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Final review of driver distraction effects due to the interaction with IVIS

Deliverable D.5

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List of Abbreviations

ADAS	-	Advanced Driver Assistance System
FOT	-	Field Operational Test
HMI		Human-Machine Interface
ICT	-	Information and Communication Technologies
IVIS	-	In-Vehicle Information and Communication Systems
ITS	-	Intelligent Transportation Systems
ND	-	Naturalistic Driving
PDT		Peripheral Detection Task
SA	-	Situation Awareness
SAGAT	-	Situation Awareness Global Assessment Technique
TSOT	-	Total Shutter Open Time
WM	-	Working Memory

Executive Summary

The present report aims at completing Deliverable D.2/E.2 by summarising relevant activities on a European and national level which were started during the time period after the HUMANIST Toulouse workshop on 9th of September 2004. Selected relevant projects and activities are highlighted and reviewed in order to arrive at conclusions for further research activities.

There is an increasing number of studies analysing driving behaviour in a naturalistic context. The joint HUMANIST/AIDE workshop conducted on 13th of September 2006 in Munich and reviewed in this Deliverable addressed the methodological rules to be followed when planning Field Operational Tests and Naturalistic Driving studies, in order to reduce the effort of such studies, produce interpretable sets of data, analyse existing data, strengthen the conclusions drawn from such studies. As one important result of the general discussion following the presentations it was concluded that Naturalistic Driving studies can be considered as one step on a scale/continuum of data acquisition methods with a low level of information given to the participants and no instructions. Naturalistic Driving studies were assessed as an interesting methodological approach especially if intra-individual variances over long periods of time are to be analysed.

The development of Information and Communication Technologies in transport provides drivers with various functions and services that may not be related to driving or related to the trip management. In the framework of the COST Action 352, several senior and young researchers of HUMANIST Network of Excellence have been involved in a literature review on the impact of IVIS on driver behaviour and road safety. The main results of this collective work are summarised, missing knowledge is highlighted and the main questions for further research activities are identified.

Since several years also a considerable interest in the concept of "Situation Awareness" can be noted among researchers concerned with driver behaviour and in particular with the impacts of ITS on driving behaviour. This concept was developed in order to understand operator performance in dynamically changing environments, e.g. of pilots when flying an aircraft. The implications of Situation Awareness for the analysis of impacts of ITS on driving behaviour are at least twofold. On the one hand one might have concerns that an increasing automation of the driving task or parts of it which aims at increasing comfort and reducing workload might also lead to a loss of Situation Awareness. On the other hand a loss of Situation Awareness might also be the result of performing in-vehicle tasks while driving. The two German national projects reviewed in the present report were devoted to this issue. More precisely, both project made an attempt to develop methods for the measurement of Situation Awareness in the automotive domain.

Recent relevant research projects in the U.K. which were performed at TRL and which will be briefly summarised in the chapter on national projects had a strong methodological orientation. First, a research programme was launched which targets at the examination and further development of the occlusion technique as a procedure to assess visual demands from In-Vehicle Information and Communication Systems thereby focusing in particular on age effects. Second, a project was recently finalised which was performed to benchmark the distraction caused by mobile phone use in the driving simulator.

INTRODUCTION: RECENT DEVELOPMENTS AND ACTIVITIES IN EUROPE

As an overall goal Task Force D aims at describing and continuously updating the "state-of-the-art" on the impact of ITS on relevant criteria of driving behaviour. This is done primarily from a safety-oriented perspective, i.e. special focus is put on potential risks due to perceptive and/or cognitive interference with the primary task of driving or, for instance, phenomena like behavioural adaptation. From a system-oriented perspective the focus is on in-vehicle information and communication systems (IVIS) on the one hand and speed management systems on the other. The reason for this division is simply that the impact assessment for these two types of systems implies that for each different behavioural aspects have to be addressed. Whereas for speed management systems issues like behavioural adaptation, overreliance, delegation of responsibility but also acceptance are of major concern the main question to be addressed for IVIS is their compatibility with the primary task of driving as they are not designed to support aspects of driving (i.e. longitudinal control) but basically constitute some secondary task.

As a first practical step to initialise an exchange of knowledge within the network as a starting point for a review on the impact of IVIS use on driving behaviour including the necessary behavioural methods both Task Force D and E performed workshops on 9th of September 2004 in Toulouse, France. One of the main conclusions from these two workshops was that there was a considerable overlap in the themes and contents of the presentations given, i.e. most of the studies reported at the Task Force D workshop also fitted fairly well into the framework of Task Force E and vice versa. Thus, it was decided to merge the contributions into Deliverable D.2/E.2 as one more comprehensive document. Thus, in Deliverable D.2/E.2 the presentations given at the Toulouse workshops were reviewed. These presentations covered a broad range of topics including issues concerning impact and assessment of Nomadic Devices and information management systems, assessment methods (visual occlusion, PDT etc.). Moreover, the "matrix approach" was outlined as a summary of the main aspects of applicability of various available methods.

The present report aims at completing Deliverable D.2/E.2 by summarising relevant activities on a European and national level which were started during the time period after the HUMANIST Toulouse workshop on 9th of September 2004. Thereby it is not intended to provide a complete review on the extensive empirical and/or theoretical research that has been performed in the last three years. This has recently been done e.g. by COST Action 352 (Brusque, 2007; see also chapter 4). Rather selected relevant projects and activities will be highlighted and reviewed in order to arrive at conclusions for activities under the umbrella of the NoE HUMANIST. In that sense the present report can be understood as a supplement of Deliverable D.2/E.2.

In detail, we will start with a summary of the joint AIDE/HUMANIST workshop on Naturalistic Driving (ND) studies which took place on 13th of September 2006 at the BMW premises in Munich and which represented a milestone of the recent TF D activities. Another relevant activity on the European level dealing with the impacts of information technologies on road traffic safety is COST Action 352. Main results achieved so far will be summarised in chapter 3. Finally, we will consider results from national projects performed by HUMANIST partners in Germany and in the U.K. in chapter 4 before reaching to some conclusions in chapter 5.

SUMMARY OF THE JOINT HUMANIST/AIDE MUNICH WORKSHOP ON NATURALISTIC DRIVING STUDIES

There is an increasing number of studies analysing driving behaviour in a naturalistic context. As a general rule, no measures of experimental control are taken. Rather these studies are following an observational approach by trying to examine driving behaviour on a descriptive level under conditions of everyday life, i.e. variables of driving behaviour and driver performance are recorded over a longer period of time (e.g. one year) for all rides a driver performs as part of his daily activities (e.g. commuting to/from work). Usually these studies are conducted in order to specify driver needs from observations and/or describe the impact of certain measures or systems on observed driving behaviour (e.g. Dingus et al., 2006; Sayer et al., 2005; Stutts et al., 2003).

However, as by definition these Naturalistic Driving (ND) studies do not follow an experimental approach there are concerns about their validity which are arising from numerous alternative explanations for the results produced. This means that some minimum methodological requirements need to be defined in order to ensure valid results from these time consuming large-scale studies. The joint HUMANIST/AIDE "Workshop on Naturalistic Driving Studies" on 13th of September 2006 was conducted as a pilot step towards this goal.

More precisely, the workshop addressed the methodological rules to be followed when planning Field Operational Tests (FOT) and ND studies, in order to reduce the effort of such studies, produce interpretable sets of data, analyse existing data, strengthen the conclusions drawn from such studies.

SUMMARY OF THE PRESENTATIONS

As a basis for discussion five presentations were given. The key note lecture was given by Jim Sayer (UMTRI) who can be considered as an expert with tremendous practical experiences with ND studies from studies performed by his institute.

- *"Effects of Secondary Tasks on Naturalistic Driving Performance"* (Jim Sayer, UMTRI): A comprehensive review was given on research projects performed by UMTRI in the area of field operational tests (6 projects during the last 12 years). It became clear that the UMTRI Naturalistic Driving data archive is a product of both Engineering Research Domains and Human Factors research. Results on the effects of secondary tasks on driving performance can therefore be considered as a product of a specific strategy of analysing the available data on naturalistic driving performance guided by a set of research questions. This presentation ended with several conclusions on the conditions under which drivers decide to perform secondary task activities while driving. According to the results of the UMTRI research drivers seem to prefer those situations for secondary task activities where driving skills are least needed. Moreover, some cell phone use was observed more often under special traffic conditions which may reflect a specific unexamined form of exposure to the risk of an accident.
- *"Is the 100-car study an 1000 answers study?"* (Hans-Peter Krüger, IZVW): It was pointed out that all observations one can make are naturalistic in some way. The main difference between the ND approach and an experimental approach for the analysis of driver behaviour lies in the fact that in the former case one has to "wait" until the behaviour under consideration appears whereas in the latter case it is provoked. Doubts about the unobtrusiveness of data from ND-studies were raised. Moreover, the external validity of the 100-car-study was questioned. But it was also pointed out as an endeavour

of this approach that it makes it possible to separately analyse effects of certain influences on inter-individual and intra-individual variability of driving behaviour.

- *“Naturalistic driving studies to investigate IVIS uses and distraction exposure: interests and constraints of the approach”* (Corinne Brusque, Arnaud Bonnard, INRETS): This presentation started with a review of the kind of questions for which ND studies seem to be a promising methodological tool. This was followed by detailed discussion of methodological constraints due to data protection requirements, lack of sample representativeness, lack of reliability of the data coding system and statistical problems. However, the final conclusion was that ND *“is an interesting challenge that promises many visionary outcomes”*.
- *“Driving for safety – naturalistic field studies”* (Mark Vollrath, DLR): An interesting summary of practical experiences from studies on driver behaviour under conditions of real traffic was given in terms of general statements (e.g. “Effects will always be different than you think”) which were then illustrated and exemplified. As a conclusion these statements were detailed with respect to the ND approach and closed with the statement that it is worthwhile to take all the costs and efforts to be expected.
- *“Finding a position of naturalistic driving studies in the methodological spectrum”* (Richard van der Horst, TNO): This presentation started with an extensive review of research at TNO Human Factors in the area of field observational and simulator studies which ended with several comments on the ND approach. As a weakness of the ND approach it was pointed out that it does not tell us anything about the (psychological) mechanisms underlying the observed driving behaviour. Thus, ND cannot replace “traditional” experimentally oriented approaches. Nevertheless, ND research is in an early phase of its development and future research activities should consider this and the potentials ND studies offer to generate hypotheses.

DISCUSSION

The discussion following the presentations focused on the following three general issues: comparative understanding of the utility of ND studies; interpretation of results and exchange between different methodological approaches. The results and conclusions concerning these issues will be summarised in the next paragraphs.

Comparative understanding of the utility of ND studies vs. FOT vs. experimental studies (simulator, laboratory) vs. accidentology

As a result of the discussion it was concluded that ND are one step on a scale/continuum of data acquisition methods with a low level of information given to the participants and no instructions. ND studies were considered as a reasonable methodological approach to reach the following aims:

- estimate the size of a problem or an effect,
- determine driver needs,
- study intra-individual longitudinal effects,
- test or develop algorithms,
- generate exposure data (e.g. for secondary tasks), and
- describe/understand pre-crash behaviour.

ND studies can be conducted to generate hypotheses and also to test hypotheses (BUT caveat: if data are used to test hypotheses consider that data include totally uncontrolled conditions). However, in most cases experiments are a more suitable approach to test hypotheses and should supplement ND studies. It was also stressed several times in the discussion of this point that ND studies an interesting approach to analyse intra-individual variance of driver behaviour as it is possible to collect from one driver a great amount of data over a long period of time in many different situations.

Interpretation of results (causal vs. correlational, generalization of results)

The discussion resulted in the following general conclusions:

- A final causal interpretation of data from ND studies is impossible due to numerous unknown confounded variables.
- In case of a specific ND study the relevant confounded variables have to be identified by inspection and expert check.
- The final interpretation of ND results always has to take into account results achieved with other in particular experimental techniques.
- Usually in ND studies only behaviour which is observable by means of video recordings and other data logging techniques is available. for further processing. Subjective, physiological or other performance data are usually not collected in ND- studies.
- An interesting advantage of ND studies in comparison to experiments lies in the fact that the relevant variables are on a continuum and not discrete treatments.
- Another advantage of ND studies lies in the fact that they provide information about intra-individual **and** inter-individual variance.
- Correlations and descriptive statistics can be derived e.g. as input for modelling.

Data analysis approaches (frequencies vs. link analyses vs. multiple regressions vs. data-mining)

During the discussion it was pointed out that:

- all descriptive statistics are only usable within the limits of the vehicle sensors being used.
- pattern recognition could be used to label events in the data (online and offline).
- a video protocol is necessary as confirmation of physical constellations and in depth-understanding of context related driver behaviour.
- the usage and potentials of data-mining tools have to be further investigated.
- a detailed documentation of data and (pre-)processing procedures is essential both for the exchange of data and the communication of data processing procedures and results.
- time effects and longitudinal effects (e.g. learning) have to be taken into account when data of ND studies are analysed.

REVIEW OF RELEVANT RESULTS FROM COST ACTION 352

In the framework of the COST Action 352: "Influence of in-vehicle information systems on road safety requirements", a review of existing knowledge on the impact of IVIS on driver behaviour and road safety has been produced (Brusque, 2007). This work involved several senior and young researchers of HUMANIST Network of Excellence.

The development of Information and Communication Technologies (ICT) in the field of road transport provides drivers with various functions and services that may not be related to driving or related to the trip management. Amongst these different functions, four functions have been retained as subjects of interest for this literature review:

- Phoning
- Consulting other information and communication services
- Consulting traffic and weather information
- Consulting guidance and navigation information

Moreover, a focus has been made on three driver populations, the novice drivers, the elderly drivers and the professional drivers which present a specific issue for IVIS use. Lastly, the literature review is discussed to highlight missing knowledge and to identify main questions for further researches.

NON DRIVING-RELATED FUNCTIONS

Amongst all the ICT, mobile phone is the electronic device that receives most attention from researchers and European Stakeholders. Since the years 1990, numerous researches have been carried out, using various experimental contexts to evaluate the impact of mobile phone use on the driver's behaviour (Brusque et al., 2007). If various actions can be performed on mobile phones, such as reaching for the phone, dialling a number, answering the phone or talking, research mainly focused on the impairment of driving performances due to conversing by phone, by asking participants to perform different verbal tasks intended to replicate phone conversations.

All research concluded that phoning at the wheel has a negative impact on driving, whatever the type of phone used (hand-held or hands-free). More precisely, conversing by phone while driving increases the drivers' response times and mental workload and alters their visual scanning and their Situation Awareness (SA) (Brusque et al., 2007; McCartt et al., 2006). The conversation contents and the exchange interactivity have been considered as being important factors of disturbance variations. Divergent results don't allow to conclude that drivers compensate their performance impairment by increasing safety margins. In parallel, epidemiological studies have been conducted in order to evaluate whether phone use while driving increases accident risk. These showed that cellular phone activity while driving is associated with a fourfold increased likelihood of crashing (McEvoy et al., 2005; Redelmeier & Tibshirani, 1997). Lastly, questionnaire-based surveys permitted to identify the drivers more prone to phone at the wheel and to propose some factors explaining phoning while driving (Brusque & Alauzet, 2006, in press; Lambie et al., 2002; Poysti et al., 2005; Troglauer et al., 2006). These research works, by highlighting the impact of driver's distraction on road safety, led several countries to implement specific laws to ban the use of mobile phone while driving.

Although researchers and policy makers are focused on the safety issues raised by phoning while driving, other information and communication services are available for drivers. They

can also receive, read, key and send SMS through their mobile phone or check their calls on their answerphone. Moreover, wireless Internet and in-car laptops allow them to check and to send electronic mails “on the move”.

Until now, only a few researchers have investigated exchanging messages while driving. Moreover, these works have mainly focused on the different modalities of human-machine interactions offered by such services to compare their respective impact on driving performances. Thus, visual-manual and voiced-based interfaces have been studied (Hosking et al., 2005; Ranney et al., 2005). Characteristics of voice-based interfaces have also been investigated: messages presented in a synthetic speech and human voice recorded messages (Harbluk & Lalande, 2005); system-controlled and driver-controlled interface (Jamson et al., 2004); so as levels of complexity of interface menu (Lee et al., 2001). If the impact of message exchanges on driver behaviour has been revealed whatever the modalities of the systems interface, on the other hand the driving impairment produced by message exchanges has not been compared with the driving impairment produced by phone calls. The difference between a speech communication and a message exchange still remains to be investigated.

DRIVING-RELATED FUNCTIONS

In the case of IVIS delivering driving-related information, the risk and the benefits of these systems on road safety have to be balanced. These systems are proposed to the drivers with the objectives to facilitate their driving task and to improve the safety of their travels. Indeed, the access to guidance and navigation information can reduce drivers' workload and stress induced by way finding and the provision of traffic or weather information can help drivers in managing the difficult situations related to critical driving conditions. But these system benefits could be overcompensated by poorly designed Human-Machine Interfaces (HMI), introducing distraction or inducing inappropriate driver behaviour.

In the case of traffic information, research dealt with the identification of users' needs on pre-trip or on-trip information and the identification of the target groups who are more likely to use them. These research outcomes have a direct interest for the systems design with regard to both their contents and their technical usability. Nevertheless, more research should be carried out, focusing on the systems acceptance and on their potential influences on road user behaviour, mode choice, travel planning, etc (Kaufmann et al., 2007). The same acknowledgement is pointed out by authors for weather information. Until now, research focused mainly on the technical issues raised by providing drivers with relevant weather information and on the development required on data-collection, data-forecast and data-transmission for delivering to drivers, exact and real-time information. On the other hand, there is a lack of research analysing the possible influences on road user behaviour of weather information systems.

Amongst the IVIS delivering driving-related information, guidance and navigation systems are the device that presented the most interest for human factors researchers. The benefit of electronic devices in comparison with paper maps have been highlighted by several authors in terms of navigation errors, trip durations, drivers' workload and driving behaviour (Burnett & Joyner, 1997; Lee & Cheng, in press; Wochinger & Boehm-Davis, 1997). Besides this benefit, many researchers have pointed out their potential distracting effect and their potential relation to the risk of crash. The statistics of the Japanese National Police Agency confirmed this link by identifying interactions with navigation systems as being one of the cause or the contributing factor for crashes.

To reduce these potential negative consequences, it is of major importance to design these systems properly. Several investigations have been conducted and permitted to edit guidelines for the development of these devices. Thus, their Human-Machine Interfaces could be optimized in terms of information content (turn-by-turn information, electronic maps; landmarks...), presentation modes (vocal or/and visual) and interaction protocols (destination entry methods) in order to limit the risks of distraction (European Commission, 2007; Pereira & Carvalhais, 2007). While the penetration of navigation systems in the European market becomes higher and higher, their patterns of use in everyday life remain unknown just as their long-term effects on driver behaviour.

DIFFERENTIATION ACCORDING TO THE DRIVER CHARACTERISTICS

Amongst the driver population, three driver groups have been identified as presenting specific safety issues related to IVIS use.

Novice drivers are the first group of interest due to the road safety issues they raise (Pereira & Turetscheck, 2007). Amongst the drivers groups, they have the highest crash rates and road accidents are a major cause of death among them. Nevertheless, the crash-risk exposure of novice drivers is not the same during the first years of driving. Indeed, Novice drivers seem less exposed to crash risks during the learning period. Their crash rates are highest during the first months just after the licensure, but drop substantially over after this period. This high accident risk has been attributed according to the authors to the risk-takings of the youth and to the skill deficits due to driving inexperience. On one hand, young drivers drive more at night and they are more exposed to extra risk at these moments. On the other hand, the early stage of driving is a period of skill acquisition; that goes from the use of declarative knowledge to the use of procedural knowledge that can be applied quickly and automatically in specific situations. Driving experience has also an impact on the efficiency of visual attention allocation to keep the vehicle in its line and to detect potential critical events.

Until now little research investigated the interaction of novice drivers with IVIS, even if several IVIS on the market can help to solve some of the problems that are typical of novice drivers, such as: speeding and driving with short following distances (Burnett & Joyner, 1997; Young, 2004). Nevertheless, the smaller experience of novice drivers forces them to devote larger amounts of attentional resources to their actions, their decisions and to monitoring their own vehicles. They are so more likely to suffer from overload; their attentional capacities can be insufficient to fulfil the demands of the driving situation or to perform a dual task while driving such as IVIS use (Lansdown, 2002). Lastly, technology seems more acceptable by young subjects which are also more ready to use it, as for example mobile phone. However, their degree of acceptance seems not equal for every technology. Additionally, much more research is needed for analysing the effects of IVIS on young drivers but also on the acceptance of such systems.

The elderly population, that represents the most growing segment of the overall population, has been identified as the second driver group of interest (Simoes, 2007). In most OECD member countries, it is expected that by the year 2030 one person out of four will be 65 years old and over (OECD, 2001). In terms of road safety, elderly people are three times more likely to suffer a fatality than younger people if injured in an accident due to their frailty and vulnerability. Moreover, as one grows older, many structural and functional changes occur, leading to declines in the ability to perform common daily tasks and a continuous need for medication. The main findings concerning age-related declines and their effects on the driving task are the following (Holland, 2001):

- Declines of visual, cognitive and motor abilities;
- Difficulties in discriminating relevant information and more needed time to process it;
- Reduction of the size of the useful field of view (UFOV);
- Temporary UFOV reduction with increasing mental workload;
- Declines in selective attention and attention switching;
- Highly distractible and may easily be confused by competing sources of information.

However, in a healthy ageing process, the effects of age-related decrements on driving performance can be limited with a stable and user-friendly road environment and if elderly drivers can mobilize their previous experience and develop some strategies to compensate their declines.

New technologies can also support elderly drivers while driving by compensating some of their functional limitations (Hakamies-Blomqvist et al., 2004; Shaheen & Niemeier, 2001). The most promising ones include Route Guidance, Emergency Vehicle Location and Response systems, Collision Warning Systems, Obstacle detection Systems, Assistance on Lane Changing and Merging and Vision Enhancement Systems.

Nevertheless, elderly drivers seem more reluctant to adopt new technologies, specially the women. When they use it, they need more time to interact with the systems and they are more prone to mental overload than younger drivers. The research reviewed by Simoes (2007) stresses the importance of Human Factors studies to design easy-to-use and intuitive systems. Ergonomics recommendations are listed to design appropriate Human-Machine Interactions for elderly in accordance with the age-correlated changes in visual, cognitive and motor functioning. At last, below the risk of distraction, the author pointed up three major research issues to address by the analysis of the long terms effects of new technologies on elderly drivers behaviour and skill.

1. The difficulty to mobilize previous experience in a driving environment in constant change;
2. The potential decreases in fitness for driving due to an excessive trust on new technologies and a delegation of responsibility towards systems;
3. The potential of new technologies to change travel patterns and to increase risk exposure.

The professional drivers are the third group studied in the framework of this literature review. A difficulty to apprehend as a whole the professional drivers group is due to the diversity of this population, between the truck drivers, the emergency drivers, the taxi drivers, the delivery men, the drivers of public transport vehicles etc.

With regard to professional drivers the situation takes a new dimension of complexity due to the context of the use of IVIS (Rehnová et al., 2007). Whereas car driving in a private context implies that systems are implemented and used voluntarily this situation changes in the context of professional use. The professional drivers are in most cases not the owners of the vehicles and the decision to equip the vehicle with one or more IVIS is not taken by them. It became obvious that IVIS use has to be considered as a part of their work activity which implies that there are less degrees of freedom to decide if a system is used or not or to make choices according to personal preferences.

The first and main reason for using Telematic applications in fleet management is logistic and commercial. These applications mean higher performance, better control, organisation, document registration and checking of the work regime and the efficiency of work time. They

are used to collect and provide data transmission in the vehicle for mileage, fuel consumption and waiting times. They can monitor the driver's behaviour, speed and hours. The dispatcher can obtain information about the position of the vehicle and can evaluate the driving style. They can allow sending messages and navigation advice. For many occupational branches the introduction of new modern technologies has led to changes in the nature of the work itself (de Croon et al., 2004).

The use of fleet management systems can affect the truck driver in several ways. This impact can be positive in the sense of supporting road transport companies in the registration of their drivers' work and rest hours. But fleet management systems can also influence the driver in negative manners as well. These systems can lead to tighter schedules, because they support more efficient route planning. Moreover, truck drivers can perceive these systems as a tool to monitor their work performance. As a result, the truck driver may feel restricted in determining how and when to perform his work (routing, when and where take a break etc.). These negative feelings can result in psychosocial problems. In particular, low job control and high job demands have been found to predict mental health complaints such as depression and fatigue, and unfavourable organizational outcomes such as decreased organizational commitment (de Croon et al., 2002).

The research reviewed in the COST Action 352 report focused on the truck drivers' work, in its organisational context and on how this is influenced by ICT with positive or negative manners (Rehnová et al., 2007). However, none of the research explicitly addressed the question of the impact of these technologies on actual driving behaviour from a safety perspective. This seems to be a significant issue for future research in particular because professional drivers, on the one hand, seem to be restricted in their choices to use or not use the systems. On the other hand professional drivers spend almost their working time driving a vehicle and they can be so expected to be highly experienced and skilled drivers.

NEEDS OF FURTHER RESEARCH

This literature review permits to highlight the missing knowledge and to give some recommendations for further researches (Gelau, 2007).

The impacts of phoning on the different aspects of driving behaviour are well documented by a sound body of knowledge whereas the impacts of other ICT and the functions they provide seem to be largely unexplored. Taking into account the rapid development in the field of ICT, not only more research but also a different view on the systems are required. Developing a generic taxonomy of the performed tasks with these various systems while driving seems necessary in order to produce results which can be generalised and allow for predictions of the impacts of future developments.

For information related to the trip management, until now the research approach that prevailed over was a user centred design approach that permits to identify users' needs, to specify systems functionalities and to edit recommendations in terms of Human-Machine interactions. There is yet a lack of knowledge on their conditions of use by drivers in everyday life, on their impact on travel patterns, and on their long term effects on driver behaviour. More precisely, further research is needed to evaluate how IVIS influences actual driving behaviour on strategic, tactical or operational levels and if correlations with indicators like workload, stress, comfort etc. exist.

The focus of the review of literature on three driver populations shows that drivers' characteristics and specificities are important parameters to consider in further behavioural studies. The effects of age and gender are to be taken in consideration. But also the driving

experience, the driving style, the practice of new technologies and the work constraints must be considered as potential factors, explaining observed behaviour while drivers interact with IVIS at the wheel.

NATIONAL PROJECTS*GERMANY: ONGOING PROJECTS ON DRIVERS' SITUATION AWARENESS*

Since several years a considerable interest in the concept of "Situation Awareness" (SA) can be noted among researchers concerned with driver behaviour and in particular with the impacts of ITS on driving behaviour. SA was developed in order to understand operator performance in particular in dynamically changing environments, e.g. of pilots when flying an aircraft but also of physicians during an operation (Wickens & Hollands, 2000). According to the definition proposed by Endsley (1995a) SA is "*the perception of elements in the environment within a span of time and space, the comprehension of their meaning and the projection of their status in the near future.*" In other words, the concept of SA integrates several different cognitive processes to describe how people know what is currently going on and how the situation will evolve (e.g. Baumann et al., 2006).

The implications of this concept for the analysis of impacts of ITS on driving behaviour are at least twofold. On the one hand one might have concerns that an increasing automation of the driving task or parts of it which aims at increasing comfort and reducing workload might also lead to a loss of SA. On the other hand a loss of SA might also be the result of performing in-vehicle tasks while driving. As SA is closely linked to Working Memory (WM) this has especially to be expected if in certain situation the in-vehicle task and the primary task of driving are competing for this capacity limited resource (c.f. Wickens & Hollands, 2000).

In the year 2005 BAST and the German Association for Research in Automotive Technology (FAT) have jointly initiated a research project with the title "The Concept of Situation Awareness and Driving Safety" which is currently conducted at the Institute for Traffic Sciences at the University of Würzburg (WIVW) (Rauch et al., 2007). It is the overall goal of this project to analyse the transferability and applicability of the concept and methods developed to assess SA in the aerospace domain in the context of driving an automobile. For this purpose the SAGAT-Method (Situation Awareness Global Assessment Technique; see e.g. Endsley, 1995b) was adapted for assessing drivers' SA in a driving simulator experiment. The SAGAT-method is a tool for measuring pilots SA by "freezing" the situation at randomly varying points in time, occluding the scene and interviewing the pilot about task-relevant aspects before continuing. However, first results of this research performed in the WIVW moving base driving simulator indicate some interactions between demands of the primary task of driving and the effects of performing a secondary task in the SAGAT-performance on the one hand and a lack of correlation between SAGAT-performance and indicators of driving performance on the other hand which can be considered as evidence that the SAGAT-method is not the best option when a method for assessing drivers' SA has to be selected. For this reason ongoing research activities performed under the umbrella of this project concentrate on the further development of indirect, performance based measures for application in the automotive domain. For this purpose a three-level model of compensatory behaviour was developed and tested in two simulator experiments. This model makes predictions about the self-initiated start and duration of secondary task performance depending on the demands of the traffic situation. First, preliminary results show that these parameters variables can be considered as measures of SA.

A slightly different approach was adopted by another German project which was at about the same time initiated at the Chemnitz University of Technology (Baumann et al., 2006; Baumann & Krems, 2007). This research started with a theoretical examination of the concept of SA (Endsley, 1995) which revealed that the precise cognitive mechanisms underlying SA as a process but also a person's current status of SA are not well understood. To close this gap it was suggested to combine the *Theory of Text Comprehension* (Kintsch,

1998) and the *Theory of Action Selection* (Norman & Shallice, 1986) into a *comprehension-based model* which could explain how SA is constructed and maintained. This model emphasises the role of WM processes for the construction and maintenance of SA. Thus, regarding IVIS tasks it can be concluded that the strongest effects on drivers' SA (as a precondition of safe driving) will result from those tasks which impose a high load on WM.

In order to measure the expected effects of IVIS use on SA an experimental procedure was developed which is based on the secondary task technique. Contrary to the research carried out by WIVW this procedure is designed for application in the laboratory and parameters are defined to reflect those processes which are assumed to be essential for the construction and maintenance of SA by the authors comprehension-based model, i.e. WM and visual attention (Baumann et al., 2006; Baumann & Krems, 2007). The procedure requires the subject to perform an IVIS task as the primary task and a choice reaction task as the secondary task. This choice reaction task combines a visual perception task with a memory task. The visual component is similar to the Peripheral Detection Task (PDT) (z.B. van Winsum et al., 1999) and requires the subject to respond by press of one of two buttons to one of two visual stimuli presented at an angle of 23° and with a randomly varying interstimulus interval of 1 to 3 seconds. The cognitive or WM component is addressed by the context of the choice reaction which defines its correctness. The context changes after every 3rd to 5th trial. This means that e.g. pressing button 1 which was the correct response to stimulus A in context x is the correct response to stimulus B in context y. Following the logic of the secondary task technique the performance parameters measured are expected to reflect the WM and attentional resources which are not occupied by the IVIS task (primary task in this case!) to be assessed. These measures are the *detection rate* which reflects the visual load and the *correct detection rate* which reflects WM load. First validation studies performed so far under the umbrella of this project indicate that the detection rate is indeed sensitive against experimental manipulations of the visual load induced by a task whereas the question is still not finally answered for the correct detection rate (Baumann & Krems, 2007).

UNITED KINGDOM: PROJECTS ON THE ASSESSMENT OF VISUAL DEMANDS AND DISTRACTION FROM IN-VEHICLE-SYSTEMS

Recent relevant research projects in the U.K. which were performed at TRL and which will be briefly summarised in this paragraph had a strong methodological orientation. First, a research programme was launched which targets at the examination and further development of the occlusion technique as a procedure to assess visual demands from IVIS thereby focusing in particular on age effects (Horberry et al., 2007). Second, a project was recently finalised which was performed to benchmark the distraction caused by mobile phone use in the driving simulator (Parkes et al., 2007).

The occlusion project was inspired by work done under the umbrella of ISO and aimed at supporting a recently published International Standard (ISO 16673, 2007) which defines the experimental protocol for the occlusion method to assess visual demand due to the use of in-vehicle systems. This standard does not define the age ranges of subjects participating at an occlusion tests but only recommends that 20% 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 a way that they could be expected to differ from each other with regard to Total Shutter Open Time (TSOT) and the resumability 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 (for example, to reflect a population- such as truck drivers being mainly male), but this does not appear to be a significant factor in the Occlusion results.

Although it is a well established fact that the use of mobile phones while driving is associated with an increasing accident risk there are still numerous issues to be resolved. The aim of the recently finalised TRL project on hazards of mobile phones (Parkes et al., 2007) was to benchmark the distraction caused by hands-free mobile phone conversations in relation to other conventional in-car tasks and to similar conversations with a front seat passenger. The study was conducted in the driving simulator where subjects perform one of several tasks (hands-free phone conversation, conversation with a passenger, operating climate and radio controls) simultaneously to their test drive. Moreover, there were two control conditions where participants performed the task of driving and the conversation tasks alone, i.e. under single-task conditions. The results were consistent with other experimental research substantiating that drivers experience a reduction in situation awareness when they are engaged in a conversation. In particular, when subjects were involved in the conversation tasks both with the front seat passenger and via the mobile phone, there was a reduction in time spent looking away from the road ahead leading to a reduced number of glances to the speedometer which was then reflected by a higher variation in speed. Reaction time measures indicated that the mobile phone conversation was more distracting than the conversation with a passenger. The increase in response time and the number of missed road signs showed that they were not paying the same level of attention to the road scene than under the control condition.

The nature of driver distractions from mobile phones and other wireless devices is changing rapidly with the current shift to mobile internet applications, including navigation, instant messaging, social networks and location based services. These services may be fully integrated into the driver ergonomics of new cars over time, but currently they are typically delivered through after-market devices or standard mobile phones in cradles which are not designed for multimedia interaction. Further simulation research is being considered to investigate how best to utilise the rich media capabilities of next generation devices in moving vehicles, while supporting the driving task and minimising driver distraction.

SUMMARY AND CONCLUSIONS

The “Workshop on Naturalistic Driving Studies” can be considered as a pilot activity, at least on a European level. It became very clear from the keynote lecture given by Jim Sayer (UMTRI) that this approach has already some “tradition” in the U.S. and that the experiences which were accumulated there can be used beneficially for future research efforts in Europe. Nevertheless, the conclusions drawn as the result of the discussion are still on a very global level and need further refinement in order to come to methodological recommendations for the performance of Field Operational Tests (FOT) and Naturalistic Driving studies in future European research programmes

The literature review carried out, in the framework of the COST Action 352, showed that amongst all the IVIS available on the market, all the functions provided to the drivers did not receive the same interest from researchers. The impacts of phoning on the different aspects of driving behaviour are well documented whereas the impacts of other information technologies and the functions they provide seem to be largely unexplored. In the case of the information related to the trip management, such as traffic or guidance information, the research approach that prevailed over until now was a user centred design approach. The effects of these systems on drivers' behaviour and on road safety remain to be investigated. At last, drivers' characteristics and specificities are important parameters to consider in further behavioural studies.

"Situation Awareness" (SA) is a theme which appeared in both the British and the German projects reviewed in the present report. But whereas SA was used as an explanatory concept in the TRL project the German projects focused on the development of methods for its measurement. Obviously concepts and methods developed in the area of aeronautics cannot be simply transferred into the automotive domain. There seem to be numerous constraints with regard the different nature of the environment, the task of flying an aircraft vs. driving a car and, of course, the population under consideration (pilots vs. drivers). Nevertheless, SA seems to be a promising concept also for the automotive domain and in particular for the investigation of impacts of ITS on driving behaviour which means that the paradigms developed in the projects reviewed here deserve further investigation.

Finally, further developing the occlusion technique seems to remain a relevant issue despite of the publication of ISO 16673 in April 2007. This is reflected not only by the TRL project reviewed in the present report but also e.g. by activities of HUMANIST TF 2 and the AIDE project (Schindhelm & Gelau, 2006). Strictly speaking, this is, of course, a theme which might better fit into the programme of TF E. But as already became clear at the Toulouse workshop in September 2004 there are strong overlaps between Task Forces D and E which resulted in a joint Deliverable D.2/E.2. Obviously it is difficult to deal with methods (TF E) and results (TF D) independently from each other. As a consequence this does not mean that a stronger separation of both aspects is needed but that the linkages should be used. On the one hand this could indicate a need for an update of the "The Matrix" on assessment tools and methods developed by HUMANIST TF E and finalised in December 2004 (see Deliverable D.2/E.2, Annex 16) based on recent studies on the effects of IVIS on driving behaviour and SA in the laboratory and in the driving simulator. The latter ones are clearly underrepresented in this document. On the other hand future field studies and/or ND Studies might also benefit from the methodological work performed under the umbrella of HUMANIST TF E.

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