, including ND. But while ESoP at least has been officially acknowledged by well identified stakeholders responsible for ensuring the quality of HMI design for OEM devices (ACEA) (cf. paragraph 2) there exists no comparable statement about the compliance with either ESoP or ESoP II by the stakeholders concerned with ND. These groups may be less aware of road safety issues, and may not be organised into easily identified networks.

Nevertheless, there exists actually only little research on the typical patterns of use of ND while driving, and their specific impacts on driver workload and behaviour. Moreover, there exists no comprehensive overview and classification of systems available on the market (cf. Bayly et al. 2009). Research by TRL (see Gelau and Bygrave 2004) demonstrated that checklists and the occlusion technique can be used for the HMI assessment of ND. However, it is doubtful if this list is already complete and covers all Human Factors aspects that are critical with respect to the use of ND while driving.

Thus, the project reviewed in this paragraph (Baumann et al. 2007) aimed to provide a contribution to answering the questions about typical patterns of use of ND while driving, and about the validity of the occlusion technique as a procedure for an HMI assessment of IVIS.

As a first step a classification of available ND was performed. The aim of this analysis was to generate a set of categories of ND. This set of categories should provide the possibility to reduce the tremendous number of existing different devices to a small set of device categories. The devices in each category should share a substantial amount of critical features and they should differ substantially in these features from devices of other categories.

The features identified were then divided into three basic groups: a) features relating to technical aspects of the ND, such as storage capacity, processor performance, supported communication protocols, b) features relating to the functionality of the device, such as personal information management, route
navigation, telephony, music, and c) features relating to the HMI, such as type of input device (e.g., touch screen, keyboard, joystick), size of visual display. Given this set of features six categories of ND were defined ranging from simple mobile phones to personal digital assistants and so called smart-phones or PDA phones, personal navigation assistants, and multimedia devices.

During the next stage different methods for assessing in-vehicle tasks were evaluated in terms of their validity. For this purpose a driving simulator study was performed (Baumann et al. 2007). Twenty participants performed six tasks, four of them involving ND, under three different conditions: alone (baseline), under occlusion conditions where the view of the display of the device was repeatedly occluded (occlusion), and while driving in a driving simulator. Several driving performance measures were collected and their correlation with the task assessments by means of the occlusion method (occlusion index $R$, see ISO 16673) was examined. The main findings are summarised in Table 5.1. As can be seen there were substantial correlation coefficients between the occlusion index $R$ and indicators of lateral control. These suggest that lateral control suffers from the simultaneous performance of in-vehicle tasks with poor interruptability.

<table>
<thead>
<tr>
<th>Task completion time driving simulator</th>
<th>Event detection</th>
<th>Number of lane departures per trial</th>
<th>SDLP</th>
<th>SDS</th>
<th>Speed difference</th>
<th>Mean speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio $R$</td>
<td>0.77</td>
<td>–0.54</td>
<td>0.88†</td>
<td>0.94††</td>
<td>0.77</td>
<td>–0.26</td>
</tr>
</tbody>
</table>

Stat. Sign. (p value) 0.07 0.27 0.02 0.01 0.07 0.62 0.33

† Statistically significant at the 5% level
‡ Statistically significant at the 1% level

The last step of this project consisted in performing a survey of 95 drivers on the use of ND while driving. More precisely, the objective was to gather pilot information on typical patterns of use of ND while driving, such as what kind of devices are used while driving, how often are they used, in which situations are they used. Furthermore, the relation was examined of these patterns of use to certain personality factors, attitudes, and driving skills to gather information about the characteristics of drivers that use ND while driving (Baumann et al. 2007).
Some of the main findings are summarised in Figure 5.2 and Table 5.2. Nearly all participants in the survey (98 per cent) were users of cellular phones. About one third of the participants were users of portable navigation systems or portable MP3-/CD-/DVD-players (28 per cent and 36 per cent respectively), whereas the proportion of users of PDA-Phones or PDAs was comparatively small (7 per cent and 13 per cent respectively). Of course, more interesting than the proportion of users in this small sample was the frequency of use of the ND in the context of driving. Results concerning this issue are summarised in Table 5.2 which presents participants’ mean number of trips by car per week, and the frequency of system use outside the car, in the non-moving vehicle, and while the vehicle is in motion. Here the most striking result seems to be the frequency of use of the PDA-phone while driving (AM=13.0) which is nearly five times higher than the use of a conventional PDA (AM=2.29) or a portable navigation system (AM=2.74).

![Figure 5.2](image)

Relative frequency of subjects who declared to use NDs while driving (N = 90)

<table>
<thead>
<tr>
<th>Portable device</th>
<th>Number of owners</th>
<th>Weekly trips</th>
<th>Out of town</th>
<th>In standing vehicle</th>
<th>While driving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile phone</td>
<td>90</td>
<td>15.19</td>
<td>9.83</td>
<td>55.97</td>
<td>10.77</td>
</tr>
<tr>
<td>Portable MP3-/CD-/DVD-Player</td>
<td>57</td>
<td>14.68</td>
<td>9.61</td>
<td>30.63</td>
<td>14.03</td>
</tr>
<tr>
<td>Portable Navigation system</td>
<td>23</td>
<td>18.39</td>
<td>11.51</td>
<td>1.39</td>
<td>4.10</td>
</tr>
<tr>
<td>PDA</td>
<td>14</td>
<td>18.21</td>
<td>7.14</td>
<td>18.79</td>
<td>5.79</td>
</tr>
<tr>
<td>PDA-phone</td>
<td>7</td>
<td>19.57</td>
<td>11.72</td>
<td>192.00</td>
<td>21.86</td>
</tr>
</tbody>
</table>
One should keep in mind that the proportion of users of a PDA-phone is rather small within the subject sample under investigation (n = 7). However, even when taking into account the small and not representative sample, these results together with the fairly large standard deviations (see Table 5.2) at least suggest the hypothesis of considerable inter-individual differences in ND use patterns that deserve to be further investigated.

Summary and Conclusions

The present chapter argued that HMI-Guidelines and Standards are defined in order to support the development of safe and usable products. To reach this aim, experts concerned with HMI-Guidelines and Standards depend on a scientifically well founded state-of-the-art in order to formulate requirements and recommendations. Right from the beginning the NoE HUMANIST was very clear with respect to contributions to the development of HMI-Guidelines and Standards. Some of the main ‘products’, e.g., ‘The Matrix’, which can be considered tools for practitioners for reaching decisions on appropriate methods for the HMI assessment of IVIS, have been summarised and discussed in this chapter.

On the one hand the results achieved (e.g., Cotter et al. 2008, Horberry et al. 2007) can be considered as an input for the future development of existing Standards within the framework of ISO/TC 22/SC 13/WG 8. More specifically, the occlusion experiment reported here (see paragraph 4.3) points to the impact of individual differences (age) on the results of occlusion tests, and provides some advice on how to select subject samples in order to avoid bias. As international standards are subject to periodical revisions these results might be of use for future updates of the Occlusion Standard (ISO 16673). The HUMANIST ‘Integrated Methodology’ directly refers to the Suitability Standard (ISO 17287), and may be considered when revisions of this document are required in the future.

On the other hand, research performed under the umbrella of the NoE HUMANIST provided interesting insights into the patterns of use of ND while driving which, of course, still need to be substantiated and extended by future research. Despite their pilot character the results stress the need to further investigate the influences of individual differences on use patterns of ND, and thereby their impacts on driving safety. At least the findings presented here suggest that there may be specific groups of users who use ND in a way which gives grounds for special concern regarding its compatibility with the primary task of driving.
References


Chapter 6
Evaluating Impact on Drivers
and Drivers’ Tasks
Ioanna Spyropoulou

Introduction

Intelligent Driver Support Systems (IDSS) are designed to improve road safety, driving comfort, traffic and environmental conditions, and user integration into traffic systems. Evaluating whether the systems achieve their objective is of crucial importance, hence the value and necessity of the development of evaluation methodologies. System evaluation takes place throughout the design phase to detect or remedy possible inherent technological weaknesses of the system. This type of evaluation is of a rather technical nature, and is therefore not dealt with in this chapter. Following system optimisation, evaluation concerns the interaction between the driver and the system. In particular, it is about assessing how the driver behaves while using the system, in order to identify the opportunities and threats related to road safety that may result from use of the system, as well as usability issues, acceptability issues, driver comfort, etc. Based on evaluation the aim is to develop the system further or to design other mechanisms external to the system, such as driver training, motivation for system use, etc., in order to highlight and exploit its opportunities and reduce the effect of its drawbacks. The present chapter discusses system evaluation aiming at identifying the interaction between system use and road safety. At a following level, system use evaluation may also concern the impact that the system has on driver habits (other than those involving the actual driving tasks) as well as the impact the system has on non-users, and hence on traffic flow. In broad terms, evaluation procedures involve determining the following elements (not necessarily in this order):

- Evaluation method;
- Tools and equipment;
- Measures of performance (whether driving behaviour, conditions, attitudes, etc);
- Experimental design;
- Data analysis;
- Result interpretation.
This chapter aims at describing the evaluation procedure for assessing interaction between the system user and the system through the impact of system use on drivers-users (and other road users) and drivers’ tasks, and consequently on road safety, in particular determining the important elements that need to be considered before choosing the appropriate evaluation method, and developing the experimental procedure. The different types of evaluation methods are described, and the stages comprising the design of these methods as well as significant parameters that determine crucial evaluation elements. A detailed description of several evaluation methods and tools is provided in Chapters 7 and 8.

**System Characteristics**

The choice and specification of the procedure used for system evaluation depend mainly on the objective of the experiment, as well as on a number of determining elements. Two such elements are the IDSS investigated and the Human Machine Interface (HMI).

Different types of systems produce different effects, and hence certain evaluation methods, tools and measures of performance are more suitable than others. For example, an in-vehicle navigation system providing visual information on adverse pavement conditions downstream on the driver’s route may result in reducing speed or changing the predefined route to avoid the particular road segment. The visual information that is transmitted may increase workload and reduce driver attention. On the other hand, a dynamic intervening ISA (Intelligent Speed Adaptation) system that automatically reduces driving speed because of the adverse and risky conditions downstream might result in driver irritation or in reduced alertness as the driver might come to rely more on the system. So, even for the same situation of ‘adverse pavement conditions downstream’, different systems may result in completely different effects, requiring different evaluation methods, tools and measures to be identified.

Human machine interface is also crucial in determining the evaluation procedure. Human machine interface may involve (as described in Chapter 2):

- Provision of information (visual or auditory);
- Warning transmission (visual, auditory or haptic);
- System intervention.

Hence, even for one system, e.g., ISA, different HMI will also induce different types of effects, which are particular to the HMI, and that need to be investigated using different methodologies. In particular, the informative ISA may increase the workload, the warning ISA may increase driver frustration, and might lead to the driver switching the system off, and the intervening ISA may result in reduced driver alertness as the driver may rely more on the system to modify driving speed according to the prevailing speed limits.
Types of System Impact

Before evaluation design, it is essential to decide what type of impact a system may invoke. Figure 6.1 illustrates the different types of impact that should be taken into account when evaluating an IDSS.

A more detailed description of Figure 6.1 follows, and system effects are illustrated with the appropriate examples. Any IDSS designed has a specific objective, targeting a specific element of the driver task. The first type of system effect involves the direct modification of the specific driving task and/or element of driver behaviour by the system or by the driver. The driving task or element of driving behaviour can involve the operational, tactical or strategic level of driving (Michon 1985, van der Molen and Botticher 1987).

A parenthesis to provide a quick description of the aforementioned terms is important. Functions at the strategic level include trip planning, route finding and route selection. Decision-making on the tactical level includes interaction with other road users and the driving environment (gap acceptance, speed choice, yielding to other road users at intersections); this function is based on perceptions, estimation of distances and speeds, and anticipation of traffic situations in very short time frames. The operational level includes vehicle control such as lane keeping, steering and braking. While strategic decisions are considered as predominantly appraisals on a conscious level, behaviour on tactical and operational levels is predominantly automated. IDSS targeting the improvement of road safety mainly concerns the modification of elements of driving at the operational and tactical levels, and also, but less frequently, at the strategic level.

![Figure 6.1 Driver related elements determining the potential impact of intelligent transport systems on road safety](source: Spyropoulou et al., 2008)
For example, speed limiting devices aim to reduce speeding, reducing driving speed by the driver using ISA systems offering an informative and warning function, or by the system when an intervening function involves direct modification of driver behaviour. Other examples of direct modification of driving behaviour towards the IDSS objectives involve reduced reaction time upon incident occurrence when using collision avoidance systems, speed reduction when using advanced traveller information systems (ATIS) that inform the driver of lane closure downstream, or change of route when using ATIS that inform the driver of adverse pavement conditions downstream, and so on.

The second type of system use impact concerns indirect effects, involving modification of driving behaviour in often unpredicted and to a large extent unknown ways. This can be divided into two types of impact: one involving impact as a result of system operation, and the second resulting from drivers’ urge to compensate for direct driver behaviour modification. For example, reduction of speed variability with the use of ISA, or workload increase by the use of the informative functionality of ISA, comprise (unwanted) indirect effects of systems use. In respect to the second type of indirect impact, it is anticipated that drivers will always adapt to a changing situation – also when the changing situation is a result of direct modification of driver behaviour. Drivers usually accept a certain degree of perceived risk when driving, when the perceived risk is reduced drivers usually compensate by adopting more aggressive/risky driving behaviour. This so-called behavioural adaptation due to risk compensation or due to driver over-reliance on the system will often not appear immediately with the introduction of the system, but may appear following long-term use, and is rather hard to predict. Such examples involve employing smaller headways when using collision avoidance systems as drivers anticipate that the system will alert them when a potential conflict is detected, or adopting higher speeds downstream of low speed limit zones when using ISA systems to compensate for low speeds within the low speed limit area.

The increase of safety in driving with system use can also result in a modification of driving exposure in specific situations. For example, a positive effect involves the use of alco-lock devices that reduce driving under the influence (DUI). On the other hand, a negative effect involves the use of vision enhancement systems which may result in more drivers driving during low light conditions, such as during the night or in fog.

Specific systems may not involve a modification of driving behaviour, as they operate during (crash systems) or following an accident (post-crash systems). These systems, however, modify road safety by modifying accident severity.

The aforementioned effects concern system users. However, it is anticipated that modification of drivers’ behaviour may also result in a modification of driver interaction, and hence a modification of behaviour of non-users. This element of system use impact is rather complex to identify. As an example of user–non-user interaction consider the following: a driver is using a collision warning system that transmits a warning, and the driver reacts in a panic. This leads to an inappropriate
response, such as hard braking which is uncalled for and hence not anticipated by a following vehicle, which could result in an accident.

Before deciding on the appropriate evaluation methodology and tools, one has to determine what type of impact system use is anticipated to elicit. On this basis different parameters and different evaluation methodology characteristics should be selected.

**Experimental Design**

An important element of the evaluation procedure is the evaluation method used. The experimental design is then developed on the basis of the method and needs of the study chosen. The most accurate method to assess IDSS impact on road safety would be to distribute the system, allow for its use and driver behaviour adjustment, and then to measure its effects through road safety indicators such as the numbers and types of accidents, risk rates and severity rates for users and non-users. However, this is an unrealistic scenario as system assessment is a prerequisite for market distribution. Several proxy methods have therefore been developed for the ex-ante evaluation of system use. This is accomplished through the determination of a number of appropriate measures/parameters mainly eliciting driver behaviour and attitudes that are — at the same time — parameters affecting road safety. Hence, driver behaviour under system use is identified, and thereby the impact on road safety is estimated.

Evaluation methods can be classified in the following broad categories: questionnaires and guided discussions, laboratory experiments, driving simulator experiments, instrumented vehicle experiments, and simulation. Different methods usually involve different types of measures/parameters and whereas some are more suitable for particular systems (e.g., speed in relation to the prevailing speed limit), most apply to specific aspects of any system operation (e.g., speed, vehicle position in the lane). In addition, certain methods are applied in the same study; e.g., an experiment may involve measuring driving behaviour within the framework of a driving simulator experiment, and system usability (i.e., how easily can a driver use the system in the intended manner, its use complexity, etc.) using a questionnaire following the drive.

**Questionnaires and Guided Discussions**

Questionnaires and guided discussions usually aim at obtaining measurements of perceived attitudes and behaviour, and therefore the assessment results are subjective. Certain questionnaire methods can be used on their own, whereas others can only be performed within a laboratory or in a driving simulator experiment, and so on. Questions eliciting participant opinions related to system use and operation, and their effect on driver behaviour are the most commonly used ones. Questionnaires may involve questions on system usefulness, satisfaction,
effectiveness, social acceptability, affordability, usability and reliability (examples may be found in: Comte 2000, Molin and Brookhuis 2007, Young et al. 2007). Participants are asked to rate the systems in respect to the different aspects, and the questions used are simple and straightforward. A few examples are: ‘Do you consider the system to be pleasant?’, ‘How useful do you consider the system to be?’, ‘Would you consider buying the system?’, rate the following ‘irritation’, ‘stress’, ‘safety’.

Perceived driving performance/behaviour can also be elicited by such methods. Examples of such questions/topics are: ‘Would you reduce your driving speed with the use of ISA?’, ‘Would you consider driving more in the dark when using vision enhancement systems?’, etc. In general, questionnaires/discussions eliciting driver acceptance of the system are quite common, and apply to any type of IDSS. Specific types of standardised questionnaires also allow the measuring of specific subjective parameters. An example are questionnaires measuring driver workload based on the NASA-TLX or the NASA-RTLX (Raw Task Load Index) (Byers et al. 1989) methods which ask participants to rate mental demand, physical demand, time pressure, performance, effort, and frustration in using the system, and measure driver workload. Other questionnaires may measure situation awareness (i.e., the degree of knowing what is going on) (Endsley 1989, Hughes et al. 1990) and effort when using the system (Zijlstra 1993) or are based on fault tree analysis (failure analysis in which an undesired state of a system or event is analysed through a series of lower-level events that could cause that effect, and which is added to the tree as a series of logic expressions) or early risk assessment (Kirwan 1994). The main elements in conducting a questionnaire/discussion method are:

- Design of the questionnaire/discussion;
- Determination of the sample;
- Determination of the performed analysis.

Questionnaire/discussion methods involve designing the different questions/topics of the discussion, and the scales used, and depend greatly on the investigated system and the study objective. In questionnaire studies, the questionnaire should be comprehensive, and it should not be time-consuming or tiring. Determination of the sample involves sample size, which should be adequate for the analysis, and sample characteristics such as participant demographic characteristics or other particulars relevant to the aim of the study (e.g., driving experience, familiarisation with gadgets, or drink and drive offenders for the use of alco-lock devices). In respect to the analysis, in questionnaire methods participant answers are processed through simple or more complex statistical methods.

Laboratory Methods

Laboratory methods may be used in combination with other types of methods, involving driving experiments and require method specialised equipment. By these
method specific effects of the system on the driver’s mental or psychological condition are investigated. The most common methods are psychophysiological methods to measure driver stress, attention or workload, or other factors related to the driver’s attention and workload. Methods of the latter type include the occlusion technique and the peripheral detection task, and are discussed in Chapter 7. Psychophysiological methods measure parameters related to heart rate, eye movement, brain or muscle activity, and are discussed in Chapter 8.

Driving Simulators and Instrumented Vehicles

Methods involving driving simulators and instrumented vehicles, whether performed on test tracks or under real traffic conditions (often referred to as naturalistic studies) have several similarities and certain differences. Examples of such studies can be found in: Ward et al. 1995, Srinivasan 1996, Varhelyi and Makinen 2001, Boyle and Manering 2004, Dingus et al. 2006, Ference 2006, Spyropoulou 2008. With these methods driving behaviour aspects are monitored. The main elements in designing such experiments are:

- Set-up of the equipment;
- Driving scenario design;
- Sample determination;
- Recorded parameters determination;
- Analysis methods determination.

Following the above the experiment is performed and data is collected and analysed. Setting up the equipment involves setting up the simulator, and the instrumented vehicle, according to the needs of the study, and also involves setting up the operation of the investigated system, including its human machine interface. Other elements are setting up the recording equipment, which follows determination of the parameters to be recorded, and setting up the driving environment (in the driving simulator), which follows the driving scenario design.

Driving scenario design involves the driving environment and prevailing conditions, and is more complicated in the driving simulator experiment in comparison to the instrumented vehicle experiment. In the latter several restrictions apply due to the limitation of modifying the conditions on the test-track, and of controlling them in naturalistic studies. In such studies a familiarisation period to allow the driver to familiarise him/herself with the vehicle, the system operation (and system existence, especially in the case of naturalistic studies), and the driving environment is required. The duration of the familiarisation period usually decreases with the reduction of the realism factor (representation of reality) of the method; i.e., the familiarisation period will be longer for naturalistic driving studies, and shorter for driving simulator studies. Driving scenario elements also include duration of the drive (in respect to time or distance driven), type of road (urban, rural, interurban, motorway, speed limits, etc.), types of areas (residential,
school area, etc.), road geometrical characteristics (directions, number of lanes, road gradient, lane width, radius, etc.), traffic conditions (type of vehicles, traffic flow, traffic density, slow moving vehicles ahead, pedestrians crossing the road), weather conditions (fog, rain), route choice scenarios, and incident occurrence (accident occurrence, hard braking of the preceding vehicle, lane closure, etc.). Driving scenario design is a quite complicated procedure, and is of a crucial nature, as its main purpose is to elicit driver behaviour under specific circumstances, which need to be reproduced with great accuracy.

Sample determination, as in questionnaire studies, is decided with regard to the exact aim of the experiment, and involves sample size and sample characteristics. In driving simulator experiments it is preferable to have participants who have driven the simulator successfully in prior experiments, as it is quite common to come across simulator sickness effects, which could lead to a reduction of the sample size.

Parameter determination involves the exact parameters to be recorded in the experiment. Several of these parameters are always recorded, especially in driving simulator experiments, as standard recording equipment is part of the simulator. Defining the parameters to be recorded depends on the system investigated, and the objective of the experiment. The parameters recorded in such studies will mainly be related to driving behaviour parameters. The most important and commonly investigated parameters are speed behaviour (mean/maximum speed, acceleration or deceleration, speed deviation, 85th percentile of speed, extent/duration of speeding, etc.), longitudinal behaviour (driver headways, overtaking manoeuvres), lateral behaviour (mean lane position, lateral deviation, lane changes), brake/accelerator/steering behaviour, driver reaction time, time-to-collision, etc.

Methods of analysis mainly involve simple or more complicated statistical analysis of the recorded data. This involves estimation of parameter measures (mean, maximum or minimum values, parameter value deviation, etc.) clustering of parameter categories, investigation of the effect of other parameters on driver behaviour parameters, e.g., ‘does driver age influence speeding when using ISA?’, investigation of the significance of the parameter values, e.g., ‘does use of ISA actually influence speeding’, design of behavioural patterns, etc.

Simulation

Simulation (representation of vehicle movement through appropriate mathematical formulae) – usually either of driver behaviour or traffic flow models – is a way to evaluate system use, and assess its impact on a larger scale. The aforementioned methods provide results that involve individuals, and not the whole traffic system. These results can be attributed roughly to the whole system under several assumptions. Simulation, however, mainly produces results that involve the whole system. For example, in simulation one can design scenarios that involve a large road network (a city), a great number of system users and/or non-users (system penetration rates) with similar or different characteristics, a great
number of scenarios (type of area, type of roads, type of traffic/weather/pavement conditions, etc.), and a long simulation period duration. Simulation models can be classified as microscopic, macroscopic, and mesoscopic, depending on the ‘size’ of the investigated elements. The first involve individuals (drivers or vehicles), the second, flow (with individual elements characteristics not considered), and mesoscopic models form an in-between type of model. The results are usually of a more macroscopic nature than the other evaluation methods produce, even in the case of microscopic models, and especially when using traffic flow rather than driver behaviour models.

A prerequisite for the efficiency of this evaluation method is the performance of other methods (questionnaire, laboratory, driving simulator or instrumented vehicle) prior to it. The validity of the results depends to a large extent on the accuracy of detail in the simulation of system use and impact. There are cases where only system operation is incorporated in the simulation (Liu and Tate 2004); in which cases the effects of the system use on driver behaviour are not considered. However, the results can still provide a rough indication of what to expect in certain scenarios, and under certain conditions.

Simulation methods involve the definition of the appropriate simulation model as well as of the input parameter values. These – depending on the simulation model – mainly involve general simulation parameters (e.g., duration of the simulation), network parameters that describe the road environment (providing the exact network characteristics, including number/position of nodes and links, node and link characteristics such as type of traffic control, traffic signal characteristics, maximum amount of flow, speed limit), driver behaviour characteristics (parameters related to driver perception, speed, acceleration, deceleration, spacing), traffic flow parameters (proportion of different vehicle types, amount of flow, vehicle arrivals), etc.

Simulation results are provided as the output of simulation models, and involve specific parameters that are dependent on the simulation model/software chosen. Examples include traffic flow, mean travel speed, mean travel time, average rate of delay, queue length, headways, time-to-collision, and also environmental, energy, noise or cost indicators, etc.

Discussion

System evaluation forms a crucial element of system development, and the successful introduction of the system on the market will to a large extent depend on it. System evaluation is a rather complex procedure, developed following the determination of several parameters. This chapter aimed at providing some insight into the elements determining the evaluation procedure, and the different parameters that need to be considered in system evaluation. Predominant parameters of system evaluation that were discussed are the type of system examined, in terms of the operation and the ‘assistance’ it provides, the type of human machine interface,
and the type of impact that is to be investigated, the available methods and tools. In addition, there are further parameters that need to be considered, such as time or budget constraints, and, e.g., the population the system targets.

References


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Chapter 7
Tools and Procedures for Measuring Safety-relevant Criteria
Josef Krems and Tibor Petzoldt

Introduction

On-board Traffic Information and Control Systems (TICS) or In-vehicle Information Systems (IVIS) for drivers are becoming more and more common these days. While driving, these systems provide information about the status of the vehicle, the optimal route, traffic jams, etc. Despite the usefulness of such systems, one could be concerned about the potential distraction, and the additional cognitive load these systems impose on the driver, leading to an increased risk of accidents. Proper design of the Human Machine Interface (HMI) is unequivocally a key factor in balancing the demands for an increased functionality with the already existing physical and mental load of the driver. In terms of HMI safety design, this key function is also acknowledged by standardization activities (e.g., ISO/TC 22/SC 13/WG 8) and official statements such as the EC-Recommendation ‘European Statement of Principles on Human Machine Interface for In-Vehicle Information and Communication Systems’.

Therefore, obviously, methods for assessing the HMI of in-vehicle information systems for safety are urgently needed. One possibility is to investigate new systems on-board while driving in real traffic or in a driving simulator. However, this approach is very demanding and expensive. So, looking for easy-to-use methods applicable in the very early stages of system development would be worthwhile. Several procedures, like the occlusion technique or the peripheral detection task, have recently come under consideration as candidate tools for assessment. The major goal of this chapter is to give an overview of methods available, and to discuss the validity and usability of several techniques for HMI assessment of in-vehicle information systems.

In this chapter, the typical dual-task situation for drivers using TICS while driving will be characterized from a psychological point of view. Distraction and workload are relevant issues. An overview will be given of evaluation tools, and methods available. They will be classified as performance measures and subjective measures (physiological measures are described in detail in the following chapter). For each category the most important candidates will be described in detail. All procedures will be assessed for positive and negative aspects to allow for easier comparison.
The Multi-tasking of Driving

Driving is a complex activity requiring all the functions of the cognitive systems: relevant objects and details of the current situation have to be perceived and understood; decisions have to be made based on previous experience, and actions like braking or steering have to be taken. Many of these activities have to be done in parallel, putting load on the cognitive systems. Current theories assume that resources are limited, and that distributing them between several subtasks leads to constraints.

Over the last decade new technology entered the car. Systems that support navigation, deliver additional information about the traffic situation, and provide a lot of additional services, like access to internet or email, are available in many cars today. On the one hand these systems facilitate the driving task (e.g., navigation); on the other hand they have to be operated, and therefore must be considered as an additional task on top of all the others. Entering a destination into a navigation system, reading traffic messages displayed on a screen or following the instructions of a route-guidance system might increase workload, and distract the driver. So operating new systems might interfere with the driving task, and safety related questions arise. Obviously a cost-benefit problem comes up: does the benefit new systems offer outweigh the disadvantage?

An answer to this question has to be grounded on empirical evidence. It has to be shown per system how it contributes to the workload balance of the driver, and to what degree it might increase distraction. The following pages will provide a quick overview of how to do this.

Evaluation Methods

To measure the distraction or workload caused by additional secondary tasks executed while driving, different procedures can be applied. Major categories are performance measures, physiological measures, and subjective measures. Physiological measures will be described in Chapter 8.

This chapter will focus on lab-based methods, simulator studies, field studies and subjective methods. They differ in their degree of validity and reliability, as well as in resources required for their application.

Performance Measures

One of the easiest ways to think of the impact that workload has on the driver is to think of the driver’s performance as a reflection of task demand. This performance can be the performance in the driving task, the performance in another additional task, or even the performance in the systems task itself.

Considering driving as the primary task, it appears to be obvious that workload excess might be measured as the performance in this primary task. One example for
primary-task measures of workload during driving is the number of (unintended) lane crossings that occur. Obviously, levels of workload that do not impair driving in this regard cannot be differentiated by primary-task measures of driving. It is rather simple to come up with systems that differ radically in the workload they cause, but do not cause drivers to exceed their lane once. So, this measurement would be inaccurate at quantifying the workload these systems actually produce. Secondary-task measures of spare capacity are perfectly capable of tackling this problem. If the driver is instructed to allocate enough resources to the primary task (in this case the systems task) to keep primary-task performance at the required level, then the secondary task is a ‘subsidiary task’ and secondary-task performance reflects changes in primary-task resource demand. If the secondary task is well suited to the primary task, secondary-task performance is assumed to be inversely proportional to primary-task performance. But the systems task itself can also deliver valuable information. How long does it take, how many steps are necessary to complete the task, how many errors do occur when entering necessary data – all these are questions that directly relate to the amount of workload a certain system might cause as well.

There are three major types of performance measures that differ in validity:

- Lab-based procedures
- Simulator studies
- Field studies

**Lab-based procedures – occlusion method** The occlusion method is a tool that is mainly intended to assess the visual demand of a certain task. It was first described by Senders et al. (1967), and has now become an ISO-standardized procedure (ISO 16673 2007). The basic idea of the method is to obstruct a participant’s sight temporarily, while he or she is engaged in a more or less visually demanding task. In its earliest incarnation, the method was used to assess the visual demand of driving, which implied occluding the participant’s view of the street (for an impressive example see http://www.youtube.com/watch?v=kOguslSPpqo). Today, occlusion is used to represent the visual demand of driving itself, whereas the task that is to be interrupted by occlusion intervals is a TICS-task (e.g., tuning the radio). The standard approach is to use some sort of visor (e.g., occlusion goggles, see Figure 7.1), with fixed or self-paced occlusion intervals. Phases where vision is obstructed represent the time one would be looking outside the car, whereas phases of unobstructed vision are supposed to be used for looking at the TICS in question. By employing this method, it should be possible to determine (a) whether a task can be carried out with only few and short glances applied to it, or if more and longer glances are necessary, and (b) whether a task is interruptable so that it can easily be resumed after an occlusion interval, or if the short obstruction of vision makes it difficult to continue.
The most important performance metric is the index $R$ (also called chunkability index), which is calculated by relating the total task time without occlusion to the total shutter-open time for the occluded condition (Noy et al. 2004). In recent years, various projects have evaluated the validity of the method (Baumann et al. 2003, 2004, Van der Horst 2004, Gelau et al. 1999, Keinath et al. 2001, Krems et al. 2000, 2004, Monk, Boehm-Davies and Trafton 2002, Weir, Chang and Brooks 2003). Gelau, Henning and Krems (2009) investigated the method’s reliability. In general, the studies have found that the occlusion method is a valid and reliable procedure for assessing visual demand caused by TICS.

One of the method’s main advantages is its ease of use. For the usual set-up, only the visor and an off-the-shelf computer system is necessary. Also, the computation of the most common metrics is not a demanding exercise. Furthermore, relevant variables can be directly assessed. The accuracy in task processing, and the time to acquire information to do so are available without further processing, making the method even easier to employ. Finally, occlusion allows for the study of numerous aspects of a TICS task. It is possible to evaluate overall visual demand as well as to differentiate between tasks in terms of total task time and interruptability. Since the method is not a task itself, one can also add additional cognitive load by introducing secondary tasks, and use the method to evaluate the respective effects.

However, there are some negative aspects to be considered too. First of all, the estimation of effect sizes is quite difficult. A relatively high number of participants is necessary to do so. Also, the method does not include any instance of switching between tasks or dividing attention between different sources of information, which is rather artificial, and does not correspond to what is going on in real traffic. Another problem might occur with tasks that can be broken into shorter subtasks. If those subtasks require very little time, allowing for carrying out more

Figure 7.1 Occlusion goggles
than one subtask in one interval, it is possible to overestimate the distractiveness of the task as a whole. The use of predefined occlusion intervals can introduce some additional cost for the resumption of the task that does not occur in real traffic, as intervals of turning to and turning away from the road may be adjusted corresponding to subtask-time. Finally, the method does become quite annoying. While this at first is only a threat to the participant-experimenter relationship, with increasing time it can also result in a reduced motivation on the participant’s side, and thus might influence performance.

Lab-based procedures – the peripheral detection task The peripheral detection task (PDT) has been used in simulator studies and in driving studies in recent years to assess changes in workload during driving, and to assess workload and distraction caused by in-vehicle systems (Harms and Patten 2003). The task requires simple manual responses to stimuli usually presented to the left of the drivers’ normal line of sight. Stimuli are visible for 1 to 2 seconds, and are presented with intervals of a few seconds, e.g., 3 to 5s or 3 to 6s. Van Winsum, Martens and Herland (1999) developed the task, mainly based on studies of Miura (1986) and Williams (1985, 1995). Miura (1986) found that response times to spots of light that were presented at different horizontal eccentricities on the windscreen during driving increased with traffic density, and thus reflected demands of the driving task. Williams (1985, 1995) showed that the accuracy of responses to stimuli presented peripherally decreased with increasing foveal load.

Figure 7.2 Head-mounted PDT – stimuli are presented on the inside of the black apparatus on the left side of the head, with varying position (picture courtesy of TNO)
The sensitivity of the PDT to changes in demands of the driving task was shown in several simulator and driving studies. For example, Martens and van Winsum (2000) used the PDT in a simulator study, and demonstrated that response times increased, and hit rates decreased when task demands increased. Large effects were observed for critical incidents such as a braking lead vehicle or an obstacle on the road. Similar evidence of PDT sensitivity was obtained in a simulator study on collision warning systems (Burns, Knabe and Tevell 2000). In a third simulator study, Nakayama et al. (1999) found that response times in the detection task were sensitive to differences in task demand, and correlated with a steering entropy measure.

The PDT has also been applied in real traffic studies. Olsson and Burns (2000) used LED projections on the windscreen in an area of 11 to 23 degrees left of the drivers’ normal line of vision, and 2 to 4 degrees above the horizon. Response times and hit rates in the PDT were impaired relative to baseline driving when additional tasks were performed. In 30s intervals surrounding the tasks, PDT performance suffered from radio tuning, and even more from changing CDs, and backward counting as an experimental cognitive task.

The same PDT task with identical parameters was used in a driving study at VTI (Harms and Patten 2003). Professional drivers (mostly taxi drivers) completed two trips through the outskirts and centre of Linköping, one from memory, and one guided by a route guidance system. The guided trips were visually guided, verbally guided or fully guided (visually and verbally). A decrease in PDT performance was found during guided trips compared to driving from memory, which was more pronounced when intervals around intersections were analysed. Differences between visual and verbal guiding conditions were less clear. But response times suggested that the demand that the PDT is sensitive to was higher before intersections in guiding conditions with visually presented information (visually guided and fully guided) than in the verbally guided conditions (cf., Srinivasan and Jovanis 1997).

A different detection task was used in driving studies by Verwey (1993, 2000). The peripherally presented stimuli were digits that were presented for 750ms. Participants had to respond to the numerical stimuli verbally. The detection performance was sensitive to the demand of different traffic situations (e.g., driving straight ahead, turning right, turning left).

Hit rates and response times in further variants of peripheral detection tasks were also shown to be affected by driving complexity (Lee and Triggs 1976, Miura 1990). Central detection tasks (e.g., Brouwer et al. 1991, Lamble et al. 1999, Lamble, Laakso and Summala 1999, Strayer and Johnston 2001) and auditory detection tasks (e.g., Brown and Poulton 1961, Verwey 2000, Recarte and Nunes 2003) proved to be sensitive to workload during driving too.

To summarize, performance in peripheral detection tasks is sensitive to driving workload and to distraction from the use of an IVIS. It is sensitive to general withdrawal of attention, and to selective withdrawal of attention. For a certain interval of IVIS use while driving, peripheral detection performance reflects the
overall workload from driving and IVIS use. Therefore, effects of IVIS use can be discerned best, if driving demands are constant. Driving demands are easier to control in simulator studies than in driving studies.

Effects of IVIS use on visual detection performance were also demonstrated with IVIS tasks performed in the laboratory without simulated driving. In a recent study, five IVIS tasks and seven other in-vehicle tasks (e.g., searching on a map) were performed concurrently with a variant of the PDT (Baumann et al. 2003). PDT performance reflected relative differences in the visual and cognitive demand of tasks. Performance in the laboratory PDT task also correlated with demand scores for the same tasks that were established using the occlusion technique (e.g., Keinath et al. 2001) and impairment of simulated driving.

Several advantages have been noted in favour of the PDT. Its simple responses are easily performed during most driving scenarios, and the PDT does not consume resources needed for safe driving (Van der Horst and Martens 2009). Therefore, the PDT is unobtrusive with regard to driving, and suitable for field studies. It has a potential of detecting short peaks of workload that may be missed by methods integrating over longer intervals and thus has a favourable bandwidth. It proved sensitive to differences in driving demands, and to effects of in-vehicle systems. The equipment is simple and inexpensive, and data analysis is quick and straightforward. Furthermore, peripheral visual stimuli are related to objects and events that have to be noticed during driving. Hence, some validity is claimed for the PDT (cf., Höger 2001).

**Lab-based procedures – the lane change task** The lane change task (sometimes also lane change test; Mattes 2003) ‘is a dual-task method that is intended to estimate secondary task demand on the driver, resulting from the operation of an in-vehicle device in a laboratory setting. The method is simple and inexpensive so that it can be used by vehicle manufacturers, in-vehicle device manufacturers, and other organisations’ (ISO TC 22/SC 13 WG 8 2008, p. v). It basically uses a simple simulation of a driving scene, in which the amount of distraction is assessed through the lane change performance in response to signs demanding such a change of lanes. Participants have to control a vehicle on a 3-lane road, with no other traffic present, and are commanded to change lanes by, and according to signs appearing on both sides of this road. The task is controlled by a game steering wheel with foot pedals for throttle and brake. Standard performance measures are the mean deviation (MDEV) from a nominal lane change model, or the MDEV from a participant’s own baseline (adaptive model).

As the task is intended to become an ISO sanctioned procedure, recent studies have mainly been conducted to support the standardization process of the LCT. Based on the assumption that visual and cognitive tasks lead to different types of driver errors, Engström and Markkula (2007) propose the introduction of a high pass filtered standard deviation of lateral position (SDLP) and the percentage of correct lane (PCL) choices as new performance metrics. Whereas SDLP is supposed to capture effects on path control, PCL should reflect effects of reduced
sign detection/recognition. Harbluk et al. (2007) argue for lane change initiation (LCI) as a useful measure, as it incorporates the detection and response delay as a result of distraction, aspects that are part of the driving task. They also consider secondary-task time, as it accounts for risk exposure. To test the task’s robustness across different experimental contexts, Rognin et al. (2007) compared LCT performance in the usual desktop set-up to LCT performance in a simulator environment. They conclude that the task is transferable from the PC to a vehicle based set-up. The trends observed were similar, although a general degradation was observed for the PC set-up. Bruyas et al. (2008) report comparable results, explaining the differences between the set-ups with a greater immersion in the driving scene for the simulator condition.

One of the LCTs biggest advantages over occlusion and PDT is the test’s intuitive validity. The operation of this driving-like task with a steering wheel is obviously much closer to real driving. Also, it incorporates aspects of cognitive, visual and manual control, making it sensible to those kinds of workload. However, although some new performance metrics show promising results, these different aspects can hardly be separated. The MDEV value is always a result of the combination of those loading factors. It is nearly impossible to assess directly to what proportion each factor contributes to the score. Therefore, the LCT seems especially suitable when an overall workload assessment is needed.

Simulator studies   Driving simulators (e.g., Figure 7.3) have been used extensively in recent years to study driver distraction. They vary a lot in their capabilities, which influences their realism and validity. Simulators in their simplest form employ a game steering wheel to control a vehicle in an environment that is deprived of many characteristics that account for real world driving, presented on a single screen. High end simulators might be equipped with visual systems that basically surround the driver, a moving base that allows for accelerations in multiple directions, and a realistic cockpit. It has to be noted that when speaking about a simulator, hardware is not the only issue. The software that creates and controls the visual, auditory and haptic environment is important to the same degree. Only the interaction between hard- and software generates the realistic look and feel of a driving simulation.

Driving simulators in general are able to record the same basic performance metrics as data loggers in test vehicles. Acquired measures range from basics such as lane position, speed, steering wheel reversals or the position of pedals to crashes or near crashes, and the recording of TICS use. As the metrics themselves influence the progress of the simulation, and are therefore already part of the system, it is somewhat easier to obtain these measures in comparison to on-the-road testing. However, it is not easy to define whether a specific value in one of the variables can be considered critical. In most cases, the performance while operating TICS is tested against a baseline drive without secondary task or a drive with a task that is considered uncritical (e.g., tuning the radio). Depending on the presence and degree of deterioration in the performance measures while operating the system...
in comparison to the reference condition, the TICS in question is considered safe or unsafe.

Compared to the simple procedures described before, the operation of a driving simulator is a much more complex way of testing for workload, in terms of cost as well as organisations. Even the simplest simulators exceed the price of the LCT-equipment (computer, screen, steering wheel) by a factor 10, with the most expensive systems worth millions of Euros. The operation of the systems is another big challenge, as actual testing is preceded by extensive programming and debugging, and often interrupted by technical issues. Still, simulators offer a quite realistic environment for assessing the impact of TICS on driver performance.

Whereas absolute validity (numerical performance values for various tasks are nearly identical for driving in the simulator and in real traffic) is rarely achieved, research has found that most simulators go with a good relative validity (i.e. driving task variations have similar effects on performance in the simulator and in real driving; Blaauw 1982, Carsten et al. 1997, Godley, Triggs and Fildes 2001, Harms 1992, McLane and Wierwille 1975, Reed and Green 1999). In comparison to on-the-road testing, they also offer a more controllable and safer way of evaluation. Different experimental conditions can easily be set up, with a maximum of comparability between the conditions for each subject. At the same time, it is possible to introduce situations that might be risky in real traffic, without actually endangering the participants. However, this fact is also one of the major problems. As the consequences for the driver’s actions are not the same as in real traffic, one might suspect behavioural adaptations (e.g., spending more time on the TICS-task than in real traffic) that distort the results, and damage the validity of the conclusions drawn. Another problem is the so-called simulator sickness. This form of discomfort is an issue with all forms of simulations (computer games, flight simulation, etc.). It is a result of the mismatch between the observed motion, and the motion detected by the vestibular system. This may lead to performance decrement, again distorting the results, or even to drop-outs.
Test-track/on-the-road studies  The most valid way of testing a TICS is to assess its impact on actual driving performance. Test vehicles are equipped with sensors, cameras and data loggers to record driver behaviour. Acquired measures range from the simple variables such as lane position, speed, steering wheel reversals or the position of pedals to crashes or near crashes. TICS use is also recorded, and positioning information can be obtained as well. Equipping the vehicles with the necessary technology is not easy, though. As the sensors and loggers should not jeopardize the regular functionality of the vehicle, proper solutions are often costly, and not easy to install. And again, as with the simulators, the definition of critical values for specific TICS is not straightforward.

The tests can be done on test tracks or in real traffic. Test-track studies usually feature the operation of the TICS in question while navigating. They provide an acceptable level of standardization, as the itinerary itself as well as the environmental factors (other traffic) are controlled by the researcher. However, a realistic use of the TICS cannot be expected, as participants are usually not free to decide when they operate the system.

Another option is on-the-road testing. Participants drive the instrumented vehicle in real traffic, usually on a predefined route with an experimenter present. This way, a more naturalistic environment as well as a better estimation of TICS-use cases can be achieved, compared to the test-track variety of studies. Experimental control of the driving situation, however, is limited only to very basic variables, such as itinerary or time of driving. This also has an impact on possible statistical procedures that can be applied. As comparability of situations is not always given, the focus shifts away from inferential statistics to more descriptive ways of dealing with the data.

One special form of on-the-road studies are so-called field operational tests (FOT), which have become quite popular in recent years. On a European level, there have been a large number of FOTs investigating the use and impact of Intelligent Speed Adaptation (e.g., Besseling and van Boxtel 2001, Biding and Lind 2002, Ehrlich et al. 2003, Peltoła, Tapio and Rajamäki 2004). Other prominent studies feature Intelligent/Adaptive Cruise Control (ICC; Fancher et al. 1998), an Automotive Collision Avoidance System (ACAS; Ervin at al. 2005), and a Road Departure Crash Warning System (RDCW; LeBlanc et al. 2006). In FOTs an equipped vehicle is given to a participant for private use for some time (from one week up to several months), without having a researcher present. Any variable that is deemed interesting and feasible is recorded, while the driver does his/her everyday driving. This procedure facilitates the access to information like frequency of use, use cases or use strategies. The driver is expected to act more naturally than he/she would do under the suspicious eyes of an experimenter, increasing the validity of results and conclusions. This realism, however, comes at the cost of having practically no control on the testing situation. Comparing driver behaviour with and without TICS is possible only on a very global level, as there is no parallelism between situations in which the driver operates the TICS, and
those where he/she does not, and also no parallelism between different drivers in the situations they encounter.

In general, studies using actual vehicles as experimental apparatus have the highest intuitive validity one can get when studying TICS use and effects. Only those studies are able to determine what will actually happen when a new system is introduced into a car. However, there are important disadvantages. The lack of experimental control is a major issue when the question is not only of what happens, but also why it happens. As this experimental control is a requirement for statements about causality, meaningful assertions about the causes of observed effects are hardly possible, at least in a strictly scientific way. The second major factor is cost. The cars, their equipment, the management of the fleet or the compensation for the participants are only some of the issues one has to face when planning a large scale FOT.

Subjective measures  A subjective measure which has been widely used for the HMI assessment of IVIS is the ‘NASA Task Load Index’ (NASA-TLX). The NASA-TLX was developed by Hart and Staveland (1988). It is a subjective workload assessment tool. NASA-TLX requires users to perform subjective workload assessments on operator(s) working with various human-machine systems. It is a multi-dimensional rating procedure that derives an overall workload score based on a weighted average of ratings on six sub-scales. These sub-scales include Mental Demands, Physical Demands, Temporal Demands, Own Performance, Effort, and Frustration. Three dimensions relate to the demands imposed on the subject (Mental, Physical, and Temporal Demands) and three to the interaction of a subject with the task (Effort, Frustration, and Own Performance). Besides the six scales, an overall weighted measure of task load can also be calculated on the basis of the scales. The NASA-TLX was developed to assess workload in various human-machine environments such as aircraft cockpits; command, control, and communication (C3) workstations; supervisory and process control environments; simulations; and laboratory tests. This method has been tested in a variety of experimental tasks ranging from simulated flight to supervisory control simulations, and laboratory tasks (e.g., the Sternberg memory task, choice reaction time, critical instability tracking, compensatory tracking, mental arithmetic, mental rotation, target acquisition, grammatical reasoning, etc.). The derived workload scores have been found to have substantially less between-rater variability than uni-dimensional workload ratings, and the sub-scales provide diagnostic information about the sources of load.

Subjective measures have a certain appeal as they are easy to use, and easy to analyse. However, there are substantial problems associated with their application. Although different dimensions of workload may be clearly defined for academic purposes, they are often difficult or even impossible for participants to distinguish. This starts with possible confusion of mental and physical load in rating which distorts results, and ends with total frustration because participants get the impression that the same questions are asked over and over again. Also, there is the
potential inability to distinguish external demands from actual effort or workload experienced. It is difficult for participants to decide whether they are required to rate the ‘objective’ demand of a task, or the demand they experienced while performing. Further problems arise when dissociation appears between self-report measures and performance. It is not an uncommon observation that objective and subjective measures do not correlate on every occasion. So, it is questionable if subjective measures really cover the whole spectrum of workload that might be of interest for someone evaluating the impact a certain system may cause on driving performance. Still, especially because of their comparatively low intrusiveness, subjective measures are a good option to gather additional data of interest.

Conclusion

There is a wide array of methods and procedures available that might serve as potential candidates for the assessment of safety relevant criteria linked to TICS. They are all relevant and useful in their own right. Which one will be the measure of choice depends heavily on the question that needs to be answered (as well as, of course, the cost). Lab-based procedures, and to a lesser extent simulator-based studies, are practically unable to capture natural user behaviour. They basically force the participant to operate the system in question at a predefined moment and frequency, totally disregarding the possibility that a driver in a real environment might opt not to operate the system in various situations. On the other hand, field methods often lack the experimental control that is essential when it comes to actually linking the operation of a certain system to driver performance beyond a purely descriptive account. There appears to be no method that is ‘best’, or ‘optimal’. The different approaches should rather be viewed as complementary. Each of them can provide additional information and insight into the complex construct of workload. Only the combination of various procedures, at different stages of system development, will provide the researcher with a comprehensive picture of the system’s properties with respect to driver workload and distraction.

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Chapter 8
Psychophysiological Measures
of Driver State

Ellen Wilschut and Dick de Waard

Introduction
The nature of driving is changing as a result of an increase in the number of car users on the road, and the complexity of the traffic infrastructure. At the same time more and more information is being made available in the car by means of in-car technology. As discussed in the previous chapters, despite the usefulness of in-car technology, there is a concern about the potential distraction and the additional mental workload these systems impose on the driver, leading to an increased risk of accidents. Human errors in traffic related to driver state and mental workload are among the major causes of accidents (Smiley and Brookhuis 1987, Brookhuis and De Waard 2010). It is therefore important to be able to measure driver state. When trying to measure a driver’s state while involved in driving with an IDSS, different types of measurements may be used. O’Donnell and Eggemeier (1986) specify three measurement groups: subjective (i.e., self-report) measures, performance measures (e.g., maintaining an adequate lane-position), and psychophysiological measures.

This chapter focuses on measuring and assessing the state of the driver by means of psychophysiological measures. Psychophysiological measures are those that are derived directly from the participant’s physiology, for instance, heart rate or muscle tension. These physiological factors give an indication of the psychological state of humans, such as stress. The reason why psychophysiological measures may be useful in studying driving is that they give an objective indication of driver state without influencing the driver’s behaviour. Subjective data are always the result of the driver’s interpretation of his or her own behaviour. And performance measures do not explain the underlying reasons for behaviour, e.g., when a driver forgets to brake in time for a stop sign, this may be caused by very different processes. In this case both an overload of information, and reduced vigilance, may lead to the same outcome: a missed sign.

In this chapter psychophysiological measurements are discussed that have already shown a high potential for measuring mental workload and driver state. Special attention is given to techniques that have shown promise for making the transition from experimental studies in the laboratory to studies on driving in a simulator or on the road. The chapter focuses on measures of the cardio-
vascular system and on brain activity measures. For these two types of measure a
description will be given of the psychophysiological phenomena they reflect and
the indications they give of the driver’s state. Examples are given of studies in
which these measures have been used. The chapter concludes with a discussion
of the usefulness of the measures and the equipment coming onto the market to
measure them efficiently.

Heart Rate and Heart Rate Variability

Stress, information overload or underload, attention, etc., have an effect on the
working of the cardio-vascular system. A high level of stress, e.g., may lead to a
rise in blood pressure and an elevated heart rate. Measures of the cardio-vascular
system include heart rate, blood pressure, respiration (Mulder 1980). The cardiac
system should be viewed as a whole, as changes on one variable affect others.
A change in respiration rate, e.g., has an effect on the heart rate. In the electro-
cardiogram (ECG), the electrical signal of heart activity is recorded. The R-peak
is the largest peak in the ECG and the time between successive R-peaks of the
heart beats is called the Inter-Beat-Interval (IBI). The IBI may differ between
periods of rest and active periods. In driving studies it can be measured during
the driving task and before or after driving, providing a contrast with a baseline
representing a ‘resting’ state. The difference reflects metabolic activity induced by
driving with IDSS (Porges and Byrne 1992). Although the most commonly known
factor that affects heart rate is physical activity, other factors also affect heart rate
level. For instance, emotional factors, such as high responsibility or the fear of
failing a test also influence mean heart rate (Jorna 1993). But heart rate can also
be used to measure the impact of demanding subtasks, e.g., in a driving simulator
study, as IBI has been found to be sensitive both to general alertness levels and to
compensatory effort (De Waard 1996, Mulder et al. 2005).

Brookhuis et al. (2004) used a gap acceptance task when the driver had to
turn left at a junction. They found that the demanding task increased the average
heart rate of the drivers by five beats per minute. Besides measuring the IBI,
the variations in the heart rate’s time duration and oscillation patterns are also
indicative of driver state. A feedback-loop between the central nervous system
and peripheral autonomic sensors causes irregularities in heart rates. Heart rate
variability reflects performance of this feedback system and has successfully been
used as an indicator of mental load. The higher the load, the more regular the heart
rate becomes. Also, an increase in heart rate caused by a demanding situation in
traffic is often accompanied by a decrease in heart rate variability.

The electric activity of the heart consists of several components, using different
frequencies. Frequency analysis can decompose variability into components
associated with biological control mechanisms (e.g., Kramer 1991, Mulder
1992). A decrease in power in the mid-frequency band (also called the ‘0.10 Hz
component’ after the main frequency component), and in the high frequency band
have been shown to be related to mental effort and task demands (Mulder 1980,
Aasman et al. 1987, Jorna 1993, Backs and Seljos 1994, De Waard 2002). As an illustration, Figure 8.1 shows average heart rate and the 0.10 Hz component of heart rate variability during filtering into traffic on a motorway (De Waard et al. 2008). Clearly visible is the peak load during the lane change from the acceleration lane onto the main road during which the heart rate is increased and the heart rate variability is reduced.

Heart rate and heart rate variability can be used instead of giving artificial secondary tasks to drivers to assess their mental workload, as these cardio-vascular measures reflect mental effort during the driving performance. The analysis of the data is mostly done by a moving average, where averages are calculated over a predefined time window. Instead of workload estimations over an entire drive, cardiac measures can give an indication of high workload periods during the drive, i.e., moments when drivers have to invest more effort. The resolution of these periods may be 10–15 seconds. Examples of studies using these measures can be found in De Waard (1996, 2002), Hoogeboom and Mulder (2004), Mulder et al. (2005), and De Waard et al. (2008).

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**Figure 8.1** Average heart rate and heart rate variability in the 0.10 Hz band of 32 participants during the demanding task of filtering into motorway traffic (data from this simulator experiment are reported in detail in De Waard et al. 2008). Each j-measurement is 10 seconds separated from the next. j3 reflects the lane change where the driver leaves the acceleration lane and joins the main road. Note that heart rate increases with mental effort, and heart rate variability decreases.
Brain Activity

Measuring brain activity is the most direct measure of a driver’s cognition and is most sensitive to stages of information processing. There are different types of non-invasive brain activity measures like PET and fMRI but our focus is on the electro-encephalogram (EEG) which is more suitable for driving studies. First will be discussed how brain activity can be measured during a driving task using EEG. Then we will focus on those elements in the EEG that give an indication of how the brain reacts to specific events. The so-called ERP gives indications of the reactions to stimuli, e.g., to a warning from an IDSS.

The Electro-Encephalogram (EEG)

The brain contains billions of neurons which process and transmit information by electric and chemical signalling. The electric activity of the brain is caused by changes in neuronal polarization, and can be measured externally on the scalp in the electro-encephalogram (EEG; Rugg and Coles 1995). The EEG reflects the summation of activity of many neurons, as the electrical field generated by one neuron is too weak to be detected by the EEG, and the signal from all neurons is mixed together on the scalp. By attaching a pair of (AgAgCl)-electrodes with low electrical impedance (<5kΩ) to the surface of the scalp, it is possible to measure the small voltage fluctuations of a few micro-volts reflecting this summed activity (Figure 8.2). It is important to shield the EEG measurement from other electrical equipment that can cause noise (typically a 50 Hz oscillation due to the frequency of alternating current). An EEG may also detect other signals, not coming from the brain. For example, eye-movements and other muscle movements also generate electric activity. This kind of disturbance should be prevented or corrected because usually it is large compared to the effects studied in the EEG.

Raw EEG data may be visually inspected for changes, but can be hard to interpret in this manner. Spectral analysis techniques like fast Fourier transformation (FFT) can divide the raw EEG into signals in several frequency bands. The division between these frequency bands of brain activity is biologically significant: signal components in different frequency bands show different relationships to cognition. Although not all studies use exactly the same frequencies for each band, they are roughly the same across most studies:

- 1–4 Hz Delta band
- 4–8 Hz Theta band
- 8–12 Hz Alpha band
- 12–30 Hz Beta band
- > 30 Hz Gamma band
Beta activity is predominant in drivers that are awake and alert. When alpha activity increases compared to a baseline measurement it may indicate that the driver is becoming less alert or even drowsy, especially when more theta activity appears as well. Alpha activity related to reduced vigilance can be recognized in the raw EEG by visual inspection and is predominant over the parietal cortex, on the back of the head. Delta waves are an indication of actual sleep. The EEG is considered the most reliable and valid measure to detect fatigue and alertness in specific task situations like driving long distances at night (Åkerstedt 2004), and can be used as a yardstick for the validation of in-car drowsiness detection systems (Wilschut et al. 2009).

In studies in the driving domain the EEG has been used as a monitoring tool for driver state, studying workload, vigilance, drowsiness, and attention (e.g., Schier 2000, Brouwer et al. 2004). It was shown that alpha and theta power increased significantly after a few hours of driving in a simulator and on the test track. De Waard and Brookhuis (1991) have used a combined frequency index as indicator of driver state [(alpha + theta) / beta], and found a significant increase on the parameter with time-on-task while driving on the public road. When, after two hours of non-stop driving, participants returned to a busy ring road and had to follow a lead car, the activation level increased again. Clearly, the increased task demands on the ring road increased mental load and vigilance. It seems that EEG frequency analyses are useful as indicators of driver alertness and can be included in driver state research for these purposes.

**Figure 8.2**  Schematic explanation of the method to extract an ERP by segmentation and averaging of the ongoing EEG signal (Luck et al. 2000; reprinted with permission). A participant performing a driving task with electrodes around the eyes to correct for eye movement and EEG-cap with several electrodes.
The Event-related Potential (ERP)

Event related potentials (ERPs) are used to study effects on cognition and human information processing. ERPs have successfully related brain activity with operator performance under varying conditions (Rugg and Coles 1995). A time-locked signal averaging of the EEG is used to extract the ERPs (Figure 8.2) from the much larger EEG. The segments of EEG following each of a set of stimuli or responses are extracted from the EEG, and these segments are then lined up in time and averaged. Any brain activity that is unrelated to the stimulus will average to zero (assuming a sufficiently large number of trials), and any brain activity that is consistently time-locked to the stimulus will remain in the average. The resulting averaged ERP waveform consists of several positive and negative deflections that are called peaks, waves, or components, and are usually named after their polarity and latency (e.g., ‘P110’ for the positive peak 110 ms after stimulus presentation). The sequence of components following a stimulus reflects the sequence of neural processes triggered by the stimulus, beginning with early sensory processes and proceeding through decision and response related processes.

If an auditory warning is issued by the IDSS, this will within a few milliseconds elicit associated activity in the part of the brain that is responsible for hearing, the primary auditory cortex. From the ERPs can be concluded if information is attended to; e.g., ERPs of attended auditory warnings differ in amplitude from non-attended warnings. This differentiation in the ERP amplitudes of auditory stimuli with attention has been found as soon as 100 ms after a warning in a large number of trials (Rugg and Coles 1995).

The amplitude and latency of the successive peaks can be used to measure the time course of cognitive processing, and the distribution of voltage over the scalp can be used to estimate the neuro-anatomical location of these processes. The high temporal resolution is the main advantage of ERP over other non-invasive brain activity measures like fMRI. However, for the exact location of the process fMRI (functional Magnetic Resonance Imaging) is more suitable as it has a higher spatial resolution. But it has a lower temporal resolution compared to EEG, and can not yet be used in the regular driving simulator.

When stimuli are presented in a secondary task (dual-task situation), one of the standard paradigms to measure P300 is an oddball task. In an oddball task a series of events are presented to the participant, and the events are of two classes, e.g., a series of beeps presented in two tone heights. One class is generally less frequent than the other and the subject is instructed to respond in some way, for instance by counting, to the less frequent of the two events. A typical auditory oddball task could involve a tone of 1000 Hz as the frequent stimulus, while the infrequent stimulus is a 2000 Hz tone, with a ratio of 80–20 per cent. The amplitude of the P300 is dependent on probability: the less frequent the event the larger the P300 (e.g., Duncan-Johnson 1977). Many applied ERP studies have focused on the P300 component, because it is one of the largest components, and it is relatively easy to implement a secondary task. P300 reflects a process of context or memory...
Updating by which the current model of the environment is modified as a function of incoming information (Rugg and Coles 1995).

Janssen and Gaillard (1985) studied the P300 in a secondary auditory task when participants drove on rural, city and highway roads. They found that the P300 amplitude decreased, and latency increased as a result of task load. More recently Raukausas et al. (2005) studied resource allocation while driving in a car simulator and performing two secondary tasks. The first task was a cell phone conversation, and the second an in-vehicle task requiring visual attention and a manual output. They used an auditory novelty oddball (80 per cent non target tones, 10 per cent targets and 10 per cent novel sounds) to elicit a P300. Analysis of the P300 amplitude to the novel sounds showed that using a cell phone reduced the P300 amplitude and thus the resources available for attending to and evaluating sudden and unexpected events. During the in-vehicle task the P300 amplitude seemed less affected, but was still reduced. Thus, with the ERP technique effort and attention can be studied.

Discussion

An important factor affecting driving performance, and hence traffic safety, is the state of the driver. Research on driver state can help evaluate the effect of multitasking on traffic safety by determining under which conditions the driver needs to exert additional effort to protect the driving performance and prevent it from diminishing.

A number of complications occur in psychophysiological measurements (Wilson 1992). Specialized knowledge and equipment are required for the measurement and analysis of the data; e.g., artefacts have to be recognized and corrected or removed. Furthermore, electrodes and other measuring equipment have to be attached to the participant, and fitted into the vehicle. This could involve practical difficulties, can be time-consuming, and could potentially interfere with performance, although the general trend is for measuring equipment becoming smaller, easier, and faster to apply to the driver.

Psychophysiological measures have some clear advantages over subjective reports of driver state. First, subjective questionnaires require discrete moments during which driver state is probed, and the driving task has to be interrupted, whereas psychophysiological measures can continuously monitor drivers without interrupting. This also allows such data to be associated with events as they occur. Second, psychophysiological measures provide direct and specific information on states that may be difficult to capture reliably via self report.

Psychophysiology can help decide which equipment is allowed to be used in the car during driving (e.g., the cognitive effects of mobile phone use), and to assess potential challenges in human machine interactions. Furthermore, psychophysiology could be used to validate IDSS like drowsiness detection systems. And finally, when in the future driver state can be assessed in real-time, it
can be used in a loop with IDSS. Information about the driver’s current state can help adjust the IDSS to optimize the driver assistance. For example, the criteria for collision warnings could be adjusted to provide earlier warnings when a driver is drowsy, or incoming phone calls could be postponed when the driver is already under a high cognitive load. Driver state assessment can then have the potential to be used to increase comfort and safety while driving.

References


Chapter 9
Public Impact: Non-equipped and Vulnerable Road Users and Residents
Ralf Risser

Introduction

The title of this chapter refers to a broader public than just those who drive cars equipped with Intelligent Driver Support Systems (IDSS). The reason is that different types of people are involved in the traffic system. Not much research has been done so far on effects on vulnerable road users and residents. All we have today is questions. These are, however, the starting point for heuristics and hypotheses for scientific analysis. The questions mentioned here stem from the work around the traffic safety checklist, carried out in the framework of the PROMETHEUS program: The Traffic Safety Checklist was a tool developed already in the beginning of the 1990s as a part of the activities of the PROMETHEUS PRO-SAFE group. Literature and expert know-how about behaviour adaptation was summarised and transformed into items that constitute the checklist (Risser and Chaloupka 1995, Turetschek 2004). The checklist focuses on the possible consequences for road safety of introducing new equipment in road traffic. It is a prognostic instrument and allows the formulation of assumptions concerning the effects of new equipment on road users’ behaviour. Based on such ‘intelligent hypotheses’ it will be much easier both to develop prognoses and to assess the quality of those prognoses. In the following these questions are transformed into headlines.

In this chapter, the potential problems with/for vulnerable road users and residents if car drivers are equipped with different IDSS applications, e.g., will be discussed. Vehicle drivers who do not purchase an equipment could also be looked at, but in this chapter the focus will mainly be on vulnerable road users – and drivers are also pedestrians, sometimes – with only a glimpse at ‘other car drivers’. Traffic is not merely a technical, but a socio-technical, system. It consists mainly of individual actions and social interactions. Effects of new equipment depend on the end-users and what use they make of the new instrument. For those not sitting in cars, the understanding of car drivers and their intentions, and communication with car drivers will change. Changes in behaviour and interaction will be caused by risk compensation, delegation of responsibility, imitation, and the changes in communication patterns mentioned above. Thus, behaviour and interaction analyses have to be taken into account as a basis for making safety prognoses. Clearly, the comfort and safety of vulnerable road users will be influenced by all of this, and
they have to be involved in the evaluation process. Possible effects on vulnerable road users and residents have to be analysed. Methods for the assessment of possible effects will be presented, from round table discussions with road users to field surveys. At the end of the chapter an example of a comprehensive evaluation process – a large scale study on ISA in Lund – will be presented. This study dealt with the effects of new equipment in a holistic way, taking in social system effects as well when evaluating the equipment.

**Equipped Car Drivers’ Communication with Other Road Users**

It is often hypothesised that new equipment in the car might draw attention away from the social environment, and produce a stronger focus on the Human Machine Interface (HMI), like screens, sounds, signs, messages instead. This question for instance, has been dealt with in the framework of a large scale study of the Intelligent Speed Adaptation System (ISA). There, drivers who tested the system (between a few days and more than one month) generally stated that the feedback given by the ISA system had not drawn their attention away from the social environment. Rather, their attention for other road users, especially pedestrians and cyclists, had been intensified and their vigilance had increased.

But obviously, it is also necessary to look at behaviour and to find out what happens in the field. A study of an Adaptive Cruise Control (ACC) equipment (see box on next page) on behalf of the Federal Highway Research Institute of Germany (Bundesanstalt für Straßenwesen – BASt), in co-operation with BMW, showed that there were changes in the drivers’ communication with the social
environment in a non-wished-for sense. There were some indications that driving 
with the system is not only causing changes in the interaction with vulnerable road 
users, but in some cases this caused risky situations, according to the behaviour 
observation. It was also registered that the drivers’ anticipatory behaviour at all 
places where there might be vulnerable road users was worsening (behaviour 
observation; ‘driver does not look up’).

**ACC – Adaptive Cruise Control**

ACC at the time of the study referred to in the text meant Autonomous Cruise Control, 
and it was often also called AICC (Autonomous Intelligent Cruise Control) – a system 
that would keep speed at a pre-set level and adapt minimum distance to any car ahead 
accordingly.

The goal of this project was to study behaviour adaptation phenomena. Risk 
compensation is only one of several possible hypothetical constructs in this respect. 
At the same time, the consequences of adaptation processes for the traffic system 
were discussed. The traffic-safety checklist was used in order to formulate hypotheses 
concerning the new equipment’s impacts on traffic safety which then should be 
tested with the help of in-car observation. To start with, these instruments were used 
to ‘evaluate’ new equipment that had already been assessed with respect to safety 
with the help of the in-car observation method ‘Wiener Fahrprobe’. (The checklist 
compilers did not know the results of these studies). Both methods were modified 
according to the results of this comparison and adapted for use in this present study. 
The results of round-table discussions held in order to achieve better understanding 
of adaptation processes in the social context were presented. After that, the results 
of observations of drivers in the field were shown and discussed. There, the modes 
‘without equipment’, ‘with low-automation-degree equipment’, and ‘with high- 
automation-degree equipment’ were compared. Observations were followed by a short 
questionnaire that allowed dividing the groups of drivers into rudimentary ‘attitude-
types’ for differentiation according to observation results. Finally, a suggestion was 
made about instruments that should be used in order to anticipate at an early stage 
problematic behaviour adaptation effects of equipment to be implemented.


A special sub-study in the frame of the ISA project showed that the drivers of 
Lund city buses equipped with the ISA system did not give priority to pedestrians 
at a pedestrian crossing as frequently as drivers of non-ISA buses. The difference 
was not significant, only a tendency, but the result indicated that at least initially, 
when they are not yet acquainted with the system, bus drivers might try to 
compensate for time lost due to the equipment. However, the ISA studies did not 
yield comparable results with respect to private car drivers. There, test drivers’ 
behaviour was registered with the help of behaviour observations using the Wiener
Fahrprobe developed by Risser (1985). The results showed relatively positive communication behaviour with vulnerable road users (see below). The quality of communication is among other things reflected by the way in which right-of-way issues are dealt with in the communication among road users. The following results were received in the framework of driving observations of ISA-equipped drivers (Table 9.1).

Yielding by equipped car drivers for vulnerable road users has improved significantly, according to these results. This can be seen as being in accordance with expectations, as Varhelyi in his PhD thesis some years earlier (1996) showed that if cars approach pedestrian crossings at a lower speed, they are more liable to decelerate at a somewhat longer distance from the pedestrian crossing, and to yield. Under such circumstances crossing the road becomes much easier for pedestrians because the conditions – including perception of messages by the car drivers – are clearer and therefore safer. Thus one can summarise the results as follows:

1. In studies of an ACC system, according to results of systematic behaviour observation, the frequency of the communication with other road users – both motor vehicles and pedestrians and cyclists – at intersections decreased.
2. The systematic behaviour observation that was carried out in the frame of the ISA project in Lund did not produce any results that indicated any significant changes in interaction between drivers of ISA-equipped cars and other car drivers, and no negative changes of communication with vulnerable road users could be detected, as far as private-car drivers were concerned.

Table 9.1 Interaction with pedestrians inside the test area

<table>
<thead>
<tr>
<th>Interaction with pedestrians at crossings</th>
<th>Without ISA</th>
<th>With ISA</th>
<th>The difference with ISA</th>
<th>Sign. level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Yields early</td>
<td>64</td>
<td>54</td>
<td>78</td>
<td>68</td>
</tr>
<tr>
<td>Yields late</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Pedestrian insists on priority</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Pedestrian waits at roadside</td>
<td>29</td>
<td>25</td>
<td>25</td>
<td>22</td>
</tr>
<tr>
<td>Forces pedestrian to stop</td>
<td>13</td>
<td>11</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Puts pedestrian in danger</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>118</td>
<td>100</td>
<td>115</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Hjälmåhl 2004
3. Communication of bus drivers in Lund with pedestrians deteriorated when buses had been equipped with an ISA system.

A possible explanation of these differences is that in the first case the drivers were not well acquainted with the system. They used a test car they had not driven before, or just a few hours before the experiment. The same is valid for the bus drivers: their behaviour was analysed right after the buses had been equipped with ISA. On the other hand, with respect to point 2, the private cars of the test drivers were equipped with the system, and the drivers had had several weeks or months to get acquainted with the system.

**Considering Social System Necessities**

No studies have been done to analyse explicitly the question whether drivers of cars equipped with different IT systems adapt their behaviour to social system necessities, like driving at appropriately low speeds in densely inhabited areas. However, there are results of indirect approaches that allow for both negative and positive conclusions.

The test drivers in the ISA study estimated that:

- they lowered their speed on stretches with 30, 50 and 70 km/h speed limits also outside the test area (where the system was not functioning), even though not to the same extent as within the test area. This is an indication of a positive development with respect to adaptation to the social environment;
- they estimated that their speed remained unchanged on roads with 90 and 110 km/h speed limits outside the test area.

In sum, according to the test drivers, their compliance with traffic rules improved. They stated that their attention to speed limit signs decreased within the test area (the equipment would take care of that), while it increased outside the test area.

At the same time they stated that their attention to what happened along the roadside and their consideration for bicyclists and pedestrians increased. They believe that their distance keeping to the vehicle in front improved too. However, with the help of measurements, no difference could be found in drivers’ speed adaptation in low speed situations (e.g., at pedestrian crossings) when they were driving with ISA.

The analyses of STORM and ACC indicated that speeds of drivers equipped with ACC were higher in densely inhabited areas. ACC, at least during an early test period, led to increased speeds when entering urban areas; on the other hand, speed adaptation on the motorway, where ACC was in function, was better. The reason for this was that the system had limited the speeds on the motorway, but stopped working when lower speed areas were approached. It could be that the
drivers had adapted to higher speeds, and simply forgot that they had to lower their speeds themselves, as the system would not take care of that.

**STORM – Stuttgart Transportation Operation by Regional Management**

In the framework of the QUARTET project STORM, a dual-mode route-guidance (DMRG) system was implemented in Stuttgart. This system worked both in an autonomous mode, and/or an infrastructure-based mode, depending on what part of the Stuttgart road network one was using. 120 beacons were placed in and around the city centre of Stuttgart. As soon as a vehicle entered the equipped zone, the system could switch to the infrastructure-based mode automatically, depending on traffic circumstances. When leaving this zone, the autonomous system took over again. In order to assess the possible effects of such a system on driver behaviour and interaction, the Wiener Fahrprobe was used. 20 persons were observed in two rounds, first without equipment and later on with equipment. The results showed that too short distances became more frequent, heterogeneous compliance caused problematic interactions, and the system drew the driver’s attention away from the road and the other road users.

Risser et al. 1995

The experiments with ISA showed that there could be a general reduction in speeds: wherever ISA worked, speeds went down, but they partly also went down in areas where the system was turned off. It is legitimate to presume, however, that differences could be due to the fact that ISA was tested in Sweden, and ACC was tested in Germany, differences could be a consequence of different cultures with respect to speed behaviour.

In connection with the IVI system STORM it seems that the ability to react in good time to the surrounding social system is disturbed by the HMI, especially the visual display. At intersections, when information was given that one should turn left or right, behaviour observation showed that drivers would change to the left lane for turning left without making sure that there was no other (motor) vehicle in that lane that could be disturbed or endangered by the lane change. The analysis also showed explicitly that looking in the mirror decreased when the system was on: people registered the instructions given by the system and followed them, and in some cases a mirror check was omitted, which led to critical situations with other car drivers.

Results that go in the same direction refer to mobile-phone use: there it seems that especially the social communication involved in the process – and not so much the use of the equipment – interferes with the attention given to the outside environment. Studies by Alm and Nilsson (1995) showed that the degree of interference is shaped by the character of the communication on the phone.
Esbjörnsson and colleagues (2006) did a study aiming to investigate the changes in communication shown by the drivers when using a mobile phone. By observing and video recording driving and handling a mobile phone in practice, they came to the conclusion that drivers to some degree adapt their communication to the exigencies of the environment. However, in their report a fourfold higher risk of crash accidents is assumed for drivers using a mobile phone compared to drivers not using a phone (McEvoy et al. 2005, Redelmeier and Tibshirani 1997).

The results are thus not conclusive, but it is difficult to imagine that information coming in via the phone or via a HMI does not claim attention, and does not interfere with the vigilance of drivers. However, this is difficult to study and cars will definitely be equipped more and more with systems providing different types of information or allowing communication with remote persons. Therefore, the goal of behaviour-related work will be to focus on improvements of HMI in a sense that they interfere as little as possible with the driving task and with the interaction with other road users (see Kaufmann et al., 2008).

Vulnerable Road Users’ Perception of Motorised Traffic and Equipment

Vulnerable road users do in fact both perceive and assess car drivers’ behaviour, as Table 9.2 shows, giving results from the EU-project MASTER. The reason is that what car drivers do is utterly relevant for pedestrians.

MASTER – Managing speed in traffic on European roads

Starting from the assumption that a definition of appropriate speeds cannot be given independently of what road users think and feel with respect to this question, 100 semi-standardised interviews with car drivers and 100 semi-standardised interviews with persons who considered themselves as ‘mainly pedestrians’ were carried out in 6 European countries (Austria, Germany, Hungary, Portugal, Spain and Sweden). The results show that both groups (car drivers and pedestrians) find that actual speeds are too high, but as expected, pedestrians do so more. The interviewed car drivers agree that their own speed behaviour contributes to the problem. They rationalise their own motives for problematic speed behaviour. To the other car drivers they attribute slightly more egoistic and irrational motives. Almost half of both groups think that speed reducing measures are necessary. However, pedestrians prefer efficient measures that have a direct impact on car drivers’ speed choice, while car drivers prefer measures that leave the decision to them. The recommendations in MASTER had as a long term goal to improve the basis for changing road users’ behaviour, and here especially car drivers behaviour, in a way that it is acceptable for all members of society.

Risser and Lehner 1998
Table 9.2  Car drivers’ (N = 630) and pedestrians’ (N = 564) views on efficiency of measures for achieving appropriate speeds; 1 = very good, 5 = not good at all

<table>
<thead>
<tr>
<th>EFFECTIVE MEASURES FOR ACHIEVING APPROPRIATE SPEEDS</th>
<th>Very good (%)</th>
<th>Rather good (%)</th>
<th>Not so good (%)</th>
<th>Not good at all (%)</th>
<th>I do not know (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD = car drivers, P = pedestrians: CD P CD P CD P CD P CD P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Speed humps</td>
<td>28 35 32 32 16 14 18 12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) Rumble strips</td>
<td>17 20 32 30 17 17 21 17</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) Stationary radar</td>
<td>28 36 30 32 18 12 13 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d) More enforcement by police</td>
<td>31 40 30 32 17 11 13 10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e) Non stationary speed checks</td>
<td>26 39 31 29 16 8 15 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f) More and better road paintings</td>
<td>41 38 28 28 15 11 16 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g) Better info about relation between speed and accident risk</td>
<td>41 38 26 28 12 14 9 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>h) Automatic speed limiter in the car that cannot be overridden</td>
<td>20 27 13 14 12 10 34 27 21 22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) Automatic speed limiter in the car that can be overridden</td>
<td>13 15 21 19 16 13 27 25 23 28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>j) More frequent and well perceivable signs</td>
<td>42 36 28 30 12 15 11 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>k) Higher fines for speeding</td>
<td>26 35 24 25 16 16 24 13</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>l) Clear and well indicated speed limits</td>
<td>49 49 29 29 8 6 6 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Risser and Lehner 1998

Generally, it can be said that all systems that lead to speed reductions will help to achieve improvements in subjective safety. This would, of course, be a positive development, e.g., being afraid for one’s children and feeling stress would be reduced. Whether vulnerable road users change their view on motorised traffic due to the implementation of new IT equipment depends on what changes take place in the behaviour of equipped drivers, in combination with the information about the system distributed in public. It will also depend on the possibilities one has to realise that a vehicle is equipped with a certain system, and the experience that vehicle drivers equipped with such a system behave in a certain way. So far, we do not have any information about such observations, no studies are known to us that could provide any results with respect to this question. However, from Table 9.2 one can conclude that there are some distinct differences in how vulnerable road users would like to control car drivers’ speed behaviour, and what car drivers themselves are prepared to accept. For example, when discussing a
system like ISA that would control motor vehicles’ speed (line h in Table 9.2) people who describe themselves as pedestrians are significantly more in favour of introducing such systems in practice than are car drivers.

Whether the identification or anticipation of risk in the public becomes more or less accurate depends on the same factors as mentioned above. However, there are only few empirical results to discuss this. In Lund, 100 pedestrians were interviewed at two intersections from January to March 2001 (before-phase), and approximately 160 at the same intersections from September to November 2001 (after-phase) in connection with the ISA studies. In parallel, ca. 110 pedestrians were interviewed at two control-sites in Helsingborg during the before-phase, and at one of them during the after-phase; one of the sites was skipped because only few events could be registered there. However, no effects on pedestrians due to the fact that around 300 cars in Lund were equipped with ISA, among them five buses of the local public-transport company, could be detected (NB: ISA equipped cars were labelled and could be recognised).

It is unclear whether understanding the intentions of drivers of equipped vehicles by other drivers or by vulnerable road users has changed: there are no results available that allow answering the question whether there will be a change in difficulty for vulnerable road users to understand the intentions of drivers, due to any system. One important aspect of such understanding is, e.g., connected to estimating the ability of equipped vehicles to take evasive action. Will the ability attributed to the drivers to brake or swerve change in accuracy? This is one research question that should be dealt with, not least because of the fact that fatal accidents involving pedestrians constitute ~15 per cent of all fatal accidents in the EU 14, which are the ‘old’ EU countries without Luxemburg, as in 2006 complete data sets were available only from these countries, according to ERSO 2007.

**Quality of Life in Cities**

Changes in social climate in road traffic are, of course, connected to changes in car-driver behaviour. Speed and movements of vehicles in interaction areas of cars and other road users seem to be very relevant for the social climate in the public space. This has, for instance, been shown in the EU-project SIZE.

A study in Malmö, carried out by Kaufmann et al. in 2001, demonstrated that lower speeds of vehicles are associated with better subjective safety and well-being. Among other things, the degree to which parents are afraid for their children correlates directly and significantly with the real speeds of vehicles.

In the framework of ISA it has been stated that equipped car drivers’ interaction with vulnerable road users has probably become more considerate, and that one may assume that this will be even more the case when everybody is equipped with an ISA:
Test drivers perceived their own communicative behaviour towards pedestrians and cyclists as more friendly and considerate with ISA than before; generally, they say they have become more conscious of other road users, which improves preconditions for communicating well and safely; they perceive that their attention given especially to pedestrians increased during the test phase with ISA.

**SIZE (Life quality of senior citizens in relation to mobility conditions)**

The EU-project focused on the special needs of senior citizens in Europe regarding mobility, applying a user-oriented approach in order to explain the present mobility situation, and the problems of different groups of senior citizens, to identify relevant input and guidance for setting up policies aimed at ‘keeping seniors mobile’. In interviews and questionnaires with representative samples of senior citizens, and experts of infrastructure and traffic management problems, inter-personal and inter-generational frictions, lacking lobby power, and health problems were referred to. Inconsiderate car drivers moving at high speed, and a lack of toilets in the public space are important sources of disturbance and stress for older citizens. The safety issue is brought up more in connection with the wish to be protected by police presence from being harassed, etc. Traffic safety problems mainly become clear by ‘ruthless car drivers’ being considered as an important hindrance, and the enforcement in the respect of speed limits being considered as the most urgent measure.

Amann et al. 2006

From all this results the fact that the quality of life in residential areas may improve when systems that help reduce and/or control speed are introduced (ISA). Spontaneous mobility of pedestrians could improve, fear of parents for their children’s safety could decrease. However, no statements can be made with respect to other systems, although the results of the STORM and ACC indicate that somewhat more negative effects could be expected as far as these two system types are concerned. The same is valid for mobile phones or other interactive devices in cars: they could have the potential to cause more stress for road users outside the equipped cars.

**Possible Developments Concerning Accidents**

Collisions between vehicles travelling straight ahead, and pedestrians and bicyclists crossing the road will depend both on the speed in the interaction area, and on the
interference with the attention dedicated to the social environment that could/will be caused by any system.

For collisions of turning vehicles with P & C crossing a side road the same as above is valid: the effects will depend both on the speed in interaction areas, and on the interference with the attention dedicated to the social environment that could/will be caused by any system.

This is also the case with respect to accidents between motor vehicles and P & C travelling along a road. One may assume that the effects here will depend both on the speed in interaction areas and on the interference with the attention dedicated to the social environment that could/will be caused by any system. However, the lateral distances chosen by drivers, will play an important additional role here.

Aspects like quality of HMI, clearness of the instructions one receives, etc., may be important but we hypothesise that vehicle speed is the most important aspect where vulnerable road users are concerned. Trying to summarise the possible safety effects for unprotected road users from the study results that are available: an improvement of the safety of vulnerable road users may be expected if an equipment generally helps to reduce car speeds or to adapt speeds in inhabited areas appropriately (Risser et al. 2000, Ekman 1999). The prognosis concerning safety in relation to IDSS, especially safety with respect to vulnerable road users, is good if more ISA-like equipment will be introduced into the traffic system (Oguri 2007). On the other hand, it is difficult to make any statement concerning the effects on the safety of vulnerable road users as far as ACC, STORM and interactive devices like mobile phones are concerned.

**Methods for Assessment of Traffic Safety**

Traditionally, traffic safety is evaluated by referring to accident criteria. That implies that one refers to what happened in the past. But when trying to assess the effects of IDSS we want to look into the future. Accident prognoses in connection with new equipment, however, are speculative and not reliable as this equipment does not have any history. And even if accident data related to the use of new equipment existed, the general problem with such data would still be: they do not answer the question in which way a system should be improved, or if it should be implemented at all (e.g. Risser and Chaloupka 1995).

Traffic is not merely a technical, but a socio-technical system. It consists of individual actions and social interactions. With regard to the effects new equipment has, this actually depends on the end-users and what use they make of a new instrument. Changes in behaviour and interaction can be expected. Behaviour adaptation (possibly risk compensation, delegation of responsibility, imitation of others, changes in communication patterns, etc.) has to be dealt with when evaluating new equipment. Thus, behaviour and interaction analyses have to be included as a basis for making safety prognoses. Interaction will happen among
drivers of vehicles that are equipped with certain IT-systems, but also of course, with all kinds of non-equipped road users, and with residents. Therefore it is very important to assess possible consequences for the whole traffic system. This means that, clearly, vulnerable road users have to be involved in the evaluation process as well.

It is difficult to make good safety prognoses, but in any case the importance of integrated methods and a multidisciplinary approach cannot be doubted.

This final part of the chapter deals with a discussion of how different types of equipment could be analysed with respect to social-system effects (Risser and Lehner 1997). In Table 9.3 symbols are allocated to different methods indicating how much they may contribute to prognoses, viz. to assessments of the effects of new equipment. The symbols used are (x), x, and X.

- ‘(x)’ means that a method may contribute to some degree to the assessment of certain equipment. An attempt at quantification is made there, attributing to (x) 0.5 points.
- ‘x’ means that a method can provide an important contribution for the assessment of an equipment, but should still be used in combination with other methods. 1 point is given to ‘x’.
- ‘X’ means that the method in question can be used for assessing a certain area and that using this method alone may be sufficient. This does not mean, however, that the use of this method alone is recommended, it is always better to work with a combination of methods. 2 points are attributed to ‘X’.

Systematic behaviour observation, the use of safety checklists, test rides combined with discussions, and round table discussions to prepare studies and to reflect on results, can contribute very much to the improvement of assessment processes. However, with the methods mentioned it is not possible to assess system safety and the development of the safety image of equipment in the long run very well. Any piece of equipment should, of course, work safely in the social environment. All methods mentioned above, with respect to aspect a in Table 9.3, can only provide rough assumptions: experience teaches that such assumptions very often turn out to be wrong as soon as any equipment is used in real life. One could say that, for instance, sudden antagonism against any equipment will always come unexpectedly. The way acceptance develops is not predictable. Maybe more regular use of repeated study designs could help, as such designs help to achieve a more thorough insight into processes concerning the development of behaviour and communication.
Validity of Results

The results of studies after the implementation, or after the first use of any system, are probably only of short term validity. The methods used may give an impression of what may happen in the future when any equipment is used on a larger scale in society, but they do not allow for robust predictions. To tackle this problem, one could work more with repeated-study designs. With the help of such designs, one could learn more about how behaviour, communication and acceptance develop over a longer time period. So far, there are no, or hardly any, studies that tell us about the processes going on when drivers and the general public become more acquainted with new systems, and what behaviour and interaction will look like, compared to the evaluation results we have discussed above, when one analyses them some months or even years later. Knowledge about such developments would allow us to interpret results of the usual short-term-after (or even during) evaluations in a more valid way. Repeated studies with medium-term and long-term-after analyses would be necessary to achieve this.

Table 9.3  Methods for prospective analysis of new car equipment

<table>
<thead>
<tr>
<th>Analysed aspects: Methods</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Round table discussions with road users</td>
<td>(x)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>3.5</td>
</tr>
<tr>
<td>(2) Traffic Safety Checklist</td>
<td>X</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>4.0</td>
</tr>
<tr>
<td>(3) Interviews with car drivers</td>
<td>(x)</td>
<td>(x)</td>
<td>(x)</td>
<td>x</td>
<td>2.5</td>
</tr>
<tr>
<td>(4) Systematic behaviour observations</td>
<td>X</td>
<td>(x)</td>
<td>x</td>
<td>x</td>
<td>3.5</td>
</tr>
<tr>
<td>(5) Simulator</td>
<td>X</td>
<td>(x)</td>
<td>x</td>
<td>x</td>
<td>2.5</td>
</tr>
<tr>
<td>(6) Test rides combined with discussion</td>
<td>X</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>5.0</td>
</tr>
<tr>
<td>(7) Traffic simulator</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td>(8) Round-tables with experts, Delphi Studies†</td>
<td>X</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>4.0</td>
</tr>
<tr>
<td>(9) Representative questionnaire with road users</td>
<td>x</td>
<td>X</td>
<td>x</td>
<td>x</td>
<td>4.0</td>
</tr>
<tr>
<td>(10) Field survey</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>3.0</td>
</tr>
<tr>
<td>Possible covering of the aspect with the method mentioned</td>
<td>7</td>
<td>10</td>
<td>7.5</td>
<td>8.5</td>
<td></td>
</tr>
</tbody>
</table>

†  Note: Panels of experts forecast the development of societal processes or phenomena by answering questions or questionnaires. They do this in several rounds, and between answer rounds the results of the anterior round are summarised in connection with the explication of reasons behind the answers. The next set of questions then leads to new and more detailed conclusions. Respondents are encouraged to revise earlier answers in the light of answers that other members of the panel have given.
The Safety of Intelligent Driver Support Systems

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Chapter 10
Different Types of Drivers’ Social Problems
Juliane Haupt and Ralf Risser

Introduction

All kinds of road users may be subject to certain demands or restrictions imposed on them by their social environment or produced by the social situation they are in. This may cause, or lead to, problems which we will refer to here as ‘social problems’. There is no global definition of social problems which is generally accepted. Different definitions are often related to different points of reference. Glicken defined a social problem as: ‘[.] an issue within the society that makes it difficult (for subjects) to achieve their full potential’ (Glicken 2007: 493).

A similar definition is mentioned by Nygren (2004), taken from the Social Report, 2001. There social problems are seen as a lack of resources in ‘important areas’ (Nygren 2004). The important area in this chapter is the driving task. Problems related to stress, fatigue, social relations, etc., may arise here. Ironically, however, it may be the road users’ own behaviour that causes these problems.

In this chapter not only the operational part of driving, but also the tactical and strategic aspects (according to Michon 1985) are looked at. Another way to divide the driving task into different abilities and skills, similar to Michon’s, is represented by the three-level model of Heijer, Brookhuis and Van Winsum, et al. (1997). Their three levels are the control level, the manoeuvring level, and the strategic level. Skills related to these three levels of the driving task are psychomotor skills, perceptual skills and cognitive skills (Wundersitz, 2007). Keskinen (1996) also postulated a driving model that includes goals for life and skills for living on the highest level, while the other three levels, with goal and context of driving, mastering traffic situations, and vehicle manoeuvring, roughly reflect the three levels postulated by Michon (see Figure 10.1). Keskinen’s fourth level: the goals for life and skills for living reflects the position of the driver vis-a-vis his/her social environment, and its consequences for the driving task with respect to personal motives, behavioural style and abilities, and the social relations of a driver with his/her environment. Past research hinted at different personality factors which have an influence on drivers’ choices and behaviour. These factors are self-control, lifestyle, social background, attitudes, gender, age, group affiliation, importance of cars, driving as a part of one’s self-image and other preconditions (see Peräaho, Keskinen and Hatakka 2003).
The concept of social problems refers to issues in daily life that are socially induced. Furthermore, we do not refer to problems due to IDSS but to those problems IDSS could help to solve. Age groups and gender are in focus. Peers exert pressure especially for younger drivers, inducing behaviour that (probably) would otherwise not be adopted, or less frequently. Assistance is needed in order to prevent dangerous behaviour (racing, drugs, alcohol). ISA and alcocolock devices are possible steps in this direction. For older drivers the car is in many cases necessary for remaining mobile, which is the most relevant social issue for this group. Assistance to compensate for possible skill shortcomings is needed, related to peripheric vision, control of simultaneously varying processes (intersections), stress by perceived high dynamics of traffic processes, overview to the rear (restrictions of neck moveability), etc. But another approach to this group is also necessary: when shortcomings in skills make the use of a car difficult, other transport solutions for keeping people mobile are necessary. With respect to gender an interesting fact is that women still drive less than men. Especially when aging there is lack of skills exercise that could cause problems, which is quite relevant when thinking about support by IDSS. However, the financial situation of

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**Figure 10.1 Hierarchical model of driver behaviour (adapted from Keskinen 1996)**

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<table>
<thead>
<tr>
<th>Level 4: Goals for life and skills for living</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overriding function over levels 3-1, independent of traffic domain</td>
</tr>
<tr>
<td>- Importance of cars and driving for personal development</td>
</tr>
<tr>
<td>- Skills for self-control, social skills, habits, beliefs etc.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level 3: Goals and context of driving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic domain specific function</td>
</tr>
<tr>
<td>- Global decisions, e.g. whether to drive or not</td>
</tr>
<tr>
<td>- Purpose of driving, driving environment, social context and company</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level 2: Mastering traffic situations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Situation specific function</td>
</tr>
<tr>
<td>- Adapting level 1 functions to the demands of specific driving situations</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level 1: Vehicle manoeuvring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Executive function</td>
</tr>
<tr>
<td>- Knowledge of car control, speed, direction and position</td>
</tr>
</tbody>
</table>
women in higher age groups may often not allow them to make use of expensive equipment, which has to be considered when bringing equipment on the market. Generally, strain and stress of drivers can be reduced by ‘classical’ assistance functions for navigation, congestion avoidance, and all those types of equipment that make the driving task easier. Traffic safety can be improved in this way, but acceptance issues will have to be considered as well.

Below, different kinds of social problems will be discussed, focussing on the importance they (may) have in connection with the driving task. For making traffic safer it is essential to consider such characteristics, not least because they could be related to higher accident risks. Distinguishing the different characteristics is important with respect to measures that have to be taken in order to enhance traffic safety for all road users.

**Driver Experience**

As mentioned in the introduction, various skills are needed to carry out the driving task. These are: **psychomotor skills** in order to be able to control the vehicle and to allocate attention; **perceptual skills** in order to perceive hazards, and to do visual search, and **cognitive skills** for making decisions, and to assess risks (Wundersitz 2007). Skills are characteristics that facilitate performance. One may, for instance, differentiate between novice drivers who have not yet developed all driving skills, and experienced drivers who drive almost automatically. Young drivers are often novice drivers. For natural reasons many among them have had a driving licence for only a short time. The crash risk for novice drivers is greater than for experienced drivers. During the first months after obtaining the driving license this risk decreases rapidly (Sagberg and Bjornskau 2006). This underlines that relevant skills are learnt during this period.

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<table>
<thead>
<tr>
<th>A typical novice driver and an experienced driver</th>
</tr>
</thead>
</table>

**The novice driver** settles down in the car. First he/she fastens his/her seatbelt. Next he/she checks the correct position of the seat and the mirrors. Carefully he/she inserts the key into ignition and starts the engine. Concentrated, he/she engages the first gear and tries to let the dragging point come to drive off, having both hands on the steering wheel. While driving his/her gaze focuses the road-scene in front of the car.

**The experienced driver** settles down in the car. First he/she puts the key into ignition and starts the engine. While doing this he/she slips into clutch, and while driving off he/she fastens his/her seatbelt and turns the radio on in search of a convenient radio station. Perhaps he/she lights a cigarette. During driving he/she looks around and views the entire road scene without focusing. If a passenger is with him/her lively conversations could be held.
For the experienced driver driving is automated. He/she does not think about what he/she is doing. While driving, he/she can also concentrate on other things, like conversation. Trusting in his/her driving abilities he/she does not feel a need to concentrate completely on driving. The experienced driver may do other things while driving, like for instance, using cell-phone, holding lively or cognitively demanding conversations, or eating and drinking.

The novice driver is very concentrated in doing the driving task, and is aware of almost everything he/she is doing. The novice driver does not yet possess the skills for driving safely, so in the beginning he/she tries to compensate for this deficit by being very concentrated. Later on, when the driving task will become more automated for the novice driver the concentration will decrease.

So, whereas the experienced driver may tend to an over-reliance on his/her driving ability, and may engage in distracting activities while driving, the novice driver has not yet fully developed his/her driving skills. But both, over-reliance as well as skill deficits, are potential risk-factors.

Lifestyle and Risky Driving

Lifestyle may affect driving in different ways. Young people tend to go out at night, especially during weekends, and many young people begin to drink alcohol regularly (Catchpole, MacDonald and Bowland 1994). Young drivers tend to drive by night and during weekends more than other drivers (Wundersitz 2007, Catchpole, MacDonald and Bowland 1994).

In 1977 Jessor and Jessor postulated the ‘Problem Behaviour Theory’. This theory considers risky types of behaviour of young people which may serve different functions. Apart from opposing authorities, searching independence and, at the same time, peer approval or acceptance, the functions of risky behaviour are: coping with anxiety and frustration, satisfying needs for thrill or sensation, demonstrating adulthood, and overcoming limits (see Wundersitz 2007). This risky behaviour may also be shown while driving, e.g., by speeding, drinking and driving, or risky driving manoeuvres. For instance, young people may go to a discotheque at night, drink some alcohol, possibly take other substances, and afterwards drive home under the influence. However grown-ups also go out, and some of them drink and drive, etc. From this perspective one could say that the behaviour of young people – often beginners – in this respect belongs to becoming a part of the grown-up world.

Another interesting point in connection with lifestyle is sleeping behaviour. People who amuse themselves a lot by night have a different sleeping rhythm from those who stay at home with a family, and have a regular job of eight working hours a day from Monday to Friday. But working (too much) may steal sleep as well, and the sleep quality necessary to recover. Because of their working conditions professional drivers may have to deal with much stress and fatigue. For instance, driving by night may be imposed (by the employer) because there is so much less
traffic at night and thus driving conditions are better. Furthermore, the breaks that professional long-distance drivers take are usually too short, as are their resting periods. In this way they often sleep too little (see also Hargutt 2005).

Apart from adolescence and sleep related problems, there are several other factors that lead to risky driving. One, linked to risky driving in terms of speeding, driving under the influence of alcohol (DUI), and/or driving while being intoxicated, is a personality trait: sensation-seeking. The definition of sensation-seeking is ‘the seeking of varied, novel, complex, and intense sensations and experiences, and the willingness to take physical, social, legal and financial risks for the sake of such experience.’ (Zuckerman 1994, p.27).

Risk taking, as a relevant part of the definition of sensation-seeking, can also be labelled as thrill and adventure seeking. With increasing age, sensation-seeking tendencies decrease. According to research, sensation-seeking is strongly related to adolescence, and is to be found predominantly among males. Typical features of a strongly developed sensation-seeking tendency would be smoking and drinking alcohol or taking drugs (more than the average), engaging in risky sports, showing dominant social behaviour, and last but not least, underestimating risks. Here we will not discuss how sensation-seeking tendencies develop. However, one should be aware of the fact that some persons, especially younger ones, could show a strong tendency to take risks due to their personal sensation-seeking features.

Ageing

Ageing brings many changes in lifestyle. Social ageing has an influence on drivers’ behaviour, and changes in the mobility of older persons: social ageing comprises different levels: the individual level, the interpersonal level, and the societal level (Hakamies-Blomqvist, Sirén and Davidse 2004). Social ageing on an individual level regards changes in social roles or their transitions, e.g., many older people become grandparents, turn from employee into retiree, or for instance, change from being married to becoming widowed (Hakamies-Blomqvist, Sirén and Davidse 2004). It is possible that changes in the personal role in connection with the social context trigger changes in attitudes and values of older persons. For instance, many older persons feel discriminated because of their age (Huebscher 1998). It is one of the main problems of older persons that they have to deal with (assumed) negative social attitudes (‘ageism’) on a daily basis. A classical example of such discrimination is the proposal made by many younger people to ‘help’ older drivers by taking away their driving license (Huebscher 1998) or by conducting the mobility debate in terms of the increased risk posed by older drivers, instead of stating the reduced mobility of this group as a problem (Hakamies-Blomqvist, Sirén and Davidse 2004). However, the wish to take away an older person’s driving licence may well not be the result of focussing on safety, but rather of considering older drivers as obstacles; Nelson, Evelyn and Taylor (1993) found that younger drivers view older drivers as over-cautious (in Huebscher 1998).
At the societal level changes in social life are at play, like today’s trend of older people moving more and more from the countryside to urban areas (about 70 per cent of the age of 60 and above in developed countries live in urban areas). This may be a problem in the sense that older citizens who live in rural areas on the one hand are more likely to be involved in community activities, and to be integrated, which is not so much the case in the urban environment. On the other hand, for those who stay in rural areas, one disadvantage is definitely that many younger people also move to urban areas, and the (physical) supply for senior citizens often becomes a difficult task due to deteriorating social and transportation infrastructures (Hakamies-Blomqvist, Sirén and Davidse 2004). The interaction of these facts with role changes, losing partners/mates, and, consequently, living alone, can lead to the social isolation of older people (CITRA 2007). Being able to drive a car could help to avoid isolation.

Do older drivers cause risks on the road? According to the empirical investigation by Hakamies-Blomqvist et al. (2002) increased accident rates of older persons are not so much related to their age, but rather to distances driven; or in other words, they are connected to a low mileage bias (Hakamies-Blomqvist et al. 2002: 273). Older citizens generally drive fewer kilometres per year than do younger drivers (e.g., Oxley et al. 2004, Benekohal et al. 1994, Rosenbloom 1999), and, comparing them to younger drivers in a general way, produce errors that are referred to as the ‘low mileage bias’. A comparison with groups of younger drivers with similar mileage shows that accident rates of older drivers are not significantly higher.

To finish this section, one aspect should be mentioned that is not really a social ‘problem’ of the older persons we talk about here, but an interesting fact (that has to be analysed further): older persons who are married are more likely to keep on driving a car (Chipman, Payne and McDonough 1998 in Hakamies-Blomqvist, Sirén and Davidse 2004).

Peer Influence

Humans are social beings. Failure and success of persons have also to be seen in this light; they depend on the assessment of facts and activities by other persons, and have long-term consequences for all persons involved. Indicators for failure and success are the rank someone has and his/her reputation (Wilson and Daly 1985). Generally, humans tend to make riskier decisions when they are in groups than when they are alone (e.g., Kogan and Wallach 1964, Zaleska 1976 in Wilson and Daly 1985), obviously related to the assumption that taking higher risks opens up possibilities for more success, or types of success that are highly rated. This effect of being more daring in groups appears to be stronger in men than in women (e.g., Johnson, Stemler and Hunter 1977 in Wilson and Daly 1985).

Peer group dependence is the most relevant structural problem in the group of young drivers. According to studies (Chaloupka and Risser 1998), young people tend to do things in a group that they would never do when alone. Group pressure
enforcing ‘incorrect’ and risky behaviour in order to impress peers or to impress the other sex is a strong motivation, similar in character to the need for affiliation, or the need to be respected as a full member of the group. Social norms – in their case related mostly to norms of the peer group – are very important for young people. The subjective perception of these norms determines whether a particular behaviour is performed or not performed by a young individual (see Wundersitz 2007).

Peer pressure leads to risky driving behaviour such as speeding, driving under the influence of alcohol or dangerous overtaking manoeuvres. Awkward or risky driving behaviour may also be a consequence when (young) passengers are present. While the risk of an accident decreases with the number of passengers for drivers between 30 and 59 years, travelling speed and fatal-accident risk for young novice drivers increase when young passengers are present. Especially young male passengers are associated with higher crash risk (Baxter et al. 1990, McKenna and Crick 1994, Preusser et al. 1998, Chen et al. 2000, Williams 2003 in Wundersitz 2007).

Apart from the fact that the driver wants to impress peer passengers, there could be other negative influences as well. Passengers could distract the driver by speaking with him. More directly, passengers could play loud music, nudge the driver, or even grasp the steering wheel from behind, etc.

But peers may also have a positive influence, for instance by displaying wished-for driving behaviour or by reinforcing appropriate driving behaviour by giving positive comments concerning a peer’s safe driving (Allen and Brown 2008).

Gender

Catchpole, MacDonald and Bowland (1994) in their ‘self-report-study’ pointed out that gender is an important predictor for accident risk of young drivers. Males see themselves as being more skilful in driving, and at the same time as taking more risks than females. But one should differentiate between males and females reporting past accidents, and the actual number of accidents they have been involved in. It is often mentioned that males have a greater accident rate per capita of the population than females (e.g., Ryan et al. 1998 in Wundersitz 2007). This statement suggests that young male drivers have a higher accident risk than young females, which is the case in absolute figures. But there is no difference in the rates of reported accidents per 100 million kilometres. Thus, at first sight it could be concluded that higher accident numbers of young male drivers in comparison to young females are a result of higher driving exposure of young males, and that they do not perform worse than females on the road. However, according to the already mentioned Low Mileage Bias (Janke 1991) which relates crash risks to yearly exposure, the risk of having an accident per number of kilometres decreases with more kilometres driven. Thus, young males who drive significantly more kilometres than young females should actually have a lower crash rate per distance.
travelled. Thus, one may assume that there is a relatively higher risk of young males to become involved in an accident than there is for young female drivers. Moreover, the fact remains that many more young males than females are involved in fatal accidents. This implies that young males’ lifestyle is more related to the likelihood of a (fatal) road accident.

As in all other age groups, older men (above 65) drive more often than older women do, and fewer older women than men hold a driving license (e.g., Oxley 2000, Rosenbloom 2000, Hakamies-Blomqvist and Sirén 2001 in Oxley et al. 2004). Less driving experience of women could be the reason that older male drivers are safer in vehicle manoeuvring (Chandraratna and Stamatiadis 2003). In contrast to this statement it should be underlined that older women who drive a car are a subgroup that could be classified according to status indicators as usually living under better socio-economic and educational preconditions, which in today’s traffic may be advantageous for their traffic safety (older road users are safer as drivers than as pedestrians and cyclists, per capita, and regular exercising of driving reduces risk of an accident as a driver). Older women are more likely to cease driving voluntarily than older men as they look at their own state of health more critically, and more often estimate that it could affect safe driving (Oxley et al. 2004).

The marital status which is a social factor that influences driving behaviour differs by gender. Women are more often widowed or single than older men, who are more often married. Older women are usually poorer (in terms of money and related resources availability) than older men. Women who live alone are the poorest subgroup of older citizens. This has effects on (driving) behaviour. For example, more older women tend to renounce their driving license when they are still healthy. They may also renounce other things related to fulfilling their own mobility needs, not least because of their lack of money and other resources. Their financial status may not allow them to make use of options like buying expensive cars with sophisticated equipment (Hakamies-Blomqvist, Sirén and Davidse 2004).

State of Health

Investigations into the influence of the state of health have often focused on older persons, because ageing in a stochastic sense comes with deterioration of health status. **Physical ageing** includes bodily changes like changes in blood circulation and pressure, sensory system, immune system, body mass and muscles. **Psychological ageing** encompasses changes in cognitive functioning, psychomotor performance and personality. Many of these changes affect the individual’s physical and psychophysical performance. As mentioned above, sufficient psychomotor skills, perceptual skills and cognitive skills are important requirements for the driving task. These skills may deteriorate with age, and in addition illnesses and dementia
may impair the overall performance (e.g., Hakamies-Blomqvist, Sirén and Davidse 2004, Chandraratna and Stamatiadis 2003, Oxley et al. 2004).

On the other hand, if older people reduce their mobility a reduction of social contacts could be the consequence, which would definitely be connected to the risk of declining health and a higher probability of chronic disease (CITRA 2007). Next, and in a vicious circle, reductions in health could negatively affect the functioning of the abilities necessary for driving. Deterioration of any function could reduce the performance in the driving task, and increase the risk of an accident (e.g., Oxley et al. 2004).

Sagberg (2006) investigated the influence of drivers’ health in crash involvement. The study included drivers of all ages. Significant illness-factors that were identified in this study were non-medicated diabetes, a history of myocardial infarction, needing spectacles for driving, myopia, insomnia, frequent tiredness, anxiety, feeling depressed, and taking antidepressants. It appeared that physical illness decreases skills that are needed for driving, and it does so not only in older persons but also in younger ones.

Acceptability of IDSS

The aspects discussed may influence driving behaviour in a safety-relevant way. The main reason is that skills needed for safe driving are often limited because they have not yet been fully developed (novice driver), because a person is distracted (e.g., when using a cell phone, speaking with passengers; in the case of young drivers, by peer activities), because a person is tired, intoxicated or ill. Certain activities leading to such situations are forbidden by law, like driving when intoxicated or using the mobile phone while driving. But this, of course, does not keep all from doing them (e.g., sensation-seekers). IDSS could increase law-abiding behaviour, or at least, many experts believe so. IDSS could support drivers by compensating for shortcomings of skills, or they could in fact prevent persons from driving at all under certain conditions; e.g., under the influence of substances or when being too tired. In Chapter 3 of this book (‘Safety According to IDSS Functions and to Different Driver Types’) is listed which IDSS are supposed to be helpful in the case of shortcomings in skills.

It is, especially with respect to youths’ problems related to social norms and peer pressure, necessary to implement safety measures which are accepted by young/novice drivers. Young et al. (2003) carried out a study in which they asked 58 young novice drivers aged 17 to 25 years about the acceptability of IDSS technologies. The IDSS technologies which were discussed in eight focus groups were: ISA (Intelligent Speed Adaptation), FCW (Forward Collision Warning), FDW (Following Distance Warning), LDW (Lane Departure Warning), FWS (Fatigue Warning System), ALC (Alcohol Interlock and Sniffer Systems and the Drink Performance Test), SBR (Seat Belt Reminder and Interlock Systems) and LIC (Electronic Licence). In general, young drivers are rather sceptic in assessing
IDSS. But they do not usually decline the use of such systems. While discussing the IDSS in the focus groups suggestions were made about how systems could be made more acceptable. Great value was attached to the reliability of such systems and hence to a low false alarm rate. On the one hand the young drivers had a very critical view of the functionality of IDSS, and made some propositions to enhance it (e.g., the warnings various systems give should be very salient, systems should be tamper-proof), on the other hand the novice drivers do not want the systems to restrict them too much in the driving task. In general, one main aspect that was mentioned by the young persons, which may lead to a better acceptability, is regulation to make IDSS compulsory.

For reducing accident numbers, and for improving road safety it is, of course, recommendable to respect the needs of drivers. If these are respected it is more likely that IDSS technologies will attain their goal of improving safety (Young et al. 2003). However, the problem is that especially those systems that really would address safety problems – compulsory ISA, and an Alcohol interlock that prevents driving when performance is impaired – are not accepted, especially by young drivers. Thus, it seems that other measures – marketing, education, enforcement – are necessary in order to make drivers accept and use those types of IDSS that from a safety point of view they need most.

References


Chapter 11
The Future of IDSS

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Introduction

Intelligent Driver Support Systems (IDSS) are becoming more and more widely available, and new ones are being developed, tested and brought on the market. Several trends may be distinguished:

• Systems are integrated in new vehicles, so buying a new car means getting a car equipped with several systems, which work together and/or share interfaces. A single electronic screen may provide a wide range of information and interaction options. While this development began with vehicles at the higher end of the market, the trend will continue with cars for the larger public.

• Systems are becoming available on nomadic devices. In a sense this trend is the opposite of the one mentioned before, with IDSS applications becoming available on devices such as intelligent phones or Personal Digital Assistants (PDA). The mass market for smaller computing and communication devices is rapidly evolving, and applications are being developed to run on these devices. For example, navigation systems are available on mobile telephones, and internet connections may provide traffic related information.

• There is a growing interest in cooperative systems. These systems may consist of vehicle-to-vehicle communication or infrastructure-to-vehicle communication. The infrastructure may communicate with drivers, providing information or warnings, but also with the vehicle itself, for example, automatically reducing the speed to comply with a speed limit. Vehicle-to-vehicle communication may also consist of information sharing between drivers and vehicles.

• Automation of driving. Several IDSS already take over a part of the driver task, for example speed adaptation systems that do not allow the driver to exceed a certain speed limit. However, systems are being developed that take over a much larger part of the driving task, or even all of it. Technically, completely automated vehicles, which do not need a driver, are feasible. Automated vehicles have already been demonstrated or been driving around in limited environments.
These trends may contribute to driving becoming safer, supporting drivers in the driving task, warning drivers of potential dangers, and taking over when drivers are not able to cope with certain situations. However, the most important future step, and one that will lead to further changes, will be to consider IDSS as a part of the whole traffic system rather than as just a stand-alone system used by drivers. Incorporating IDSS in national road safety strategies may be expected to relieve some of the concerns that come with their use. So far there is little interaction between IDSS and other road safety measures or other supporting actions, and hence the effects of IDSS consist mainly in the impact of system use on driver behaviour.

Besides improving safety, there is an urgent need for rethinking road transport in terms of energy use and carbon emissions. IDSS have a major role to play in realizing these policy goals. Eco-driving systems informing the driver about fuel use are one option, but one should also think of forms of automated driving that adopt a driving style minimizing energy use. Cooperative systems may measure pollution, and redirect traffic or impose a lower speed. In addition to this, such systems are expected to be employed together with road pricing schemes. These systems may also contribute to improving mobility by reducing traffic jams which form an important economic problem in many regions.

However, all these trends may be beneficial but they may also raise questions about undesirable consequences. Many concerns about the use of IDSS have been addressed in this book, such as effects on vulnerable road-users, increased risk taking, and over-reliance. Interface issues have been discussed, addressing questions such as the development of human machine interfaces for these systems that are usable, do not distract the driver, and subsequently do not lead to information overload.

As not all problems have yet been solved, new trends in IDSS development may add even more concerns. Human-factors questions arise in the areas of:

- Interfaces: what new forms of interfaces, such as haptic ones, may improve drivers’ performance, comfort, and safety?
- Unintended use: how to avoid unintended use of new IDSS, such as over-reliance on the systems?
- Acceptability and adoption: will drivers accept these new systems, and deploy them to their full potential, and how can we encourage adoption of new technologies by different segments of the population?
- What new standardization is needed to harmonize driving in different countries, especially with cooperative systems?
- How to develop new test methods that do not only test one system at a time, but also test the interaction between systems, and with the road infrastructure and other users?
In this book we have addressed design, evaluation and social perspectives of IDSS from the safety and human factors point of view. For the future these topics will remain of primary concern.

Possibly the most important human factors question is: how will the driver task change? Driving the vehicle is now considered the main task of a driver who has full control, and is fully responsible. With systems taking over (parts of) the task, and systems that override decisions of drivers, the driving task may need to be redefined. If there is less to do for the driver, if his/her role becomes a more supervisory one, do we need to accept that drivers will start to perform other, non-driving related activities? Is it realistic to require of the driver that he/she is aware of the situation at all times, and gives all his/her attention to the road? As we know from industrial control processes, passive supervision is not easy to perform for a longer stretch of time. Or will systems become so perfect that the need for full attention will no longer exist? At the moment we view the driver and his/her vehicle as a unit, an autonomous system that moves around in the environment according to the intentions of the driver. With the introduction of cooperative systems, the vehicle-driver unit may become less autonomous, and more of an element of a larger traffic system, where its movement is partially controlled by the larger system.

In this chapter we will discuss the future trends in the development of IDSS in relation to human factors. The three areas covered by this book, design, evaluation, and social perspectives, will be addressed again, but focusing now on the future. Possible changes in driving behaviour will be discussed. Concerning design, the development of cooperative systems will be described, systems providing communication between roadside infrastructure and vehicles, and between vehicles. Next, new trends in the design of IDSS interfaces will be highlighted, especially multi-modal interfaces and augmented reality. As for evaluation, we will describe methods for evaluating IDSS on the road, by means of field operational tests and naturalistic driving studies. In the social perspectives section we will look at both individual and societal aspects. Acceptance and adoption of IDSS will be discussed, and policies in Europe with regard to IDSS will be addressed. This section concludes with a discussion of how the goal of improving safety may be reached. The chapter concludes with a discussion of the development in driving from a situation where the driver is fully in control, towards one where driving will become more autonomous.

**Future Developments in IDSS Design**

*Cooperative Systems*

In this book we have mainly discussed driver support and information systems, systems working in vehicles, supporting individual drivers. Advances in telematic technologies now make it possible to connect vehicles and infrastructure.
Cooperative systems are the next step in providing support for drivers, and influencing the traffic system. Developments in network technologies, radio, Broadband, mobile, cellular, infra-red, microwave and wireless communication, satellite connections, and real-time updatable electronic maps, will provide the opportunities for continuous communication, and communication between vehicles (V2V), and between vehicles and infrastructure (V2I). The development of cooperative systems provides new opportunities in realising safety goals. Some examples:

- Cars encountering an accident, bad road conditions or other hazards on the road in front of them, can send warnings to vehicles behind them, so that the drivers of these vehicles may either avoid the dangerous spot or be prepared for the situation.
- Black spots on roads, where accidents happen, can be equipped with intelligent road side systems, ensuring that vehicles slow down, and drivers are presented with all the information needed.
- Drivers may receive warnings about other road users, such as bicycles, pedestrians, other vehicles approaching on a collision course, ghost riders, cars approaching on intersections with bad visibility.
- Monitoring and guidance of dangerous goods and heavy vehicles in adverse conditions, such as bad weather and busy traffic, and controlling access to sensitive areas.
- Information from traffic signs, and variable message signs are displayed in the vehicle, so that drivers will not easily miss important information.

Safety is only one of the object areas for cooperative systems. Other important objectives are improvement of traffic efficiency, and environmental and economic benefits. Examples are road pricing, and traffic calming measures.

Although many safety benefits may be envisaged, there are also reasons for concern. The widespread availability of cooperative systems may provide drivers with a large amount of information, potentially leading to information overload and distraction. Prioritization of information becomes a major issue. Drivers will need to find a balance between looking at the information screen and listening to audio messages, and paying attention to the road-scene. There are questions of trust and responsibility. Should the driver always rely on information provided by cooperative systems? Can drivers be sure that the information is always completely correct? If cooperative systems take over control, for example, by automatically reducing the speed of a car entering a residential area, will that be acceptable for drivers? There are as yet no simple answers to these questions. There are also questions about which applications are beneficial, and which ones are dangerous. There is not much doubt about the usefulness of warnings about accidents on the motorway ahead, but what about the possibilities for social networking with drivers of other cars, and information coming in from hotels and restaurants?
Future Trends of In-vehicle Interfaces

Since the end of the last century the number of in-vehicle telematic systems has been growing, and it will continue to grow in the years to come (Starry 2001). This development will inevitably lead to more complex and diverse information the driver will have to deal with besides the primary task of driving. The Human Machine Interface (HMI) plays an important role when the perception of information should be facilitated to the greatest possible extent. The information sent by the HMI needs to be easy to understand, and must clearly indicate the action to be taken by the driver. The aim of a well designed interface is to keep the mental workload (O’Donnell and Eggemeier 1986) as low as possible, and to avoid a sensory or cognitive overload of the driver (Van Erp and Van Veen 2004).

Standardization  Within the International Standards Organization (ISO 9241) three criteria were defined in order to guarantee the quality of HMI with respect to their usability. These criteria must be followed in the design of HMI for in-vehicle telematics:

- Effectiveness: Does the product do what the user requires? Does it do the right thing?
- Efficiency: Can users learn how to operate the HMI quickly? Can users carry out their tasks with minimum effort, including a minimum of errors? Does it do the thing right?
- Satisfaction: Are users satisfied with the product? Does the new product reduce stress, increase comfort, etc.?

Besides these three basic criteria there are many other aspects to be considered when designing an HMI in an effective way; these are summarized in various international standards and guidelines (ISO, JAMA 2004, HMI-EU 1999, Stevens et al. 2002, Green et al. 1994) and other literature. Here the design of HMI is described more specifically with regard to their information output, the design and handling of systems they are associated with, or the methods of assessing problems, for instance, distraction, produced by them.

Activation of different senses  Basically, three of the five human senses are important for information perception from an HMI: the visual, acoustic, and haptic. While the first two senses are already quite often used for receiving information while driving, there is still much room for making use of the haptic sense. Several (new) possibilities of including the haptic sense for sending and/or receiving information may be anticipated. The following solutions have so far not been used frequently in cars:
Interfaces where acoustic or auditory feedback is supplemented or replaced by haptic feedback (for example, vibrating gas pedal indicating that speed limit is exceeded).

- Touch-screen displays as a combined input and output device.
- Interfaces able to check user’s attention level in order to decide, for example, when to warn the user, or what type or detail of information to forward.
- Graphical user interfaces working on the basis of inputs in the form of mimics, hand gestures or mouse gestures executed with a computer mouse or a stylus.
- HMI aiming to improve the efficiency and effectiveness of human machine interaction by better understanding all types of signals coming from drivers (para-verbal signals, gestures, mimics), and by increasing naturalness of feedback (for example, natural language, graphics).
- Interfaces which both accept input, and provide output on a voice basis. User input is executed by either pressing keys or buttons or a verbal command, and can be responded to verbally by the interface.

The problem of receiving information simultaneously  As stated, the number of systems the driver has to control or has to react to is quite large: pedals, control-levers, signals from the dashboard and In-vehicle Information Systems (IVIS) as well as Advanced Driver Assistance Systems (ADAS). The EU-Project AIDE defined HMI as ‘a set of components that govern the interaction between the user and one or more systems’ (AIDE-glossary-v1.4 2007). This definition indicates that the challenge for the driver is not only to take care of one system but sometimes of two or several different systems at the same time. Generally, it can be said that a simultaneous release of information with different contents always causes problems (whereas according to the literature, simultaneous release of the same information via two different modalities could be advantageous). Thus, interfaces of the future will have to meet the requirement of not being ignored by the driver due to sensory overload. HMI need to channel the information provided in such a way that the most important instructions will infallibly reach the driver.

Multi-modal interfaces provide several possibilities to keep workload low. Sarter (2006) mentions two important aspects of multi-modal interfaces. One is to combine various input modes such as speech, pen, touch, manual gestures, gaze, head and body movements. For instance, input into navigation systems or commands to control the temperature in the car can be forwarded with the help of different input modes. And output can be provided both visually and auditorily, according the preference of the driver. She does not, however, mention the haptic mode.

When different types of information become relevant simultaneously, another possibility to keep workload low is the so called ‘workload manager’ (Green 2004, Green et al. 1994) or ‘information manager’ (Hoedemaeker et al. 2002). As soon as several types of information become relevant for the driver simultaneously, the ‘manager’ decides which information is the most important, and therefore
should be presented to the driver, and, on the other hand, which information can be suppressed for the moment and provided later, under better conditions.

**Augmented reality – the future**
Looking into the near future, the combination of a real image with a virtual one – the so called ‘Augmented Reality’ (AR) – is one of the most promising systems researchers are focusing on. Navigation systems are already in a developmental phase in which relevant data can be transmitted to a mobile phone where they merge with the real picture, taken previously, on the phone display. Some examples for projects in which augmented reality is used for navigation on mobile phones are junaio,¹ Wikitude,² Layar,³ Nearest Tube,⁴ or MARA.⁵

In-vehicle augmented reality also gives a chance to make windshield projected head-up displays a useful interface, already used in air transport. Researchers are also developing augmented reality systems that use head-up displays to detect potential hazard situations, like bad weather conditions, and support the driver with either warning symbols or graphics which show the course of the road (Lange 2010).

From a technical point of view the challenge in the introduction of AR into the car is that both reference points (the environment and the car) are moving. From the driver’s point of view one will face the same questions as with any other in-vehicle technology system; namely ergonomic questions (where and how to show the information), cognitive questions (avoiding information overload, etc.) and behaviour adaptation questions (delegation of responsibility) (compare Bengler and Passaro 2006).

**Future Methods of Evaluation of IDSS on the Road**

**Field Operational Tests**
IDSS are rapidly maturing and becoming available on the market, and they are increasingly evaluated in real-life driving. In Chapter 7 the method of Field Operational Tests (FOT) is described. This way of testing allows for a better understanding of everyday behaviour of drivers driving with IDSS as well as providing insight in the systems’ operation in a variety of situations. FOT are possible because of the technological advances in measuring a wide variety of driving parameters. Technology is available that can be used to equip vehicles, and that is able to monitor both vehicle and driver behaviour, as well as to register environmental aspects.

Vehicle dynamics can be monitored by means of specially developed sensors (for example, acceleration and yaw rate). Data are available from the data CAN

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¹ [http://www.junaio.com](http://www.junaio.com)
² [http://www.wikitude.org](http://www.wikitude.org)
³ [http://layar.eu](http://layar.eu)
⁴ [http://www.acrossair.com/apps_nearesttube.htm](http://www.acrossair.com/apps_nearesttube.htm)
bus. Activation of the system can be registered, for example, whether an IDSS gave a warning or intervened. The environment, such as the road, other traffic, etc., can be perceived by using radar, laser, infra-red and video. Global Positioning Systems and digital maps can determine the location of the vehicle at any given moment. The driver’s condition can be monitored by head and eye-closure tracking technologies and video. Finally, the driver can be asked by means of interview or questionnaire to give a subjective assessment of his/her own behaviour and that of the system. By combining all these data it is possible to obtain a relatively complete picture of what happened at any given moment, be it a critical situation, a specific use case, etc. The technologies that allow collecting and storing these data are rapidly becoming cheaper, which allows performing large-scale and extended FOT with vehicles equipped with monitoring systems. Monitoring systems are also commercially available, and used, for example, by fleet owners to monitor their drivers, and to have data available to determine who was at fault in the case of accidents. IDSS themselves may also contain monitoring technology. Forward Collision Warning (FCW) systems, as well as Adaptive Cruise Control (ACC) and others, contain a radar scanning for obstacles in front of the vehicle. Lane-departure warning or lane-keeping assistance systems provide information on lane position. Intelligent Speed Adaptation (ISA) systems, but also simple navigation systems using GPS, are able to provide information about current speed. Driver-monitoring systems to prevent drivers from falling asleep keep an eye on the driver all the time.

The European Commission has underlined the importance of performing FOT, and several European projects have been (co-)financed in the 7th framework programme. To support the development and execution of FOT, both at a European and at national levels, two support actions have been put in place: FESTA and FOT-Net. In the FESTA project (Field opErational teSt supporT Action; a consortium of a large number of partners, both industrial and academic) a methodology was developed to conduct these studies. Using such a methodology helps to ensure a sound approach to conducting studies, and obtaining reliable results, but also allows for data and results that may be compared between tests. A handbook was written in which the methodology is described in detail (FESTA 2008). The methodology consists of a process which systematically details the steps to be taken to set up the test, the actual data acquisition, the analysis of the data, and the evaluation and interpretation of the results. This methodology is generally adopted by European FOT. FOT-Net supports the FOT in progress by transferring and sharing knowledge, networking and training. It maintains a Wiki-encyclopaedia where information about all known FOT is made available.

6 http://www.fot-net.eu
7 http://wiki.fot-net.eu
In 2008 two large-scale pan-European FOT started: euroFOT\(^8\) – European Large-Scale Field Operational Tests on In-Vehicle Systems; and TeleFOT\(^9\) – Field Operational Test of Aftermarket and Nomadic Devices. In 2009 FOT-Net had identified some 30 FOT at national levels which were then running or had recently been completed in countries such as Belgium, Denmark, Finland, France, Germany, The Netherlands, Sweden, Spain and the UK. A large variety of systems is being tested, to name a few: Intelligent Speed Adaptation, Adaptive Cruise Control, Lane Departure Warning, Forward Collision Warning, Eco-driving, Drowsiness Warning, eCall, information and navigation systems. Projects may be financed by the private sector (such as the car industry) or by national and European bodies, or by both. In the US, Asia and Australia, FOT are also being performed, with comparable systems.

Concerning cooperative systems, in 2010, three large European projects (COOPERS, CVIS and Safespot) were finalized that aimed to study the feasibility of a large variety of systems. COOPERS\(^10\) (CO-OPerative systEms for intelligent Road Safety) developed and tested new safety related services, equipment and applications using two-way communication between road infrastructure and vehicles from a traffic management point of view. CVIS\(^11\) (Cooperative Vehicle-Infrastructure Systems) developed and tested technologies for car-to-car communication, and communication with nearby roadside infrastructure. Safespot\(^12\) worked on key enabling technologies, allowing the use of infrastructure and vehicles as sources and destinations for safety-related information.

Future Field Operational Tests (FOT) will have to deal even more with the emerging cooperation between systems. The installation of technology in cars is becoming more and more common, and not only cars are equipped but so is the infrastructure, and the new opportunities and problems that might arise will have to be thoroughly studied. Beginning, probably, with somewhat technological showcases, there will soon, as some clarity emerges as to systems and functions, be a need to assess the impact of devices on driver behaviour. As new technologies will always be connected with new and unprecedented use, FOT set-ups will have to be flexible. It may prove to be possible to evaluate some IDSS within a time span of a few weeks, as they are constantly active, whereas others may require months or even years, as they only rarely intervene. For some systems Controller Area Network (CAN) or video data may be essential, whereas others may be assessed by means of questionnaires or interviews.

However, the inclusion of data from sources outside the vehicle is important for all kinds of FOT, not only relevant for cooperative system FOT. The integration of external data like accident statistics, weather information, information on traffic

\(^8\) http://www.eurofot-ip.eu
\(^9\) http://www.telefot.eu
\(^10\) http://www.coopers-ip.eu
\(^11\) http://www.cvisproject.org
\(^12\) http://www.safespot-eu.org
flow and density, and similar that might be obtained from other sources than vehicle sensors alone, is one of the big challenges for the FOT methodology. The successful inclusion of such data might result in the easier and/or more effective acquisition of information that before had to be extracted from video recordings, in more accurate information where vehicle data might show shortcomings, or even in enriched information when data was not available from the vehicle itself at all.

Although the FOT approach is promising there is still a lot of unused potential. Many studies are limited to relatively simple descriptive analyses. The usefulness in this field of methods like cluster analysis or time series analysis should be investigated. Effective and efficient research designs are also as important as they are rare. The sheer size of FOT, the numbers of partners and different interests is often a drawback rather than an advantage. Ways have still to be found of dealing with these issues, to profit from the full potential the FOT methodology has no doubt to offer.

Naturalistic driving studies Where FOT study the behavioural impact, use and functioning of particular systems, Naturalistic Driving (ND) studies are focused solely on the driving behaviour of drivers, usually without interference of additional assistance systems. The same kind of monitoring equipment is used as in FOT, but the aim of ND is to investigate the interaction between the driver, the vehicle, the road, and the environment, and not to evaluate the impact of new driver support and information systems. However, insight from ND studies may provide a deep and detailed insight into what ‘normal’ driving behaviour consists of, knowledge of which is still lacking. This insight will help to establish a baseline comparison for the effects to be found by using IDSS in FOT. The first large ND study was performed in the United States: the 100-car study, carried out by Virginia Tech Transportation Institute (VTTI) between 2001 and 2005, and funded by the US National Highway Traffic Safety Administration (NHTSA) (Dingus et al. 2006). ND studies in the US continue in the SHRP2 Program. The Second Strategic Highway Research Program (SHRP2) is administered by the Transportation Research Board of the National Academy of Sciences of the United States of America. Safety is a major strand of the work programme. The central goal of the SHRP2 Safety Research Plan is to address the role of driver performance and behaviour in traffic safety (SHRP2 2010). This includes developing an understanding of how the driver interacts with, and adapts to the vehicle, traffic environment, roadway characteristics, traffic control devices, and the environment. It also includes assessing the changes in collision risk associated with each of these factors and interactions. This information will support the development of new and improved countermeasures with greater effectiveness. The full-scale study will involve at least 2,500 instrumented vehicles operating over a period of 2 to 3 years. The study will be conducted with volunteer drivers using instrumented vehicles for their everyday use. An instrumentation package
will be developed that can be installed on many vehicle models. The participants will use their own vehicle during the study period.

**Data analysis**  FOT and ND studies may provide detailed insights in the behaviour of drivers in everyday driving, and are new, promising evaluation methods. A major issue is the huge amount of data that is collected and that needs to be analysed. Video data are especially hard to analyse, and require substantial effort by human analysts. For the future, automation of analysis is needed. Computer software should be able to detect in the continuous stream of data those situations that are worthwhile investigating further, for example, near-accidents and potentially dangerous situations. Patterns in driving behaviour also need to be identified. New techniques such as data-mining and intelligent-analysis software need to be further developed in order to realise the potential of FOT fully. The same is true for the analysis of other large data sets, such as psychophysiological data.

Future IDSS evaluations will also have to consider that IDSS are part of the traffic system. This will lead to their inclusion into ‘conventional’ evaluation methods such as traffic simulation models, and will allow the investigation of several scenarios, modifying systems, driver, and road environment characteristics.

**Social Perspectives for the Future**

**Acceptance and Adoption of IDSS**

The success of IDSS in improving safety will depend largely on their acceptance by users. Drivers should be willing to buy systems and have them installed in their vehicles. However, acceptance is more than just the possession of a system, users should also be willing to use it, and to use it in the way it is intended. If the user uses the system to its full potential we may speak of adoption. For example, drivers may have a speed warning system in their car, but they may use it in different ways. Some may never turn it on, others may use it only on those stretches of the motorway where there are speed cameras, in order to avoid a speeding ticket. Drivers who fully adopt the system will have it activated all the time, and use it as support to maintain the speed that is appropriate for different situations. If in the future IDSS become more common, and come automatically with a new car or will even be obligatory, drivers may not have made an explicit choice to have the system, and full adoption may not necessarily always take place.

Rogers (1995) proposed a five-stage process of adoption. The first stage is the knowledge phase, in which the user becomes aware that the system exists and of what it is able to do. The second phase is the persuasion phase in which the user has to be persuaded that he or she has a need for the system. The third phase is the decision phase, in which the user decides whether to buy the system. In the fourth phase, the implementation phase, the user uses the system, and in the last phase, the confirmation phase, the user seeks to be confirmed that the right decision has been
made. For the first two phases, different sources of information are available. Car and system manufacturers aim to inform potential users, and convince them of the advantages of buying an IDSS. Also governments may aim to persuade the public that certain systems are necessary for safety reasons, for example, e-call systems. Consumer organisations and the press may provide objective information about the different options available for a certain type of system, and the advantages and disadvantages of systems. If wide-spread use of systems to enhance safety is the purpose, providing information becomes an issue. Many people are not especially interested in new technologies in their cars, they do not, for example, read specialized car magazines or watch television programmes on these topics. They are dependent on the information they get when they buy a new car or the things they hear from better informed relatives and friends. This information is not necessarily correct and complete.

Information and persuasion may also be part of the driver’s licence test. If IDSS use is incorporated in the training procedure it is expected that a large part of the population – novice drivers – will be informed of the systems, and will also be made aware of all the aspects of their use. Information and persuasion may also be implemented in a relatively coercive way, by allowing highway-code offenders to have either to face the usual penalty (pay a fine, have their vehicle confiscated, etc.) or equip their vehicle with the appropriate IDSS. This type of procedure has been tested, and it can have a positive impact, especially in the case of driving under the influence of alcohol or other substances offences.

The decision to buy a system depends of course on the financial means of potential buyers, but they will only buy it if they are persuaded they have a need for the system. This need is not necessarily for more safety. Comfort, status, and social pressure are examples of other needs people may have. Sometimes users do not have to make a decision, the system just comes with the car, or users are obliged to have a certain system. The use of systems may be enforced by law, but also by employers who may make the use of some IDSS obligatory for company cars. However, if the user is not well informed or does not perceive a real need, having a system does not mean using it. For example, some drivers do have advanced cruise control in their cars without ever using it.

Another way to reinforce the decision to buy IDSS is by providing motivation for prospective users. One example could be reduced insurance fees when using specific IDSS expected to improve road safety. In the same way reduced vehicle registration tax could be applied for vehicles equipped with IDSS improving road safety, or traffic and hence environmental conditions. If IDSS becomes part of a national agenda, vehicles equipped with specific IDSS might be subsidized and sold with deferred payment.

In the fourth phase, when the user starts using the system, its success is dependent on how well the user knows how to use it, and whether the anticipated benefits do indeed occur. In the last phase the user will seek confirmation that the choice of acquisition was indeed the right one, and the system does have advantages. The user will do this, for example, by talking about it with relatives and friends, or will
read it when he or she sees an article on the system in a newspaper. The user may search for new situations in which the system operates successfully, for example, trying out different parking positions with a parking aid. In this way the system becomes more and more familiar, and the user has integrated the system as a part of the normal driving situation.

There are different theories concerning the factors that influence acceptance and use of technology. The Unified Theory of Acceptance and Use of Technology has sought to synthesize theoretical models of acceptance (Venkatesh et al. 2003). UTAUT distinguishes four components that predict intentions to use a system, and subsequent usage. Intention to use a system depends on what people expect of the system. Does it help them realise their goals, and what efforts are needed in order to learn and to use the system? Furthermore, social influence plays a role; what do significant others such as relatives, friends, and peer groups think about the use of the system. For example, an alcohol-lock system will not be very acceptable in a social group where driving after a few glasses of wine is seen as normal. Finally, the presence or absence of facilitating conditions, the assistance available to facilitate use, will determine whether people will actually use the system. An example of a facilitating condition for using an IDSS is the possibility to have a system installed and serviced at a low price at the local garage.

Another way to describe the process of acceptance, rejection and use of technology is by using the concept of ‘domestication of technology’ (Silverstone and Haddon 1996). A successful domestication process of a system has the dimensions of appropriation, objectification, incorporation, and conversion. The user should acquire the system (appropriation), determine which role it should play in driving (objectification), learn to use the system, and to interact with it (incorporation). The user may finally convert (the use of) the system to his or her own needs, which may also result in unintended use of the product. If there are difficulties in one of these dimensions, for example, the system is too hard to learn or does not fit the normal driving style, the user may reject the system and not buy it, not use it or use it in an unintended way.

One main issue connected with the use of systems is trust. Lee and See (2004: 51) define trust as ‘the attitude that an agent will help achieve an individual’s goals in a situation characterized by uncertainty and vulnerability’. Especially where systems that influence driving directly are concerned, for example, automatic braking in emergency situations to avoid an imminent crash, trust is essential. Trust as a term is often used interchangeably with acceptance, but although related, they are not the same. Users may sometimes use automation that they are suspicious of, for example, because they do not have the time or the capability to do otherwise (Miller 2005). For example, even if drivers do not fully trust their navigation system to bring them to their destinations by the optimal route, they still may use it because they do not have the time to figure out the route for themselves. The opposite could also happen: users may not use automation they believe is completely reliable, for example, because they enjoy doing the task themselves. People may trust their ACC system but still prefer not to drive with
it. Trust may change over time, increasing as users experience that the system is reliable, and diminishing when they experience system failures. Trust is not only based on experience, but also on understanding what the system does and how it works.

Acceptance and trust in IDSS may become more and more of an issue in the future when vehicles will be equipped with many different systems, more complex systems, and systems that take over parts of the driving task. It will become harder to understand how exactly the systems work, how they will react in all different situations, and how they will interact with each other. Especially in the case of cooperative systems, where information is coming from the infrastructure and from other vehicles it will become impossible for ordinary drivers to know exactly what the systems do, and why and how information, warnings and/or take-over are generated. The driver will simply be required to trust the systems, and rely on them. In itself this is no problem, only few drivers know how their cars work even without IDSS, but they still trust that it will accelerate, decelerate, and change direction properly according to the directions they give by using the pedals and steering wheel. However, if users in the future would not have sufficient trust in systems, full and widespread adoption might not occur, and safety benefits might not materialize.

If we want to promote the large scale deployment of IDSS to enhance safety, measures are needed both in the design, and in the social aspects areas. In order for people to buy and use systems, the systems should meet expectations, both in terms of trustworthiness and functionality. The systems should be extremely reliable, so that users are really justified in trusting them. They should provide a functionality that meets needs, both on an individual and on a societal level. They should be easy to use and to learn, requiring minimum effort of users. On the user side, good, easily available, and objective information is needed to convince people to accept systems. A social culture is needed in which it is normal and acceptable to use the systems, and in which negative perceptions and peer pressure are absent. This last requirement may be the hardest to fulfil. Technological advances have a tendency to be much faster than social change. It is also important to remain critical; a reasonable amount of distrust and reluctance to accept any new system may prevent us from over-reliance on technology, and will force manufacturers to keep a sharp eye on the reliability and usability of their products. Finally, acceptance and effectiveness do not necessarily always go hand in hand, as El Jaafari et al. (2008) point out. They found that some types of warnings from an IDSS were more acceptable than others, however, these were not always the most effective ones. For example, an auditory warning was found to be the most acceptable for drivers, while this was not the most effective way of warning drivers about lane departures.
Policy Goals Connected to IDSS

When dealing with IDSS it is always important to discuss the functions of such systems. Why are they developed and why is there increasing research related to this issue? Such developments have, of course, a market value; they represent new products that can be sold, and thus provide employment and income. But this would probably not be enough. Useless products would not sell sufficiently. Any product that should sell well has to be accepted by a larger part of the public, and it is definitely an advantage if it is supported by public institutions. Therefore, the question of what societal function IDSS have is relevant. Among other things, policy papers or policy arguments in introductions to research programmes, master plans, white books, etc. reflect what functions are attributed to IDSS. They may sometimes reflect an optimistic attitude. But on the other hand, if the wishes represented by this optimistic attitude are sensible, for example, from a sustainability perspective, they offer a big advantage, having the potential to attract sponsoring of research, and thereby to give research work a direction, and to influence implementation, evaluation, and further development of IDSS.

A policy paper of the European Union in 2001 stated already that ‘the aim of the Community’s land transport policy is to promote sustainable mobility that is efficient, safe and with reduced negative effects on the environment.’ Therefore, efficient road freight and passenger transport services should be promoted, fair conditions for competition should be created, safe and environmentally friendly technical standards should be introduced in combination with ensuring a minimum fiscal and social harmonisation. Not least, effective application without discrimination of the rules in road transport should be ascertained. ‘The existing legislation applying to road transport services establishes common rules on access to the market and to the profession, sets minimal standards for working time, driving and rest periods (including enforcement and the use of a tachograph), sets minimal annual vehicle taxes and common rules for tolls and user charges.’ Of course, IDSS have an important function in connection with this definition of policy goals. They can help to solve technical problems inherent to these goals, like collecting tolls, supporting ‘green driving’, etc.

A policy paper by the federal ministry for Transport, Innovation and Technology in Austria claims that research, development and technological innovation provide the basis for economic growth, competitiveness, employment, and ultimately, the prosperity of a country and its citizens. Therefore, the ministry promotes research at all levels, and there is definitely a focus on IDSS, reflected by the points ‘co-operation between industry and the scientific community’, and ‘orientation towards key technologies’.

The UK Department for Transport produced a long list of policy goals: improve effectiveness and efficiency; make better use of the existing network (strategies and logistics); improve the safety, security and accessibility of transport; deliver...
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improved driver and vehicle services; minimize the impact of transport on the environment.

The Transport Research Knowledge Centre (TRKC)\(^\text{13}\) operating on behalf of the European Commission deals with questions regarding information on ongoing or completed projects. It produces Thematic Research Summaries (TRS) of research projects that aim at providing a synthesis of research results and policy implications from completed projects from the Fifth and the Sixth Framework Programmes, including projects dealing with Intelligent Transport Systems (IDSS) applied with different goals: to improve system performance; transport safety, efficiency, productivity, and level of service; to reduce environmental impacts and energy consumption; and to steer mobility in a wished-for direction. The papers also remind of the fact that policy developments at the EU level have traditionally been related to: the promotion of inter-modality and inter-operability, with particular regard to traffic management systems; the development of the Trans-European network infrastructure; legislative initiatives to open the market of transport services to competition; and infrastructure charging as a means to achieve a better balance between transport modes. A synthesis of the main findings and policy implications from research projects is concluded with an overview of the implications for further research. Among others, the following themes are considered:

- Real-time Traffic and Travel Information (RTTI) should be developed: a new generation of telematics services for drivers and other travellers based primarily on existing RDS-TMC broadcast technology.
- Generation of knowledge, and development of methodologies and human machine interface technologies required for the safe and efficient integration of ADAS, IVSS (Intelligent Vehicle Safety Systems), and nomadic devices into the driving environment.
- Developing, testing and validating of common specifications for the vehicle emergency call at all levels in the vehicle emergency call chain, and investigation into the technical, organisational, and business structure for a Europe-wide adoption of the solutions.
- Investigation of conceptual and technical issues concerning the technical feasibility of using DAB satellite, terrestrial cellular communications (GSM, GPRS) capabilities for the provision of integrated navigation and fleet-management services.
- State of the art in practice (for example, IDSS industry) concerning intelligent support of inter-modal transport, including personalized info-mobility services, covering the whole travel chain, possibly Europe-wide.
- Making IDSS fully compatible, not only within a single country, but also at the international level; providing guidelines for the planning, design and implementation of IDSS application.

\(^{13}\) http://www.transport-research.info
Harmonisation and integration of development of the telematics infrastructure for traffic management systems, and traffic information services, and interoperable systems of automatic tools applicable in European countries.

Definitions of the framework for an interoperable European EFC service for road tolls and charges based on a central account; the issue of having on-board equipment and an associated contract that enables them to travel through all concession areas.

Clearly, all the papers cited look for IDSS to help improve safety and capacity. In addition, the UK Department for Transport paper formulates an extra policy goal: to promote smarter and sustainable transport choices. Even if IDSS are not mentioned explicitly here, the connection between sustainability goals, the goal of improving life quality in those areas of life that are connected to, or affected by transport and mobility, and the advantages often attributed to IDSS are clear. For instance, the HUMANIST Virtual Centre of Excellence (VCE) formulated the expected advantages as part of its working programme (Lyon declaration). This programme refers to all the goals listed above, but most weight is given to those that underline protection of the environment, and sustainability, in combination with the necessity to enhance Europe’s economic strength and competitiveness.

Without doubt the papers summarized here list a lot of issues relevant in order to make the transport system more sustainable. The future will show if the traffic system with the help of IDSS really will develop in the wished-for direction.

How to Achieve the Goals

Many more papers exist – white books, master plans, etc. – sketching goals to be reached. But there is not much, if any, literature about the ways to reach these goals, or how to make sure that things develop in the right direction. In order to give some perspective in this respect the following types of measures may be suggested:

Instruction of buyers, users of IDSS  People who buy a car with certain types of equipment, or who buy the equipment separately, should be supplied with instruction materials that are acceptable from a scientific point of view, and of assured good quality, that is, they should be understandable and behaviour relevant. This refers to both oral and written instructions (handbooks). In addition, translations of handbooks into other languages than the original should be checked for their understandability.

Training  Some hours of training, driving with a new system, accompanied by a supervisor, would of course, be useful and could be made obligatory in connection with the acquisition of any new electronic equipment. If this appears overly resource consuming, at least a test ride should be carried out with a seller
who has practical experience with the systems, and has been trained to inform the customers properly.

Awareness raising measures Another promising measure that should be implemented in any case, and in addition to all other measures, is raising awareness by information campaigns. These campaigns should propagate practical information about systems, but also discuss possible risks connected to them. The main focus should be on those risks that the user/buyer will run involuntarily. Persons with a tendency for unintended use (‘testers’, those who want to satisfy other motives than getting safely from A to B) should be made to hear the arguments, and they should get the message that only responsible behaviour could protect them from law enforcing measures and prosecution.

Technical barriers to unintended use There are several ways to prevent or reduce (detrimental) unintended use of IDSS electronically. One way is to monitor use; all use can be recorded with the help of, for example, black boxes. Another possibility is to design systems, for instance speed limiters, so that they cannot be overridden. Concerning mobile phones or other systems that rely on signals from outside the car equipment, it is possible to, for example, disturb transmission when the vehicle moves at or above a certain speed. One known system that follows this idea is the so-called work load manager that prevents phone calls from being transmitted to the driver when, for instance, the weather is bad, and instructs the caller to phone later (Kaufmann et al. 2008).

Law enforcement Law enforcement could play a role in those cases where unintended use of equipment is clearly visible, for instance, a mobile phone used without a hands-free set. Moreover, law enforcement can also be applied in connection with monitoring equipment (black-box, etc.) that registers unintended use, and allows police to verify that unintended use has occurred.

Self explaining environment A last point is a self-explaining environment: road traffic infrastructure should be structured in a way that makes misuse of certain types of IDSS less likely; for instance, when roads are self-explaining with respect to speeds, the overriding of a speed limiter or ISA will become less likely.

The Future Use of IDSS – from Control to Autonomous Driving

In their famous song ‘In the year 2525’ Denny Zager and Rick Evans questioned if mankind will be still alive. We don’t know the answer yet, but for the moment the European Commission put forward the goal to save as many lives as possible, and to reduce the fatalities on the road from 40,000 in the year 2000 to 20,000 in the year 2010. Apart from a better infrastructure, improved driver education, elaborated law enforcement, etc., IDSS are considered a key factor to reach this
The Future of IDSS

goal. Systems like collision avoidance, lane departure warning, etc. shall help to increase safety. In this sense safety is the ultimate goal of IDSS. A second goal is to increase comfort and to make the driving task easier. For example, modern navigation systems completely take over control to get from A to B. Drivers don’t even have to care about traffic jams or reconstruction zones making detours necessary. The navigation system will handle it. A third goal coming up currently for using IDSS is resource optimizing. IDSS might help to reduce CO2 emission, and to optimize energy saving. A current example are mobility assistance systems that will provide on-line information, for example, on a smart phone, where one could connect to the public transportation system or how one could make a reservation for a parking lot in advance.

Having these benefits on one hand, what are the costs on the other? IDSS is continuously changing the driving task. ACC, Heading Control, Lane Departure Warning, etc. not only assist the driver in doing her/his job but they also take away sub-tasks from the driver allocating them to a technical system. What might the consequences be?

The ‘out-of-the-loop performance’ is the major concern with regard to automation. It includes the difficulty of human operators to detect system malfunctions or automation failures when they do not actively (manually) control a process. This difficulty is generally attributed to a lack of involvement of the human operator in the automation-controlled processes inherent in the shift from active to supervisory control. According to Popken (2009) a number of cognitive and motivational factors accompany humans’ adaptation to the changing task demands. Among them are vigilance problems associated with excessive system monitoring demands or due to underload and boredom, an inaccurate or incomplete mental representation of the current situation (Situation Awareness), over-reliance on automation, and inappropriate trust in system capabilities. Those adaptation effects are insofar problematic as, despite the sophistication of current technologies, systems often do not meet the requirement of working completely reliably in any type of expected and unforeseen conditions characterizing highly dynamic environments such as road traffic. Also over reliance on a driver assistance system’s actions, accompanied by an incomplete mental representation of the current driving situation, is a major safety concern because of the requirement that drivers must be prepared to intervene appropriately and take over manual control in case of a system failure. Finally, loss of competence is an issue. Getting rid of complicated tasks, like using a parking assist system to do the job, might end in being unable to do the manoeuvre by yourself.

The current trend towards increasing automation of the driving task shows similarities with technological developments in other transport areas like aviation and air traffic control in the 1980s and 1990s (see Popken 2009). There it became apparent that automation does not simply supplant human activity, but changes the nature of tasks, which often leads to unanticipated consequences for human performance and underlying cognitive processes. It seems promising to learn from automation issues in other transport areas, and to take the human-factors
insights, pro-actively rather than retro-actively, into account in the design of IDSS. The ‘human factor’ is widely acknowledged nowadays by manufacturers and researchers who foster a ‘human-centred’ or ‘driver-centred’ design of IDSS.

Finally, IDSS are a preliminary but necessary step towards autonomous driving, even if at this moment, neither from the technological level available nor from the juridical situation, autonomous driving is in reach within the next ten years. But in the year 2525?

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