Methodologies for the assessment of ITS in terms of driver appropriation processes over time

Deliverable 6 of Task Force E
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1. Summary

This report provides information on methodologies for the assessment of ITS in terms of driver appropriation processes over time. The report provides the background theory of what is meant by “driver appropriation”. Driver appropriation is described on three levels: operational (concerning skill acquisition), tactical (concerning behaviour in specific situations) and strategic (concerning attitudes and knowledge). Several factors are believed to influence driver appropriation including system characteristics, situation characteristics and driver characteristics. A conceptual model is developed which aims to draw attention to relevant variables and their interdependences in influencing driver appropriation.

The report introduces methods to assess driver appropriation and discusses a model for integration of the methods. Because driver appropriation and the integration of appropriation methods is such a new work area important new issues have been raised and explored although much work remains to be done. The next phase of work in this area should focus on further developing the conceptual model of driver appropriation and the model for integration of appropriation methods.

2. Introduction

Main objectives

One of the main objectives of TF E is to identify methodologies to assess the impact of ITS on driver cognitive processes over time. The aim of this deliverable was to determine a set of methodologies suitable for the assessment of ITS in terms of driver appropriation processes over time. Eight methods were collated and presented during a workshop in Soesterberg. The presentations were presented in Deliverable E.5. This deliverable (E.6) provides a detailed description of 12 methods that can be used to assess driver appropriation of ITS over time. The methods are described using a standard template (Appendix 1). In addition brief descriptions are provided in Appendix 2 and case studies for two methods are provided in Appendix 3. The main body of the deliverable provides an overview of driver appropriation processes and a discussion of scope for an integrated methodology for appropriation measurement informed by an underlying model of driver appropriation processes. Appendix 4 cites an article written for the elimpact project to summarise how ITS affects safety and the mechanisms for dependancy.

Issues of equipped/unequipped users and learning of drivers from other drivers is outsider of the scope of our consideration. TF E decided to focus on the appropriation issues of individual drivers. It was suggested that these important context-setting remark should be made in the introduction to subsequent TF deliverables.

3. Theoretical Background of Driver Appropriation

Road safety related to IVIS and ADAS

In an attempt to increase road safety and to reduce the number of traffic deaths and injuries, active safety in-vehicle technologies gain more and more importance compared to passive safety technologies. The main aim is not only to reduce actual crash consequences, but also to minimise crash risk. Advanced Driver Assistance Systems (ADAS) are electronic in-vehicle systems that support the driver while driving and thereby enhance driver (and traffic) safety and comfort. Often a distinction is made between In-Vehicle Information Systems (termed IVIS) - that primarily support the driver by providing him/her with driving-related information (e.g. route guidance...
systems) - and ADAS that to a higher degree actively intervene in the driving task and in vehicle control. Such systems range from warning systems that give notice to the driver if specific safety limits are reached (e.g. Lane Departure Warning – LDW), through to systems that advice the driver to act in a particular manner (e.g. lane change assistance systems), to systems that take over some part of vehicle control (e.g. Adaptive Cruise Control – ACC - that controls headway to the vehicle in front). However, because the distinction between ADAS and IVIS is sometimes difficult to follow and apart from that somewhat artificial, it is more reasonable to talk about ‘functions’ than about ‘systems’ and the particular driving subtask(s) these systems aim to support in hierarchical control models of driving (e.g. COCOM/ECOM, Hollnagel & Woods, 2005).

Although Intelligent Transportation Systems (ITS – including both IVIS and ADAS) have the ultimate goal to enhance traffic safety, their effects on driver behaviour and human performance may not be as positive as expected in all situations. In fact, currently it seems difficult to predict the full range of possible effects.

Safety concerns with IVIS are primarily related with the Human-Machine Interface and Human-Machine Interaction (HMI), which should be designed in a way to minimise driver distraction and overload. Safety concerns with ADAS however are primarily about all negative human performance consequences that arise in relation with the automation of task processes, as extensively studied in other domains like aviation (Parasuraman & Mouloua, 1996). Because ADAS - according to their type and functionality - intervene in different levels of the control processes involved in driving, they change the way the driving task is performed and affect the information processing and action regulation processes involved in driving. The “relying” function of ADAS may indeed positively influence driver performance and comfort in non-critical (“normal”) driving situations, but may have negative impacts in situations that suddenly demand for drivers’ intervention; for instance situations that lie beyond the ADAS’s functional scope or disturbing events such as system failures or malfunctions. Problematic effects of driver assistance systems that may compromise safety are for example overreliance on systems and excessive trust in system capabilities (Muir, 1994; Muir & Moray, 1996; Lee & See, 2004; Lee & Moray, 1994; Lee & Moray, 1992; Parasuraman & Riley, 1997; Dzindolet et al., 2003), complacency (Parasuraman, Molloy, & Singh, 1993; Moray & Inagaki, 2000; Moray, 2003; Farrell & Lewandowsky, 2000), vigilance problems and high mental workload due to system monitoring demands (Parasuraman et al., 1996; Warm, Dember, & Hancock, 1996; Molloy & Parasuraman, 1996; Hancock & Warm, 1989; Desmond & Hancock, 2001; Masalonis, Duley, & Parasuraman, 1999; Parasuraman 1987), underload (Matthews & Desmond, 2002; Desmond, Hancock, & Monette, 1998; Carsten & Nilsson, 2001), and reduced Situation Awareness (Endsley, 1996; Kaber & Endsley, 2004; Endsley & Kaber, 1999; Endsley & Kiris, 1995; Adams, Tenney, & Pew, 1995; Parasuraman, Sheridan, & Wickens, 2000).

The effects that one particular system or function may have in the short-term or long-term are difficult to predict. First of all, the above mentioned causes or underlying factors are interrelated. If a drivers’ vigilance decreases over time due to underload, he or she may invest less effort in suspiciously monitoring the system and may be more prone to rely on a system’s actions than he or she would probably do so in the first instance. Second, a particular system or function does not lead to a number of effects “per se”, but the effects evolve from an interplay of different factors, such as system characteristics (performance, purpose, functionality, reliability), characteristics of the HMI (transparency, predictability, comprehensibility, feedback), the context of use (simulator vs. real traffic, time constraints, task demands), and driver characteristics (age, gender, driving experiences, cognitive abilities etc.), attitudes and motives (locus of control, sensation seeking, driving style, propensity to trust etc.). Third, particular observable behaviours may be caused by different underlying factors, which are often difficult to distinguish/assess (e.g. If a driver fails to detect a system malfunction event, did he/she trust the system “too much” and therefore stop continuous system monitoring? Or did he/she delegate responsibility to the system and intentionally monitor the systems’ actions less often than what would be considered optimal? Or did the system provide insufficient feedback about its state and behaviour, and the driver was “out-of-the-loop”?). Fourth, apart from changes in information processing and action regulation induced
by ADAS, drivers may adapt their behaviour in a “voluntary” way to the changed demands according to their attitudes and motives. One particular concern in this regard is the problem of risk compensation, i.e. the fear that drivers may adapt their behaviour to the changes in the human-vehicle system in a way that offsets the intended safety benefits (e.g. by omitting to check the left outside mirror before lane changing when equipped with a blind spot detection warning system).

**Risk compensation and its influence on behaviour**

Risk compensation is frequently mentioned as the underlying reason why traffic safety measures do not always show the expected positive benefits. Drivers are found to adapt to changes in their environment previously expected to enhance traffic safety in a way that sometimes even counteract the intended effect (e.g. Aschenbrenner et al., 1992).

Motivational theories of driving emerged in the 1960s and 1970s to account for driver motives and attitudes in determining driver behaviour and drivers’ response to changes in the road-traffic system. They focus on the concept of risk which is seen as the main factor influencing behaviour. Examples of motivational theories include risk compensation models (risk homeostasis theory, Wilde, 1982), risk threshold models (zero-risk model, Näätänen & Summala, 1974; Summala, 1988), and risk-avoidance models (Fuller, 1984; 1988). Motivational models have been criticised for several reasons (e.g. McKenna, 1982, 1985, 1988; Evans, 1986) and produced debates on the nature and validation (measurement) of the internal mechanism (of risk evaluation) guiding behaviour and on the different facets of risk (e.g. Janssen & Tenkink, 1988; Summala, 1988; Rothengatter, 1988). Recent theoretical accounts on the modelling of risk and motivational aspects of driving behaviour were presented during the ‘International Workshop on Modelling Driver Behaviour in Automotive Environments’ which was organised by HUMANIST Task Force C in Ispra, in May 2005 (Vaa, 2005; Summala, 2005; Fuller, 2005; Janssen, 2005; Van der Horst, 2005).

Will drivers compensate for the safety-features brought into their vehicle with new driver assistance systems? Evidence on the effects of safety measures in general as well as common sense suggests that there is clearly a potential for compensatory behaviour. Risk compensation is likely to influence actions, but not determine them absolutely (Hedlund, 2000). So there is a need for studies investigating short-term and long-term changes in driver behaviour when they drive with a particular assistance system. Empirical evaluation of compensating behavioural changes in response to a measure or a system on an individual level is, however, associated with some difficulties: “First, risk compensation predicts that behaviour will change but does not predict how it will change, so we don’t know what to observe. Studies could not examine all the possible ways in which compensating behaviour might occur. Second, behaviour change is difficult to measure. We may be able to measure large changes such as performing a task more quickly but usually cannot measure more subtle changes such as increased carelessness” (Hedlund, 2000, p. 84).

On an aggregate level, for instance, Evans examined a number of studies and compared the actual effects of road safety measures with the effect that was predicted in the absence of any compensating behaviour change (Evans, 1991, 1985). Evans found that there is no evidence for the complete compensation predicted by risk homeostasis (Janssen & Tenkink, 1988); however, effects can be very widespread. In a review of studies on vehicle safety standards, seat belt laws, and motorcycle helmet laws, Hedlund (2000) concludes that “evidence strongly suggests that various amounts of risk compensation have occurred in response to some safety measures but not in response to others” (p. 86).

In summary, the question seems not to be whether there is risk compensation or not, but “when and how much”. When may compensation occur in response to a safety measure? How likely is it to occur? What are its possible consequences, both direct and indirect?” (Hedlund, 2000, p. 87) Or, as Janssen discusses: “While ABS and seat belts are apparently demonstrations of the
Hedlund, following others (e.g. OECD), mentions four factors that influence compensation in response to safety measures. These factors are supposed to interact with each other.

| (1) Visibility: | Compensation occurs only in response to changes that are visible. Sagberg, Fosser, & Sætermo (1997) argued in a similar way when they found changes in drivers car-following behaviour (i.e. closer following) when they were equipped with an ABS, but not when they were equipped with an airbag.

   “Rule 1: If I don’t know it’s there, I won’t compensate for a safety measure.”

(2) Effect: Compensation occurs only to changes that affect drivers’ behaviour or attitude. Does the measure make driving easier or harder? Is it annoying? Does it change my perception of risk?

   “Rule 2: If it doesn’t affect me, I won’t compensate for a safety measure.”

(3) Motivation: Compensation occurs only when there is a motivation to change behaviour (e.g. habits, utility maximisation, Janssen & Tenkink, 1988).

   “Rule 3: If I have no reason to change my behaviour, I won’t compensate for a safety measure.”

(4) Control: Compensation occurs only when the driver can control the situation, i.e. is free to change his/her behaviour or actions if he/she wants to.

   “Rule 4: If my behaviour is tightly controlled, I won’t compensate for a safety measure.” (Hedlund, 2000, p. 87)

Hedlund proposes to combine the estimates for each factor (“no, not at all, zero”, “maybe, moderate, some”, “yes, strong, a lot”) in a combined compensation index. Compensation is:

- unlikely if any of the factors are zero;
- more likely if each factor reaches moderate levels;
- likely if each of the four factors is high.

We can be sure that drivers adapt in one way or the other in response to ITS. Risk compensation may be one effect of this adaptation that might to a more or less degree offset the expected safety benefits associated with these systems. Other causes of adaptation may be less “voluntary” in their motivation, but may arise from changes in the cognitive processes involved in driving due to the changing driving task demands caused by ITS. In HUMANIST Task Force E we have focused on the entirety of these processes on an individual level that we summarise under the term “driver appropriation”.

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Driver appropriation and behavioural adaptation

The entirety of behavioural changes in response to a safety measure is generally referred to as ‘behavioural adaptation’ (e.g. Sagberg et al., 1997; Rudin-Brown & Parker, 2004; Rudin-Brown & Noy, 2002; Hoedemaeker & Brookhuis, 1998; Comte, 2000; Dragutinovic et al., 2004). An Organisation for Economic Co-operation and Development (OECD) report states that “Behavioural adaptations are those behaviours which may occur following the introduction of changes to the road-vehicle-user system and which were not intended by the initiators of the change. Behavioural adaptations occur as road users respond to changes in the road transport system such that their personal needs are achieved as a result. The adaptations create a continuum of effects ranging from positive increase in safety to a decrease in safety” (OECD, 1990).

In HUMANIST Task Force E we have developed a definition of ‘driver appropriation’ (refer to previous Deliverable: E.5). In developing this definition we follow the OECD definition of behavioural adaptation. In addition, we further emphasise that appropriation does not only include observable behavioural changes, but also changes in cognitive, regulatory and motivational processes that underlie those observable behaviours. We therefore adopt a wider view regarding the nature of the adaptation processes.

Two workshops; one in Bron in March 2006; and the other in Soesterberg in December 2006 (Deliverable E.5) were held for HUMANIST Task Force E. During these workshops we arrived at the following common working definition of driver appropriation:

“Acquisition of knowledge, skills and attitudes underlying short term and long term changes in behaviour”

As stated in this working definition, driver appropriation in response to ADAS may occur directly after introducing a new system into the vehicle (e.g. short-term changes in workload), as well as after a certain period of time of driving with the system. Furthermore, the definition emphasises the different nature of causes underlying driver appropriation, which are knowledge (e.g. of how a system works in different conditions), skills (e.g. in using /driving with the system), and attitudes (e.g. trust in the system).

In order to conceptualise driver appropriation we regard it as useful to view different aspects of appropriation in relation to the three levels of the driving task as proposed by hierarchical control models of driving (Michon, 1985).

![Driver appropriation diagram](#)

Appropriation on the ‘operational level’ of the driving task is mainly concerned with skill acquisition in how to operate a system. For IVIS, this refers primarily to learning how to “navigate” through a human-system dialogue (e.g. menu structures, when and how to enter certain inputs...
etc.), and how to operate the controls (e.g. dial and push button). When driving with ADAS, drivers have to learn how to operate a system (to integrate a system’s actions) during vehicle control actions (e.g. steering, braking etc.)

Decisions and skill in how to use or to apply a system in particular situations and driving manoeuvres (overtaking, turning, or lane changing) primarily affect driving on the ‘tactical level’. For IVIS, learning to time-share system operations with the driving task is the most important task on this level. Overall, behavioural adaptation in response to ITS is observable on the tactical level of the driving task.

Changes in drivers’ knowledge, attitudes and motives (e.g. overall risk taking, trust in a system) will mostly affect the ‘strategic level’ of the driving task, and thereby influence control on the lower levels. As the three hierarchical levels do interact with each other, adaptation at one level of driver control has influence on the other levels as well.

With regard to IVIS possible negative appropriation effects are visual distraction and cognitive overload, i.e. drivers inappropriately allocate their visual attention between the road scene and the visual in-vehicle display (and take glances away from the road that are too long) or, in the case of cognitive overload, drivers are “mentally distracted” resulting in a diminished cognitive capacity that can lead to poor situation assessments and event detection (Engström, Johansson, & Östlund, 2005; Recarte & Nunes, 2003).

Appropriation in response to ADAS will in the first instance occur in that specific aspect of the driving task where a system is intervening. For instance, a Heading Control system that automates the driver’s lane keeping task is likely to improve lane keeping performance and reduce lateral position variation. Aside from that apparent and somewhat predictable effect, it is important to consider and assess unanticipated appropriation effects in other driving subtasks and underlying information processes that may occur following this change in the driving task or as compensation to this change. For example, in a study on Adaptive Cruise Control (ACC) Hoedemaker & Brookhuis (1998) found that headway to vehicles in front decreased, but average speed increased. Furthermore, the use of the left lane and variation in lateral position increased. In response to the changes in task demands and the impact on driver attitudes and motives there is an additional potential for other indirect - “secondary” – appropriation effects, for instance a withdrawal of attention away from the driving task and an allocation of attention to non-driving related activities (e.g. mobile office functions like Email, mobile phone etc.).

A review of studies on behavioural adaptation in response to ADAS carried out in the European AIDE project indeed shows a diversity of behavioural changes that were observed and which differed in magnitude and direction (Saad et al., 2004). Even with regard to one particular system, results were sometimes similar, and sometimes contradictory, highlighting the influence of the functional system characteristics (algorithm) and the design of the HMI on drivers’ behavioural response. Aside from that, results highly depend on the “methods used, the type and number of variables selected for assessing the impact of the system, and finally the (implicit or explicit) models governing their choice” (Saad et al., 2004, p. 10).

**Factors influencing driver appropriation**

A number of factors influence drivers’ response to ITS. We focus here on appropriation processes in response to IVIS and ADAS that are influenced by three interacting factors: system characteristics, situation characteristics and driver characteristics. In the following sections we briefly discuss each of these factors in turn.
System characteristics

Two aspects of system characteristics affect driver appropriation: First, the system’s “hard facts” (algorithm, performance, reliability) and second, the system’s behaviour which is perceivable for the driver via the Human-Machine-Interface (HMI). Characteristics of the HMI that influence driver appropriation are transparency, predictability, and comprehensibility that are all a function of the system’s feedback. Another important aspect of the HMI that particularly has an impact on drivers’ Situational Awareness (SA) is the task allocation between the driver and the system, i.e. the extent to which a specific function is controlled by the driver or the system (level of automation) and the design of their interaction/cooperation (Hoc, 2000, Hollnagel & Bye, 2000).

Reliability, transparency, predictability, and comprehensibility determine drivers’ trust in the system (as an attitude towards the system), which in turn affects drivers’ monitoring behaviour (supervisory function induced by ADAS) and his/her intention to rely on the system (Lee & See, 2004; Muir, 1994; Muir & Moray, 1996; Lee & Moray, 1992; Goodrich & Boer, 2003). The final reliance action (behaviour) is mediated by this intention to rely and other psychological, system, and environmental constraints (Lee & See, 2004). In general, people tend to rely on systems they trust and to reject systems they do not (Parasuraman & Riley, 1997; Lee & See, 2004; Dzindolet et al., 2003; Lee & Moray, 1992).

The reliability and consistency of a system are critical aspects affecting the use of a system because of their influence on human trust and monitoring (Parasuraman et al., 1993). Reliability may either lead to misuse (overreliance on automation) or disuse (neglect or underutilisation of automation (Parasuraman & Riley, 1997). A number of studies have focused on the dynamic evolution and adjustment of trust and its effects on operator reliance and system use in response to varying degrees of system reliability (Moray, Inagaki, & Itoh, 2000; Muir & Moray, 1996; Lee & Moray, 1994; Lee & Moray, 1992; Parasuraman et al., 1993; Parasuraman et al., 1996; Bliss & Acton, 2003; Bliss, Gilson, & Deaton, 1995; Wiegmann, Rich, & Zhang, 2001; Dzindolet et al., 2003) A low reliability usually provokes disuse of a system, whereas a high reliability holds the danger of “over”-trust in a system and/or complacency, followed by overreliance on the system and system misuse (Parasuraman & Riley, 1997; Beck, Dzindolet, & Pierce, 2002). Humans are assumed to increasingly neglect to monitor systems for their proper functioning with perpetual use of a system paired with positive experiences regarding its use (Lee & See, 2004).

The level of reliability which leads to distrust or disuse of a system also depends on the timing, consequence and expectations associated with a failure (Parasuraman, 2000; Meyer, 2004). Although a system might be highly reliable, there may be some driving situations for which the algorithm wasn’t designed. In such cases, performance may nevertheless not suffer as long as the driver has access to the “raw data” (e.g. in the case of a lane departure warning which fails to warn, the driver has the visual “raw” feedback about the lane markings and the position of the vehicle in the lane). Unreliability may therefore have greater negative effects on human performance and safety for higher levels of automation (automation of decision selection and action implementation; see Parasuraman et al., 2000).

On the side of the HMI, the comprehensibility, transparency, and predictability of a system’s behaviour help drivers to build up an accurate mental representation of the system’s functionality and behaviour. This in turn supports a proper calibration of trust in the system. The appropriateness of trust is reflected in the match or mismatch between the operator’s trust and the true capabilities of the system (Lee & See, 2004). Both an accurate mental representation and “well-calibrated” trust are essential for the driver’s ability to detect system limits and failures in due time and to react to them appropriately (Nilsson, 2004; Goodrich & Boer, 2003). Low system transparency and predictability increases drivers demand for system monitoring and is likely to cause vigilance to decrease and fatigue to increase, which may in turn increase the probability of delegation of responsibility to the system and the occurrence of complacency. Here we see that cognitive and motivational effects highly interact with each other.
Lee & Moray (1992) distinguished three sources of information that form the basis for trust: performance, process and purpose. **Performance** information results from a direct observation of system behaviour. It includes characteristics like reliability, predictability, and the ability of the system to achieve the driver’s goals. A system which is not found to bring the expected performance benefits will diminish drivers’ trust. **Process** information refers to how the system operates. Trust will be greater when the driver understands the system’s underlying mechanism and when the underlying algorithm is appropriate to achieve the driver’s goals in a foreseen situation. **Purpose** information refers to the intended use of a system. A driver is more likely to trust or to accept a system that he or she regards as purposeful and useful to achieve certain task-related and individual goals.

Recently, the driving task has been described as a set of simultaneous, interrelated and layered control processes. Hollnagel & Woods (2005) presented the Extended Control Model (ECOM) which distinguishes four simultaneously active layers of control: tracking, regulating, monitoring, and targeting. Under normal conditions, the outputs of a higher loop form the objectives (goals, criteria) of a lower loop. In turn, the inputs of the lower levels are required for efficient control on higher levels. Driving can be viewed as the pursuit of concurrent goals/activities with different time-frames. Goals on each level can be temporarily suspended. A critical aspect of effective vehicle control is the successful management of goals with regard to driving task demands. Ineffective vehicle control results when control is lost in one or more loops.

ADAS can be classified according to the goals or activities they support on different control layers. Automation is especially prevalent on the tracking and regulating control loops taking over basic functions of driving. Although for instance the tracking activities may be sufficiently carried out by ADAS (e.g. speed control), the efficiency of control on higher levels is likely to be impaired because important information is filtered out from the dynamic control process (Hollnagel & Woods, 2005). This may become particularly obvious in unexpected situations that demand a switch of the attentional focus to higher levels of control. This bottom-up processing may be hindered because of a lack of feedback from the lower loops. In turn, it can be assumed that the interruption of the overall dynamic control process by ADAS that intervenes in higher levels of control (e.g. monitoring) has more severe consequences for drivers’ Situational Awareness (SA) because they are associated with a higher potential for “out-of-the-loop” performance. SA demands the successful alternating of top-down and bottom-up processes (Endsley, 1995; Adams, Tenney, & Pew, 1995). SA can be viewed as “the accessibility of a comprehensive and coherent situation representation which is continuously being updated in accordance with the results of recurrent assessments” (Sarter & Woods, 1991, p. 52). This description resembles the situation assessment element in the monitoring cycle of the ECOM model. ADAS intervening in monitoring control layers are likely to hinder the setting and updating of certain monitoring sub-goals normally required for vehicle control that form the target criteria for the lower control loops. It can be assumed that drivers no longer focus their attention on all environmental information that they have to take into account during unassisted driving, but rather on system-specific cues relevant for monitoring the system (Buld & Krüger, 2002). Thus, ADAS provide appropriate feedback about their actions in order to enable drivers to continuously keep track of what they are doing without the requirement to permanently monitor the system. Goodrich & Boer (2003) propagate a “model-based human-centred task automation” that requires the identification of driver’s mental models for specific driving subtasks in order to use them as a template for automation: “If the limits of automation correspond to the limits of a subset of natural operator skills, then the limits of the automation are most likely to be perceived and detected by the operator.” (p. 329) They demonstrate this approach for the design of an ACC system.
Situation characteristics

Situational characteristics affect driver decisions and motives on an overall level (targeting control loop in ECOM, Hollnagel & Woods, 2005) as well as in specific driving situations. In terms of the overall driving context the driver’s risk perception influences the driver’s behaviour and use of ADAS. For example, driving in a driving simulator may induce the perception that driving errors won’t have severe safety-consequences and may encourage the driver to drive riskier than he/she would normally do in real traffic. Likewise, he or she may be less prone to maintain safety margins or may accept higher levels of distraction caused by an in-vehicle task.

Human operators are sensitive to changes in task demand and strategically adjust their performance strategies to account for changing task demands (Fairclough, 2001; Hockey, 1997; Hancock & Warm, 1989; Matthews & Desmond, 2002). They adaptively regulate their task-related effort in order to maintain adequate performance while minimising stress and personal discomfort. Thus, mental effort regulation is supposed to be based on subjective appraisals of (a) task demands and current performance level and (b) a self-appraisal of stress or comfort. Effort is invested or conserved on a basis of a utility assessment between performance and discomfort (Fairclough, 2001; Hockey, 1997). During effort conservation drivers can shift to task strategies where effort is minimised (Fairclough, 2001; Hockey, 1997). Thus for instance in high-demand situations (i.e. high traffic density, multiple goals/tasks competing for the driver’s attention), drivers may abandon monitoring an assistance system and rely on its actions although they do not completely trust its performance (Lee & See, 2004).

Low-demanding or even monotonous situations will cause vigilance to shrink which in turn lowers the drivers’ capability and motivation to permanently monitor a system for possible failures, and may therefore increase the probability of complacent behaviour or the occurrence of automation bias.

ADAS themself may cause alertness to decrease below an optimal level (see Hancock & Warm, 1989) especially when they are highly reliable. This may impair drivers’ capabilities to react appropriately in situations characterised by a sudden increase in task demands, for example situations that require sudden intervention. Buld & Krüger (2002) studied the effects of varying degrees of system reliability on workload, vigilance and driving performance in the case of an ACC system in an advanced driving simulator. With higher levels of reliability drivers reported increasing levels of boredom, inattention and sleepiness, whereas their workload decreased. The vigilance decrement was reflected in EEG measures as well as in driving performance (number of lane exceedences).

ADAS’ performance and reliability can vary across different driving contexts. For instance, a driver may find that a lane departure warning (LDW) system works quite well on straight roads with highly visible lane markings, but works less reliable on curvy road sections with changing lane widths and markings. If the driver is able to identify such laws of system functioning, he or she will likely adapt his or her usage decisions and monitoring behaviour to the characteristics of the situation.

Driver characteristics

Individual characteristics of the driver are believed to have an influence on the occurrence and magnitude of behavioural effects in response to ADAS as well as on system use and acceptance. One of these individual characteristics is a person’s driving style (French et al., 1993; Elander, West, & French, 1993). Driving style can be described as a person’s individual way of driving (e.g. generally adopted safety margins, interaction patterns with other road users) that is relatively stable across a number of situations. Hoedemaeker & Brookhuis (1998) found differences in driving behaviour for low and high speed drivers when driving with an ACC system in terms of minimum time headway and maximum braking level.
Personality traits such as “sensation seeking” and “locus of control” have been found to influence driver appropriation in terms of a general tendency for risk compensation (applicable to “high sensation seekers”) or in terms of a propensity to trust and to over-rely on ADAS (applicable to individuals with external locus of control – “externals”). For instance, in a study on behavioural adaptation to a Lane Departure Warning (LDW) system Rudin-Brown & Noy (2002) found that externals and low sensation-seekers were more likely to report an increase in trust in the system, regardless of its accuracy. In a subsequent study on ACC system use, Rudin-Brown & Parker (2004) reported that an increase in response times to a hazard perception task and in variability of lane position was more pronounced for high sensation seekers. Drivers with external locus of control reacted more slowly to a simulated failure of the ACC system which is in line with the results of the LDW study.

Other driver variables that are thought to influence driver appropriation (among others) are the drivers’ age, gender, cognitive abilities, driving experience, and their attitude towards ADAS.

**Conceptual model of driver appropriation**

The following model has been developed since the HUMANIST Task Force E workshop on ‘Methodologies for the assessment of ITS in terms of driver appropriation processes over time’. The model aims to draw attention to relevant variables and their interdependences in influencing driver appropriation. As an extension of existing conceptual models (e.g. Rudin-Brown & Noy, 2002; Weller & Schlag, 2004) an attempt is made to consider the full range of driver appropriation processes, including behavioural adaptation, risk compensation, and changes in information processing in response to the introduction of ADAS. The model takes into account the timely interaction of these processes as well as the mediating factors outlined in the previous section. The model provides a working representation of driver appropriation and is intended to be updated as more knowledge is available.

According to this model, driver appropriation develops in response to changes in the driving task due to driver assistance systems. The systems’ characteristics have a direct impact on driver’s information processing. The degree of assistance offered by the system, i.e. the level of automation and the systems feedback mediated by the HMI are believed to have an impact on driver’s SA and mental workload (higher levels of automation should reduce drivers workload in ‘normal’ driving situations). Feedback from the system about its current state and behaviour is necessary to build up a comprehensive situation model that governs behaviour in unforeseen situations. Driver’s workload is thought to have an influence on alertness and vigilance in such a way that vigilance decreases to a greater extent over time when workload is below or above a medium optimal level. Driver’s vigilance and alertness are also influenced by the system monitoring demands that are a function of the system’s performance, reliability and its predictability.

During the initial phases of interaction with a new system the driver begins to build up a mental representation of the system’s behaviour and functioning. This mental representation is continually elaborated and refined, thus getting more and more comprehensive and sophisticated over the time of system use. Characteristics of the HMI such as predictability, transparency and comprehensibility support the elaboration of an accurate mental representation that matches the actual performance of the system, i.e. incorporates system limits and differentiates among different contexts of use and modes of functionality. This is a prerequisite for developing an appropriate level of trust in the system and for enabling the driver to detect and react appropriately to unexpected situations (e.g. system malfunctions).

Driver characteristics such as driving experiences, attitudes towards the system and cognitive abilities affect the driver’s mental representation. The mental representation of the system’s
behaviour and driver’s evaluation of the situation (e.g. demands, time-pressure, risks) constitute the background for driver’s calibration of trust in the system and possibly the development of complacency. Complacency can be defined as „Self-satisfaction which may result in non-vigilance based on an unjustified assumption of satisfactory system state” (Billings et al., 1976, p. 23, in Parasuraman, Molloy, & Singh, 1993). Complacency was cited as a major cause for operators’ problems to detect automation failures in multitask-situations (Parasuraman, Molloy, & Singh, 1993; Parasuraman et al., 1996). For a critical review of research on complacency see Moray & Inagaki (2000) and Moray (2003). Trust and complacency can be described as attitudes towards a system which are coupled with driver’s intentions to count more or less on a system and to leave part of the driving control tasks with the system. Driver’s trust and complacency can have either a direct impact on behaviour or can be mediated by a rational decision regarding the costs and benefits (expected value) associated with certain driving and system-related behaviour, in that for example, high trust decreases the expected value associated with continuous system monitoring; and partial delegation of responsibility may appear as an attractive effort conservation strategy.

![Figure 1](https://via.placeholder.com/150)

Figure 1. A conceptual model of driver appropriation. (Developed by Anke Mogilka, CUT)
The utility judgement resembles Janssen & Tenkink's (1988) notion that risk compensation is one aspect of a general utility-maximation process. It is also in line with theories on compensatory control and effort regulation (Fairclough, 2001; Hockey, 1997). Furthermore, human operators were found to behave rationally and to strategically adjust their monitoring behaviour according to the probability of occurrence of a critical event or signal being detected, the diagnostic value of warnings, and the payoff structure of a task (Sorkin & Woods, 1985; Getty, Swets, Pickett, & Gontheir, 1995; Meyer, 2001; Meyer, 2004; Parasuraman, Hancock, & Olofinboba, 1997; Moray & Inagaki, 2000).

Driver appropriation comprises changes in driving behaviour in terms of risk compensation and changes in active control of the driving task. The latter aspect is reflected in driver’s system-related behaviour (e.g. monitoring, automation bias, delegation of responsibility) and in driving behaviour in critical situations that demand for driver intervention. Automation bias can be defined as the “use of automated cues as a heuristic replacement for vigilant information seeking and processing” (Mosier et al., 1998, S. 47; Skitka, Mosier, & Burdick, 1999; Skitka, Mosier, & Burdick, 2000).

Indirectly a withdrawal from the driving task may also be observed in drivers’ attention allocation strategies to a secondary task (which may not be driving-related). Changes in the way the driving task is performed are supposed to have an influence on underlying information processing and especially drivers’ SA. For instance, if a driver relies on system control for some aspect of the driving task he or she is unlikely to perceive and process environmental information relevant for this aspect as deeply as without the system.

The flow of processes in the model includes different time horizons. After some learning or familiarisation period the driver will have developed a relatively stable mental representation of the system that subsequently governs behaviour. Nevertheless, the consequences of drivers’ behaviour will feed back and cause the mental representation to be revised and refined accordingly.

Situation characteristics affect drivers’ actual behaviour on a rather short-term or momentary basis. However, some stable behavioural responses (e.g. modes of system use) that occur in particular contexts can likely be revealed. Furthermore, drivers’ behaviour, attitudes and information processes (e.g. attention, vigilance, workload) can change during one trip caused by exhaustion or accommodation effects.

4. Driver Appropriation Methods

Individual methods
In Deliverable E.5 eight driver appropriation methods were verbally presented and the power point presentations provided. These methods along with an additional four other methods have been described in Appendix 1. Each method is written up as an example of how it has been used to measure driver appropriation of ITS over time. A description of each method is provided including:
- The type of ADAS/IVIS or system functionality evaluated
- The type of appropriation processes that were investigated
- Which methodological approach was used to investigate appropriation processes
- The variables that were measured to assess appropriation processes
- The other variables that were measured
- How the study was designed in order to be able to measure long-term or short-term effects of appropriation
- How appropriation was measured over time
- The experimental setting
- The participants required
In addition each method details a concluding evaluation of the method, including:
• The environment for which the results are valid
• Brief conclusion of experimental work using method
• Critical analysis (evaluation) of the method (i.e. sensitivity, validity, advantages, disadvantages etc.)
• References

In Appendix 2 summaries have been provided of a further ten methods to provide a brief description of the method with advantages, disadvantages and comments on how the method is linked to driver appropriation.

**Case Studies**
In Appendix two case studies are provided. The case studies demonstrate detailed examples of the use of driver appropriation methods with subsequent results where applicable.

Case studies have been provided from each of the “levels” of driver appropriation as follows:
- Adaptation of secondary task performance by use of ADAS – “Tactical level”
- System understanding and knowledge; “Strategic level”

**Integration of Methods**
Within the latest work of TF E, a concept has been developed concerning possible integration of methods based on the theoretical background and processes of appropriation. In order to develop the concept/model the integrated methodology model presented in a previous deliverable (E.4) was used as a ‘baseline’ approach. That integrated methodology model is shown below:

```
Model from Deliverable E.4
```

When considering the above model for driver appropriation the following issues were discussed:

- At the tactical level, it is necessary to identifying potential behaviour and develop a hypothesis that can be tested (this was in the previous integrated model for driver behaviour measurement).
- At the strategic level of appropriation concerning knowledge/understanding and attitudes, it is necessary to use subjective methods in order to appreciate participants position e.g. to identify the characteristics drivers attribute to a specific system.
At the operational level of skill acquisition it was considered probably unnecessary to have a hypothesis and measurement of skill acquisition can just be measured directly based on a task analysis.

It should be noted that previous work of TF E has been more concerned with methods that relate to skill acquisition and driver behaviour measurement. The new and wider perspective requires methods that have not hitherto received as much attention including:

- Elicitation of attitudes and knowledge by “soft” means
- Extended field trials and naturalistic measurements
- Measurement of system use/ non-use
- Measurement of changes in use of vehicles

A very important issue is the need to be able to identify loss of ‘manual driving’ skills caused by new technical system and the potential impacts of this skill loss e.g. during system malfunction or failure.

Discussion within TF E has helped to understand the requirement for future work in the research area. TF E have developed a model for integration of driver appropriation:

When considering the model it should be noted that:
- The step “Generate Hypothesis” is certainly required in the ‘tactical’ stage of identifying behaviours but may not be required at the ‘operational’ and ‘strategic’ levels
- The ‘Select Measurement methods’ step is now understood to mean to decide which approach is required, which could be:
  - task analysis
  - quantitative and qualitative measures of driver behaviour (from the matrix in Deliverable E.4)
  - the “subjective and communication methods” (for strategic). Note that the HUMANIST matrix does not include these measures.
5. Future work and wider issues

Because driver appropriation and the integration of appropriation methods is such a new work area more questions have been raised than answers provided. The next phase of work in this area should focus on further developing the conceptual model of driver appropriation and the appropriation integrated methods model. In developing these models further it will be important to resolve the following issues:

- How can we measure transfer of learning from other environments?
- Some tasks are just too difficult for some people (unrelated to age). Has work been done on differences in intelligence or educational background (and how to categorise drivers according to their cognitive abilities)? No work by HUMANIST partners has been identified.
- If it is the case that skill acquisition and adaptation run at the same time, is it sufficient to just measure behaviour?
- Is it possible to identify some features of appropriation (e.g. with a checklist) to detect when the major part of the skill learning phase is completed and we have “regular” users rather than learners?
- Similarly, can we find variables to identify when a stable behaviour or level of understanding has been established? i.e. an asymptote for behavioural adaptation or knowledge acquisition…
- At which time intervals should we measure relevant variables to detect important adaptive changes?
- Finally, it has been noted that there is a dynamic feedback loop between individual drivers and the characteristics of traffic. Communication between road users is important and provides a wider context to the work of TF E. Appendix 4 helps to identify these wider mechanisms, of dependency.

6. Conclusions

The latest work of TF E has been very productive with some thought-provoking contributions in this relatively new scientific area.

Starting from a “flat” list of possible methods to measure driver appropriation, we built a better understanding of different aspects of appropriation and developed a three-level characterisation. This led to a deeper understanding and a better definition of appropriation based on common understanding. Moreover, we built on existing work to develop a richer picture of the type of methods needed and identified that softer methodologies and broader studies were required to capture the strategic and tactical level appropriation issues of knowledge, attitudes, systems use and vehicle use.

These considerations led to a better understanding of the processes of appropriation and will contribute to future work on driver appropriation models.

Finally, it was possible to develop a previous picture of an integrated methodology for behavioural measurement into a picture containing the broader aspects of driver appropriation.
List of References


APPENDIX 1 – Detailed information on a method for measuring drive appropriation over time

Wiener Fahrprobe – behaviour observation (FACTUM)

Description of method:

1. What type of ADAS/IVIS or system functionality was evaluated?

   An intelligent speed adaptation system, more detailed a adaptive accelerator pedal.

   The „Wiener Fahrprobe“ (Risser & Brandstätter 1985) is an observation method used by either one or two persons inside observed subjects` cars, in order to assess these subjects` behaviour. Several behaviour variables are registered. Driving behaviour is registered both in a standardised and non-standardised way (= non-predictable events). The total set of variables is meant to be a reflection of the observed subjects` driving behaviour, or driving style (see Lajunen et al. 1998). Changes in driving behaviour that are expected from any measures, or brought about by any other changes of the preconditions for driving, should be reflected by changes in these variables.

2. What type of appropriation processes were you aiming at investigating (research question related to driver appropriation)?

   One of the goals is/was to find out, if driver show a more safe driving behaviour (better communication with other road users for instance) if they use the ISA system. Another question to be answered is, whether there will be a long term effect on driving behaviour after the non-recurring use of the ISA system.

3. Which methodological approach was used to investigate appropriation processes? (questions, mental models, performance criteria etc.)

   behaviour observation but also questionnaires

4. Operational definition of appropriation: What variables were measured to assess appropriation processes?

   Such as use of the indicator, communication with other road users, lane and distance keeping behaviour but also speed.

5. What other variables were measured that are assumed to influence driver appropriation processes?

6. How was study designed in order to be able to measure long-term or short-term effects of appropriation? (How was appropriation designed in to the experiment? – e.g. driving for a specified number of hours …)
There was a first run of behaviour observation with all drivers. Thereafter all of the participants got the possibility to drive an ISA-equipped car and about the half of participants also took part in a group discussion. The last step is a second run of driving behaviour observations where changes in driving behaviour may occur.

7. How was appropriation measured over time? (repeated measurements, time lines, learning curves etc.)
   repeated measurements

8. Describe experimental setting (lab, field, simulator etc.)
   Behaviour observation in the field with a driving school car and with an ISA-equipped car. Qualitative and standardised questionnaires as well as a group discussion.

9. Participants required (characteristics of the sample: selection criteria, no. of participants, gender, age etc)?
   The sample consists of 78 novice drivers in Austria and Czech Republic between 18 and 25 years old. All of them hold a valid driving licence.

Concluding evaluation of the method:

10. Environment for which the results are valid (specific/broad)?
    Quite narrow – Novice drivers
    The Wiener Fahrprobe so far was used mostly in urban areas; it focuses very much on the interaction between car drivers and vulnerable road users, especially pedestrians (see Chaloupka, Risser & Roest 1991).

11. Brief conclusion of experimental work using method

12. Critical analysis (evaluation) of the method (i.e. sensitivity, validity, advantages, disadvantages etc.)
    **Advantage(s):** Holistic view of the situation and the driving behaviour. High quality data with respect to actual behaviour of car drivers especially concerning communication and interaction with vulnerable road users
    **Disadvantage(s):** Also it is a standardised method the observation remains subjective.
13. References (e.g. papers written or other useful material)

<table>
<thead>
<tr>
<th>Reference</th>
<th>Title</th>
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<tbody>
<tr>
<td>Turetschek Ch.; 2005</td>
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<td>Intelligent Speed Adaptation - Former results and a current study; Proceedings Advances in Transport System Telematics; 6th TST-Conference – Katowice; pages 503-508</td>
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</table>
Focus Group Interviews (FACTUM)

Description of method:

1. What type of ADAS/IVIS or system functionality was evaluated?
   Telematic traffic information systems for the public transport systems and the benefit for disabled people

2. What type of appropriation processes were you aiming at investigating (research question related to driver appropriation)?
   The main aim of the study was to give an insight of disabled people’s view and their attitudes on telematic traffic information systems (TTIS) and to work out guidelines, which should guarantee accessible traffic information for the target group

3. Which methodological approach was used to investigate appropriation processes? (questions, mental models, performance criteria etc.)
   - Literature study
   - Expertise on three Austrian web-sites of public transport enterprises
   - Focus group interviews with the target groups
   - Workshop with experts in the field of public transport and in the fields of disability

4. Operational definition of appropriation: What variables were measured to assess appropriation processes?
   - Benefit of telematic information systems in general
   - Observableness of information in general
   - Operability of information systems
   - Comprehensibility of information

5. What other variables were measured that are assumed to influence driver appropriation processes?

6. How was study designed in order to be able to measure long-term or short-term effects of appropriation? (How was appropriation designed in to the experiment? – e.g. driving for a specified number of hours …)


7. How was appropriation measured over time? (repeated measurements, time lines, learning curves etc.)

8. Describe experimental setting (lab, field, simulator etc.)

Four focus group interviews were carried out with 4 to 7 people. Each interview took two hours. A guideline was prepared for the discussion. The participants answered the questions one by one. They, however, had the possibility to express their opinion at any time.

9. Participants required (characteristics of the sample: selection criteria, no. of participants, gender, age etc)?

On the whole 20 people were interviewed. The participants of the focus group interviews were heterogeneous. More man than women participated. Blind, and deaf people took part and people in wheelchairs. Age was no selection criteria.

Concluding evaluation of the method:

10. Environment for which the results are valid (specific/broad)?

The results are interesting for public transport enterprises and disability associations.

Focus group interviews can be used at any point in the evaluation process.
- They can be used as preparation for a standardised questionnaire, in order to gather all relevant information about a topic.
- They can be used as additional qualitative evaluation method next to others.
- They can be used as single method to gather qualitative information about a topic, e.g. in order to understand certain psychological and/or social processes.

To sum up: Focus Group Interviews are usually a cheap and a fast way to identify the main aspects of a certain topic and to formulate assumptions that then can be analysed with appropriate methods, later-on (see e.g. Atteslander 1995, Krueger 1994, Bewyl 1992, Merton et.al. 1956, Morgan & Krueger 1998).

11. Brief conclusion of experimental work using method

The interviews give a very good overview of the advantages and shortcomings of the current traffic information system especially in Vienna.
12. Critical analysis (evaluation) of the method (i.e. sensitivity, validity, advantages, disadvantages etc.)

**Advantage(s):**
- They are an efficient qualitative data collection technique
- They allow aspects to come up that the conductor of a study has not thought of
- In just a little more than one hour the interviewer can gather information from eight people instead of only one person → the sample size can be increased significantly
- The group situation enhances answers concerning even difficult situations and emotions
- There is a valuable quality control on data collection as participants tend to check each other’s statements → increase of credibility
- The situation is usually experienced as highly motivating by the participants.

**Disadvantage(s):**
- The amount of response time to any given question is increased considerably → there is a limited number of questions that can be asked
- It is always possible that unexpected diversions occur in a focus group interview → conflicts may arise (although conflicts may give an insight into deeper-lying attitudes towards certain issues)
- When participants in a focus group do not know each other, it is difficult to guarantee confidentiality

13. References (e.g. papers written or other useful material)

Qualitative Interview (In-depth interview) - as example: EU-project “SIZE” (Life quality of senior citizens in relation to mobility conditions) (FACTUM)

Description of method:

1. What type of ADAS/IVIS or system functionality was evaluated?

   In-depth interviews are a qualitative assessment method. They are partly structured, require a format, follow a process and have to be recorded (handwritten or taped). In-depth interviews are used throughout research to determine individuals' perceptions, opinions, facts and forecasts, and their reactions to initial findings and potential solutions. They are an often underestimated technique of inquiry, because many researchers are reluctant to accept the qualitative nature.

   In-depth interviews have several roles in program evaluation and market research:
   - Obtaining evidence for a problem or issue;
   - Exploring the boundaries of a problem;
   - Identifying potential solutions;
   - Managing the research process.

2. What type of appropriation processes were you aiming at investigating (research question related to driver appropriation)?

   To explain and describe the present mobility and transport situation, the problems, needs and wishes of different groups of senior citizens from their own perspective compared with experts' points of view; to identify relevant solutions for existing problems of senior citizens. How do senior citizens cope with the present mobility situation?

3. Which methodological approach was used to investigate appropriation processes? (questions, mental models, performance criteria etc.)

   (qualitative) questions

4. Operational definition of appropriation: What variables were measured to assess appropriation processes?

   -

5. What other variables were measured that are assumed to influence driver appropriation processes?

   What typical changes occur during the ageing process?
   What are the most frequent reasons for going out for elderly?
   How do elderly care for their physical condition and good mood?
   What influence has the financial situation on the mobility of older people?
   How do they organise transport in short and long distances?
   What kind of equipment enhances and what limits the mobility? Which equipment is the most important?
   Why some seniors do without outdoor activities?
   What threats are elderly afraid of?

6. How was study designed in order to be able to measure long-term or short-term effects of appropriation? (How was appropriation designed in to the experiment? – e.g. driving for a specified number of hours …)
7. How was appropriation measured over time? (repeated measurements, time lines, learning curves etc.)

8. Describe experimental setting (lab, field, simulator etc.)

individual interviews

9. Participants required (characteristics of the sample: selection criteria, no. of participants, gender, age etc.)?

A non-random sample of 487 senior citizens (people aged 65 or more) and 225 experts from eight European countries (between 25 and 35 persons of the same characteristics in each participating country)
The senior citizens' characterisation was:
- By sex: 370 female and 180 male.
- By age group: 253 were between 65 and 74 years old; 200 between 75 and 84; and 34 aged more than 85.
- By living area: 51% of respondents belonged to urban living areas; 35% to a suburban area, and 14% to a rural area.
The experts' profile:
- Decision makers, civil engineers, road and transport designers, urban planners, etc.

Concluding evaluation of the method:

10. Environment for which the results are valid (specific/broad)?

Very broad; mainly for senior citizens; many results also benefit all (vulnerable) road users

11. Brief conclusion of experimental work using method

12. Critical analysis (evaluation) of the method (i.e. sensitivity, validity, advantages, disadvantages etc.)

Advantage(s): At an early stage of a system assessment, less structured interviews may serve to identify more clearly certain system requirements. Motivation for use, or resistance against, certain market products can be determined. In-depth interviews take time, but usually they help to make hypotheses about possible effects of any measure much more accurate.

Disadvantage(s): Time and cost intensive; interviewers have to be trained in order to produce comparable results.

13. References (e.g. papers written or other useful material)
Assessment of the Learnability of Menu-Driven Information Systems (BASt)

Description of method:

1. What type of ADAS/IVIS or system functionality was evaluated?
   Any kind of IVIS with a menu-driven Human-Machine-Interface (HMI)

2. What type of appropriation processes were you aiming at investigating (research question related to driver appropriation)?
   Improvement of the secondary task performance over time (learning) of interacting with a menu-driven HMI while performing the primary task driving (i.e. tracking task)

3. Which methodological approach was used to investigate appropriation processes? (questions, mental models, performance criteria etc.)
   Power-law of practice

4. Operational definition of appropriation: What variables were measured to assess appropriation processes?
   Speed and accuracy of IVIS tasks (i.e. finding a specific option in the menu); measures of glance behaviour; variability and “critical events” in the “primary” tracking task.

5. What other variables were measured that are assumed to influence driver appropriation processes?
   Design of the menu-driven in-vehicle HMI (broad vs. deep menu-structure)

6. How was study designed in order to be able to measure long-term or short-term effects of appropriation? (How was appropriation designed in to the experiment? – e.g. driving for a specified number of hours …)
   Laboratory approach: about 150 experimental runs per subject

7. How was appropriation measured over time? (repeated measurements, time lines, learning curves etc.)
   Repeated measurement design in a laboratory experiment with calculation of group mean values of experimental blocks

8. Describe experimental setting (lab, field, simulator etc.)
   This research started with a laboratory experiment where (n=12) where learning of the HMI tasks (i.e. finding an option in a menu) under single-task conditions was examined. In a second experiment (n=12) the HMI tasks were administered as a replication under secondary task condition in where they had to be performed while simultaneously with a tracking task.

9. Participants required (characteristics of the sample: selection criteria, no. of participants, gender, age etc.)
   Student subjects (N=24, half male, half female)
Concluding evaluation of the method:

10. Environment for which the results are valid (specific/broad)?
   
   See conclusions

11. Brief conclusion of experimental work using method
   
   The results of this research show that subjects perform better with broad menu structures under single task conditions and with broad menu structures under dual-task conditions, i.e. with a tracking task in a simulator. Thus, one might reason that future studies on driver appropriation should be aware of this effect and include dual-task conditions in the experimental design.

12. Critical analysis (evaluation) of the method (i.e. sensitivity, validity, advantages, disadvantages etc.)
   
   This approach should be extended to conditions of real driving, at the present stage it has to be considered as exploratory.

13. References (e.g. papers written or other useful material)

   Totzke, I. et al. (2004). Kompetenzerwerb für Fahrerinformationssysteme. FAT Schriftenreihe, Nr. 184. Frankfurt am Main, Forschungsvereinigung Automobiltechnik e.V.

Modelling of learning processes in drivers interaction with IVIS with the power law of practice (CUT)

Description of method:

1. What type of ADAS/IVIS or system functionality was evaluated?
   - IVIS: navigation entry in route guidance systems

2. What type of appropriation processes were you aiming at investigating (research question related to driver appropriation)?
   - Our first objective was to provide an exemplary systematic data set on the magnitude of skill acquisition effects while interacting with IVIS, taking into account known determinants of skill acquisition with information technology such as system design and the age of users. Two route guidance systems were selected with regard to the expected learnability of their HMIs. The systems differed mainly in controls and dialogue design. Both these differences yielded more demanding destination entry with System A than with System B in terms of perceptual-motor coordination and supervisory control.
   - Our second objective was to explore whether the expected differences in skill acquisition with regard to system design and age of users are reflected by learning parameters when fitting power law functions to the obtained data.
   - Finally we wanted to test whether skill acquisition while driving can be predicted by skill acquisition in a stationary vehicle.

3. Which methodological approach was used to investigate appropriation processes? (questions, mental models, performance criteria etc.)
   - Performance criteria of interaction with systems

4. Operational definition of appropriation: What variables were measured to assess appropriation processes?
   - total task times of destination entry, visual information sampling behaviour (total display glance times, single and mean glance durations, glance frequencies)

5. What other variables were measured that are assumed to influence driver appropriation processes?
   - age of participants, previous experience with systems

6. How was study designed in order to be able to measure long-term or short-term effects of appropriation? (How was appropriation designed in to the experiment? – e.g. driving for a specified number of hours …)
7. How was appropriation measured over time? (repeated measurements, time lines, learning curves etc.)

learning curves

8. Describe experimental setting (lab, field, simulator etc.)

In the driving study participants drove circuit courses on a closed racing track in reduced traffic while practicing destination entry. The circuit included easy (with and without car following) and winding routes.
In the stationary car studies the participant sat in the driver’s seat of the vehicle that was parked facing a wall. Glances were manually coded from video recordings with a precision of 100 ms.

9. Participants required (characteristics of the sample: selection criteria, no. of participants, gender, age etc)?

Driving study: Six men and 6 women between 35 and 47 years of age (M = 41.5, SD = 4.4). All of them had more than 10 years of driving experience (M = 21.0 years, SD = 5.5), and all had a total mileage above 100,000 km. All participants reported using computers at least on 5 days a week (M = 6.2), had normal or corrected to normal vision, were not familiar with the experimental vehicle, and were paid for their participation. They were assigned to two groups consisting of three women and three men each. In the System A group, the mean age was 42.8 (SD 5.1), the mean age in the System B group was 40.0 (SD 3.5).
Stationary car study 1: Sixty individuals between 31 and 56 years of age (M = 45.4, SD = 6.4) served as paid participants. All held a valid driving license and reported more than 100,000 km driving experience. They were assigned to two groups matching for age. The System A group consisted of 8 women and 21 men with a mean age of 46.3 (SD 6.2), the System B group consisted of 15 women and 16 men with a mean age of 44.6 (SD 6.4).
Stationary car study 2: Thirty-two older and younger adults who held valid driving licenses served as paid participants. The 16 older participants, 1 woman and 15 men, were between 66 and 74 years of age (M = 68.8, SD 2.6) and were recruited from the audience of a series of public lectures at the university. Seven older participants were trained with System A (M = 68.5 years, SD 2.8), 9 were trained with System B (M = 69.1, SD 2.3). The 16 younger participants, 8 women and 8 men, were students at the university between 20 and 27 years of age (M = 22.4, SD 2.0). Of the younger participants, 3 women and 5 men were assigned to the System A group (M = 22.8 years, SD 1.7), 5 women and 3 men to the System B group (M = 21.9, SD 2.2).

Concluding evaluation of the method:

10. Environment for which the results are valid (specific/broad)?
11. Brief conclusion of experimental work using method

The power law of practice was found to be applicable to fitting skill acquisition while interacting with IVIS (destination entry into route guidance systems). Furthermore, expected differences in learnability of HMI s and age-related differences were reflected in power law parameters. The results demonstrate that age effects interact strongly with a system’s demand profile. Especially in early phases of skill acquisition, the effects of system differences increase with the age of users. Age-related cognitive changes make older users highly susceptible to those system characteristics that challenge novice users’ executive control and working memory. Therefore, older samples seem to be especially “useful” for evaluating interface design.

12. Critical analysis (evaluation) of the method (i.e. sensitivity, validity, advantages, disadvantages etc.)

Potentials:
- the relative differences in skill acquisition regarding different user interfaces and user groups can be assessed
- reliable power law parameters for averaged data can be obtained rather economically (we were able to estimate learning curves with just 20 trials in the transfer blocks of the second stationary car study)

Limits:
- tasks must be comparable
- learning is mediated by inter-individual differences (age, experiences, skills)
- parameters are influenced by system performance (e.g. delays)
- problems with 3 free parameters (if variability of data is high) => specification is optional

13. References (e.g. papers written or other useful material)


# Identification of early indicators of appropriation of support system (TNO)

## Description of method:

1. **What type of ADAS/IVIS or system functionality was evaluated?**
   - Prototype integrated adaptive system (GIDS)

2. **What type of appropriation processes were you aiming at investigating (research question related to driver appropriation)?**
   - Are there any parameters in the early stages of using the support system that are predictive of performance in the final stage?

3. **Which methodological approach was used to investigate appropriation processes? (questions, mental models, performance criteria etc.)**
   - Measures of driving performance and workload over an extended period of driving with the system

4. **Operational definition of appropriation: What variables were measured to assess appropriation processes?**
   - Performance measures: navigation performance (errors); speed distribution; distributions of accelerations and decelerations; headway distribution
     - Workload measures: SWAT ratings; heart rate variability

5. **What other variables were measured that are assumed to influence driver appropriation processes?**
   - None

6. **How was study designed in order to be able to measure long-term or short-term effects of appropriation? (How was appropriation designed in to the experiment? – e.g. driving for a specified number of hours …)**
   - Subjects drove for a total of 10 hrs each within a two-week period

7. **How was appropriation measured over time? (repeated measurements, time lines, learning curves etc.)**
8. Describe experimental setting (lab, field, simulator etc.)

Instrumented-vehicle study on several types of road

9. Participants required (characteristics of the sample: selection criteria, no. of participants, gender, age etc)?

None in particular

Concluding evaluation of the method:

10. Environment for which the results are valid (specific/broad)?

Over the usual types of road

11. Brief conclusion of experimental work using method

No evidence of ‘early indicators’

12. Critical analysis (evaluation) of the method (i.e. sensitivity, validity, advantages, disadvantages etc.)

Method was OK, nothing special except that it was one of the first studies that looked into behaviour over a (relatively) long period of time

13. References (e.g. papers written or other useful material)

Several TNO-reports and proceedings
The Lane Change Task (LCT) (Loughborough/TRL)

Description of method:

1. What type of ADAS/IVIS or system functionality was evaluated?

The LCT requires participants to negotiate a 3000m long section of three lane highway. Participants are instructed by signs on the roadside (150m apart) to perform a lane change manoeuvre. During this task participants are required to perform a relevant secondary task. To avoid speed confounding the results it is controlled by the program and is kept at a constant 60kmph. The illumination should reflect daytime driving with a constant light level. Low level engine sound is provided in order to provide the driver with auditory feedback more akin to what would they would hear in the driving task. Visual information is presented using an egocentric (front) view; no visual information is presented regarding side or rear views. The vehicle dynamics are such that the simulated car will behave as a standard passenger car. Participants are required to change lane when instructed, when not performing a lane change manoeuvre they are required to maintain a central position within the lane. Performance of the lane change task by itself is used as a measure of baseline performance for comparison with performance of the LCT and a secondary task.

THE LCT IS SUITABLE FOR USE WITH THE MAJORITY OF IVIS TASKS.

It as applicable to all types of user interfaces; manual, visual, haptic and auditory. It applies to both original Equipment Manufacturer (OEM) and aftermarket IVIS and both integrated and portable devices.

2. What type of appropriation processes were you aiming at investigating (research question related to driver appropriation)?

3. Which methodological approach was used to investigate appropriation processes? (questions, mental models, performance criteria etc.)

The Lane change Task is a laboratory based combined control and event detection metric based on the dual task paradigm. The dual task paradigm posits that primary task performance will degrade with the introduction of a secondary task. In this case LCT performance can be viewed as the primary task and it is designed to be analogous to the driving task. It was developed as part of the ADAM project (Advanced Driver Attention Metrics; Mattes, 2003).
4. Operational definition of appropriation: What variables were measured to assess appropriation processes?

![Figure 1: The LCT compares the normative model (solid line) to the participants driving course (broken line).](image)

The main measure for driver appropriation of IVIS devices is a mean deviation from the normative model (see figure 1 for illustration of normative model). This deviation measure covers important aspects of the driver’s performance; namely his/her perception (late perception of the sign or missing a sign), quality of the manoeuvre (slow lane change results in larger deviation) and lane keeping quality, which all result in an increased deviation.

5. What other variables were measured that are assumed to influence driver appropriation processes?

6. How was study designed in order to be able to measure long-term or short-term effects of appropriation? (How was appropriation designed in to the experiment? – e.g. driving for a specified number of hours …)

Each LCT trial lasts three minutes; by manipulating the number of LCT trials that participants are subjected to it is possible to investigate both short and long term appropriation of IVIS tasks.

7. How was appropriation measured over time? (repeated measurements, time lines, learning curves etc.)

The use of the LCT to measure appropriation over time would be reliant on the use of a repeated measures design. The output of the LCT (mean deviation from the normative model) would allow for a direct comparison of performance with an IVIS task over any number of specified time points and would allow for the calculation of a learning curve.

8. Describe experimental setting (lab, field, simulator etc.)

The Lane change Task is a laboratory based combined control and event detection metric based on the dual task paradigm. It is a part-task simulation of the driving task. A P.C. and a game console steering wheel are the basic requirements for implementing the LCT paradigm (in addition, equipment to present the IVIS task).
9. Participants required (characteristics of the sample: selection criteria, no. of participants, gender, age etc)?

The draft standard regarding the LCT recommends at least 16 participants should be involved in the comparison of two or more secondary tasks when a within-subject design is used. They should be licensed drivers not familiar with, or technically knowledgeable about, the specific secondary tasks under investigation. Other relevant characteristics of the participants should be recorded (e.g. gender, age and driving experience). It is recommended that a within-subjects design, this allows for each participant to experience both the single and dual task conditions and facilitates statistical comparison between the two conditions.

Concluding evaluation of the method:

10. Environment for which the results are valid (specific/broad)?

- 

11. Brief conclusion of experimental work using method

- 

12. Critical analysis (evaluation) of the method (i.e. sensitivity, validity, advantages, disadvantages etc.)

The LCT has good face validity, reflects manual, visual, and components of driving and contains important elements of the driving task (path following, manoeuvring, event detection and vehicle control), it discriminates between complex and simple tasks. It can be used at most stages of product development and can be easily replicated.

13. References (e.g. papers written or other useful material)

Occlusion (TRL)

**Description of method:**

1. What type of ADAS/IVIS or system functionality was evaluated?
   - IVIS destination entry
   - Information extraction from scrolling task

2. What type of appropriation processes were you aiming at investigating (research question related to driver appropriation)?
   - The method aims to investigate rapid (short term) appropriation. Looked at training on specific tasks to improve performance to an ‘expert’ level. The tasks were all relatively simple tasks therefore rapid learning was expected.

3. Which methodological approach was used to investigate appropriation processes? (questions, mental models, performance criteria etc.)
   - Qualitative performance measurement

4. Operational definition of appropriation: What variables were measured to assess appropriation processes?
   - Total shutter open time (TSOT)

5. What other variables were measured that are assumed to influence driver appropriation processes?
   - A questionnaire was completed by each participant to gather qualitative background data. This included questions written to expose any participants that were techno-phobic.

6. How was study designed in order to be able to measure long-term or short-term effects of appropriation? (How was appropriation designed in to the experiment? – e.g. driving for a specified number of hours …)
   - Only short term learning was assessed
   - The aim was to see if 3 training trials prior to five task repetitions was enough to achieve full appropriation to an ‘expert level’ (i.e. to a point were there was no significant increase in performance following the 3 initial practice trials). Therefore 3 practices were completed, then the time taken to complete the task was recorded for five consecutive repetitions of that task. The TSOT can be compared to see if the participant had achieved consistent performance (full appropriation) or not.
7. How was appropriation measured over time? (repeated measurements, time lines, learning curves etc.)
   Repeated measurements

8. Describe experimental setting (lab, field, simulator etc.)
   Lab based trial – in a real vehicle using occlusion goggles

9. Participants required (characteristics of the sample: selection criteria, no. of participants, gender, age etc)?
   60 participants of mixed age and gender. Participants were placed into 6 age groups and were between the ages of 17 and 74.

Concluding evaluation of the method:

10. Environment for which the results are valid (specific/broad)?
    The results are limited to the tasks that were evaluated. Theses were relatively simple tasks. The scrolling task was not specifically related to a task that would be required during driving.

11. Brief conclusion of experimental work using method
    Work is in progress to validate/enhance the ISO standards

12. Critical analysis (evaluation) of the method (i.e. sensitivity, validity, advantages, disadvantages etc.)
    Limitations: Performance during the initial training (first 3 trials) was not recorded
    Method only applies to short tasks

    Advantages: Cheap compared to simulator or field trial
    Portable method that can be replicated easily
    The method is an ISO standard

13. References (e.g. papers written or other useful material)
    To be published in 2008
Field Operational Test (VTI)

Description of method:

1. What type of ADAS/IVIS or system functionality was evaluated?
   - An ISA system including a display with the speed limit and a Haptic Accelerator pedal

2. What type of appropriation processes were you aiming at investigating (research question related to driver appropriation)?
   - Short term effects compared to long term effects and how does the appropriation differ between different drivers.

3. Which methodological approach was used to investigate appropriation processes? (questions, mental models, performance criteria etc.)
   - Field Operational test with 173 vehicles for 5-11 months. Speed and position was sampled with a data recorder five times per second. In addition questionnaires were issued three times during the experiment.

4. Operational definition of appropriation: What variables were measured to assess appropriation processes?
   - The measure used was proportion of distance driven above the speed limit and how this changed with system exposure (kilometres driven).

5. What other variables were measured that are assumed to influence driver appropriation processes?
   - Attitude

6. How was study designed in order to be able to measure long-term or short-term effects of appropriation? (How was appropriation designed in to the experiment? – e.g. driving for a specified number of hours …)
   - Daily driving with their own cars for 5-11 months. The time differed between drivers depending on early or late system installation.

7. How was appropriation measured over time? (repeated measurements, time lines, learning curves etc.)
8. Describe experimental setting (lab, field, simulator etc.)

Field test carried out in the city of Lund 1999 - 2002

9. Participants required (characteristics of the sample: selection criteria, no. of participants, gender, age etc.)

In total 284 vehicles were equipped but due to technical problems, people wanting to abort the trial and drivers not generating enough data 173 drivers are included in this study. The sample represents roughly the driving population with a slight bias towards middle aged men.

Concluding evaluation of the method:

10. Environment for which the results are valid (specific/broad)?

Broad

11. Brief conclusion of experimental work using method

Based on the patterns shown in the current dataset, conclusions are drawn as follows, which will provide useful and practical inputs to the construction of the DVE model.

- Distance is a robust indicator of exposure to an ADAS system
- The interaction between the driver and an ADAS system increases in line with an increase in system exposure
- Behavioural adaptation in the presence of an ADAS system is influenced by:
  - Differences among individual drivers, such as intention to engage with the system and locus of control, and
  - the characteristics of the driving environment, such as complexity of the driving environment (e.g. urban and rural), road geometry and traffic conditions (e.g. speed zones and time of week)

12. Critical analysis (evaluation) of the method (i.e. sensitivity, validity, advantages, disadvantages etc.)

The advantage is that you get a lot of data and you get data from real driving. The long duration of the project also makes it possible to study long-term effects which is crucial when evaluating systems like this. The disadvantage is that it is expensive and it requires good skills in data processing.

13. References (e.g. papers written or other useful material)
**Group Elicitation Method (GEM) (EURISCO)**

**Description of method:**

1. What type of ADAS/IVIS or system functionality was evaluated?

   Mobile phone.

2. What type of appropriation processes were you aiming at investigating (research question related to driver appropriation)?

   The spectre of the investigation was large. The investigation was to better understand how and why drivers use mobile phones in the car. This method was used to recuperate current practices, driver needs and advantages or disadvantages to use phone in a car and usability problems.

3. Which methodological approach was used to investigate appropriation processes?

   (questions, mental models, performance criteria etc.)

   For this study, the GEM method was used and questions were:
   
   - How do you use your mobile phone in the car and how do you manage your calls?
   - What are the problems, the risks and the difficulties that you encountered when telephoning while driving and what are the possible solutions?

4. Operational definition of appropriation: What variables were measured to assess appropriation processes?

5. What other variables were measured that are assumed to influence driver appropriation processes?

6. How was study designed in order to be able to measure long-term or short-term effects of appropriation? (How was appropriation designed in to the experiment? – e.g. driving for a specified number of hours …)

   This study was designed to measure long-term effects of appropriation.
7. How was appropriation measured over time? (repeated measurements, time lines, learning curves etc.)

<table>
<thead>
<tr>
<th>Subjective measures</th>
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8. Describe experimental setting (lab, field, simulator etc.)

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9. Participants required (characteristics of the sample: selection criteria, no. of participants, gender, age etc)?

<table>
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<tr>
<th>For this study, 2 groups of 7 participants were required (student and professional drivers). Professional drivers were commercial driver.</th>
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**Concluding evaluation of the method:**

10. Environment for which the results are valid (specific/broad)?

<table>
<thead>
<tr>
<th>We can use these results to analyse, to realise models and to improve the design of new system to assist the driver when she/he uses the mobile phone while driving.</th>
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</table>

11. Brief conclusion of experimental work using method

<table>
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<tr>
<th>This method allows to recuperate point of views and to have a consensus between the users about their experience and appropriation of the system or also to show advantages and/or disadvantages of the system used.</th>
</tr>
</thead>
</table>

12. Critical analysis (evaluation) of the method (i.e. sensitivity, validity, advantages, disadvantages etc.)

<table>
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<tr>
<th>Subjective method.</th>
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</table>

13. References (e.g. papers written or other useful material)

|-------------------------------------------------------------------------------------------------------------------------------------|
In-vehicle BLACKBOX (CDV)

Description of method:

1. What type of ADAS/IVIS or system functionality was evaluated?
   Evaluated is car driver’s behaviour generally.

2. What type of appropriation processes were you aiming at investigating (research question related to driver appropriation)?
   Before starting the observation ride, we use a questionnaire to get some basic information about a driver.

3. Which methodological approach was used to investigate appropriation processes? (questions, mental models, performance criteria etc.)
   Objective performance criteria are based on data monitoring of vehicle operation.

4. Operational definition of appropriation: What variables were measured to assess appropriation processes?
   Black box measured the acceleration in the three axes. The axes X,Y are the relevant for describing the fluency of the ride.

5. What other variables were measured that are assumed to influence driver appropriation processes?
   Black box measured the acceleration in the three axes. The axes X,Y are the relevant for describing the fluency of the ride. The acceleration is record with the exact time (date, hh:mm:ss).
   We do have an experience also with measurement of other variables like a yaw rate, brake use (brake liquid pressure) and throttle pedal use (a little development necessary).

6. How was study designed in order to be able to measure long-term or short-term effects of appropriation? (How was appropriation designed in to the experiment? – e.g. driving for a specified number of hours …)
   The objective measurement is possible for both short- and long-term appropriation effects.

7. How was appropriation measured over time? (repeated measurements, time lines, learning curves etc.)
   Repeated measurements.
8. Describe experimental setting (lab, field, simulator etc.)
   Field only – experimental car.

9. Participants required (characteristics of the sample: selection criteria, no. of participants, gender, age etc)?
   Not completed yet. Estimated minimum number of participants: 25

Concluding evaluation of the method:

10. Environment for which the results are valid (specific/broad)?
    Not completed yet.

11. Brief conclusion of experimental work using method
    Data monitoring of vehicle operation from two various types of the blackbox:
    1) Embedded OEM type (more complete data)
    2) After market type (a simpler type with less data)

12. Critical analysis (evaluation) of the method (i.e. sensitivity, validity, advantages, etc.)
    Validation of this objective method is simple. Outputs in form of tables or graphs are possible. Advantage: both subjects - car and driver - can be observed at once. Subjective method can complete the study (investigation etc.).

13. References (e.g. papers written or other useful material)
## Conjoint analysis (CDV)

### Description of method:

1. **What type of ADAS/IVIS or system functionality was evaluated?**
   - Selected ADAS systems (ACC, speed control, collision avoidance..)

2. **What type of appropriation processes were you aiming at investigating (research question related to driver appropriation)?**
   - The aim to investigate the opinions and attitudes of drivers towards ADAS systems (different user groups); acceptance of ADAS. Users willingness to buy the specific systems including its variance (marketing research)

3. **Which methodological approach was used to investigate appropriation processes?** (questions, mental models, performance criteria etc.)
   - Questions.

4. **Operational definition of appropriation: What variables were measured to assess appropriation processes?**
   - Driver’s attitudes and opinions, acceptance, preferences of end users.

5. **What other variables were measured that are assumed to influence driver appropriation processes?**
   - No other variables.

6. **How was study designed in order to be able to measure long-term or short-term effects of appropriation? (How was appropriation designed in to the experiment? – e.g. driving for a specified number of hours …)**

7. **How was appropriation measured over time? (repeated measurements, time lines, learning curves etc.)**
   - Appropriation was not measured over time.
8. Describe experimental setting (lab, field, simulator etc.)
   A set of products was created and presented to respondents, who provided the overall evaluation. The respondent is about to choose from variety of products and makes a decision which product is worth to buy.

9. Participants required (characteristics of the sample: selection criteria, no. of participants, gender, age etc.)?
   **Private drivers** (young, adult, elderly, male, female, drivers with special needs)
   **Professional drivers** (bus/coach, truck/lorry, van (delivery), taxi).

**Concluding evaluation of the method:**

10. Environment for which the results are valid (specific/broad)?
    Broad.

11. Brief conclusion of experimental work using method
    The method is important for future ADAS implementation.

12. Critical analysis (evaluation) of the method (i.e. sensitivity, validity, advantages, etc.)
    High internal and external validity.
    Extensive use of the method in marketing research for decades.

13. References (e.g. papers written or other useful material)
Long-term system use – to check driver appropriation with the system (NTUA)

**Brief Description:** This method involves on-road studies. The vehicle that participants use should be equipped with the investigated system (also a new vehicle could be provided). Driver behaviour should be monitored before using the system, and at certain periods ie within the first day, first week, first month, first year etc. Changes in behaviour should be noted.

**Advantage(s):** Quite accurate (increasing with increased duration of time periods), drivers getting used to being monitored and effects being monitored on driver behaviour of this decrease with time, hence normal driving behaviour is observed.

**Disadvantage(s):** High cost.

**Other Comments:** This method involves the use of instrumented vehicles which participants will use for their everyday trips for the duration of the experiment. During this period, specific parameters of their driving behaviour should be monitored. The period of the experiment has to be set and could be defined by a number of different attributes including (a) a set number of driven kilometres, (b) a set period of time (i.e. 1 year), (c) a combination of (a) and (b) also in combination with different types of roads etc.

The instrumented vehicle could be the participants own vehicle being equipped with the necessary systems, monitoring equipment etc, or a vehicle “handed” to them to be used during the course of the experiment. First, users need to familiarise themselves with the modified or new vehicle, with the operation of the system and with the monitoring equipment (black box, cameras etc). Once a set familiarisation period has passed, data describing elements of driving behaviour will be analysed. It would be desirable to monitor driver behaviour before using the system, and this behaviour could be defined as the “default” driver behaviour. The check driver appropriation the default driver behaviour should be compared with the behaviour during short-term system use, and that after long-term system use.

Parameters related to driving behaviour and system use behaviour are related to the investigated system. For example, if the investigated system is an intelligent adaptation system the investigated parameters could involve be driving speed in relation to posted speed limit, speed variability, time driven over the speed limit, overtaking behaviour (headways with preceding vehicle and gaps with on coming traffic when overtaking), no of times or period when the system was switched off by the driver etc), whereas if the system was a navigation system providing real-time traffic information the investigated parameters could involve chosen route, reaction times, lateral position etc. In addition, to the above mentioned parameters, parameters related to system acceptability (i.e. from questionnaires) could also be extracted. Driver behaviour would then be analysed to check whether specific elements of the behaviour change with time, and through these changes identify driver appropriation.
On and off system use – to check driver appropriation even without the system (NTUA)

Brief Description: This method also involves on-road studies, but could also involve a repeated simulator experiment. Driving behaviour of users should be first recorded, then recorder again with system use, and then again without system use. The time for which the participant is using the system as well as the recording periods should be carefully defined – for short periods only the simulator could also be employed.

Advantage(s): Quite accurate (especially for on-road studies)

Disadvantage(s): Still high cost but lower from previous one especially for shorter time periods

Other Comments: This method looks at the effect of the system on driver behaviour after having used the system, but also in the case the system is not used. The experiment could take place with the use of a simulator or an experimented vehicle.

The procedure involves three distinct phases: driving without the system, driving with the system, driving without the system. The first phase, involves the actual driving behaviour before having used the system and can be defined as the “default” behaviour. The second involves driver behaviour when using the system and the third involves the behaviour of the driver after having used the system, but without him/her using it anymore.

Most of the elements of the experiment are similar to those described in the ‘long term use method’ example above. The main difference is that in this case the different phases of the experiment during which behaviour is analysed are predefined. Another difference involves the duration of the experiment, which in this case can be smaller (and should be smaller in the case of conducting the experiment using a driver simulator).
**Unobtrusive measurements with VTT’s instrumented vehicle (VTT)**

<table>
<thead>
<tr>
<th>Brief Description:</th>
<th>VTT’s instrumented vehicle enables unobtrusive measurements of driver behaviour, including speed (+ acceleration, deceleration, jerks), eye movements, steering wheel position, potential conflicts with other traffic (based on front view camera), various IVICS and HMI’s + expert evaluation (not unobtrusive)</th>
</tr>
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<tbody>
<tr>
<td>Advantage(s):</td>
<td>measurements can be made in real traffic, without subject to know the exact meaning of the study (e.g. by giving a cover task), possibility to test various IVICS and user interfaces</td>
</tr>
<tr>
<td>Disadvantage(s):</td>
<td>expensive method, especially eye movements. In addition, time consuming since the weather, traffic conditions etc. should be same for all the subjects (if between-subjects comparison is to be done). Not possible to test something until the limits of the driver capabilities (ethics!)</td>
</tr>
<tr>
<td>Other Comments:</td>
<td>More detailed description of the method, examples of use:</td>
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</table>

**HASTE Project (EC)**
The instrumented vehicle method was used for example in an European project HASTE (Human Machine Interface And the Safety of Traffic in Europe), where one of the main aims was to develop methodologies and guidelines for the assessment of In-Vehicle Information Systems, and to assess the impact of increasing task load from an IVIS on driving performance and safety. This project has involved the observation of driving performance in rural and urban road environments. More specifically, (1) the data was collected in real traffic, (2) the drivers included so-called average and elderly drivers, (3) the effects of increasing Arrows and a CMT (cognitive) workload on driver performance were quantified, (4) the road types included both rural and urban driving and (5) evaluations were based on vehicle data, observations and drivers’ reports.

**TRAVELGUIDE Project**
The study was designed to investigate driver needs for the integration of traffic sign information provided by conventional traffic signs and an IVT (In Vehicle Terminal). Specifically, four message conditions were compared in the field experiment carried out by an instrumented vehicle. The message conditions were: visual sign, visual sign + auditory message, visual sign + auditory feedback, and visual sign + complete instruction.
Unobtrusive measurements with “black box” in company vehicles 
(VTT)

**Brief Description:** The taxi company’s vehicles equipped with black boxes enables unobtrusive location based measurements of driver behaviour, including speed (compared to current speed limit) and acceleration and deceleration (strong braking, jerks).

**Advantage(s):** measurements can be made in real traffic while driving drivers normal work shift, without subject to know about the measurements or at least the exact measurements variables. Number of different driver is high.

**Disadvantage(s):** expensive method, needs to have good cooperation with company. Not possible to test something until the limits of the driver capabilities (ethics!)

**Other Comments:**
More detailed description of the method, examples of use:

**Measuring and recording driver behaviour**
The main aims were to study 1) the possibility to measure driver-specific driving style in normal traffic and 2) the possible effects of random speed recording and information and group (non-personal) feedback. Subjects of the study were professional taxi-drivers in a large Finnish taxi-company.

The recording ISA system called SPEEDAUDIT (developed and piloted in Finland in year 2003-2004) was used. The system has the GPS for location information and an (non-visible) on-board unit, which includes speed measuring and modem for sending the collected data to server. In addition to speed and location measurements, also the possibility to measure and record information about acceleration and deceleration was piloted.

The results suggest that recording ISA, in order to be efficient, needs personal feedback about unwanted driving behaviour periodically. The active monitoring and feedback of drivers’ driving behaviour stresses the importance of safety as company’s policy and therefore encourages the drivers to actually change their behaviour in daily work.

Two promising indicators for traffic safety related risky driving were speeding and strong sudden braking, called jerk. Acceleration measurements make a good supplement for the speeding measurements. However, jerks as well as other quick accelerations should be further studied to be able to find out their connections to specific traffic event and traffic safety.

Results also indicated that there are extensive differences in behaviour between individual drivers, and employers seem to have sometimes difficulties in divide the risky drivers from average drivers. It would be beneficial to be able to give feedback and training to the most extreme drivers, but also reward the non-risky drivers to motive them to continue the desired driving style.
Quantitative surveys (questionnaires and interviews) (VTT)

**Brief Description:** a representative sample of e.g. Finnish drivers is drawn of a register (e.g. register of driving licenses), subjects are interviewed by phone, person to person or are asked to fill in a questionnaire

**Advantage(s):** If the response rate is good, the method gives representative, quantitative results for questions such as “how much” – in addition, the differences between user categories can be found if the groups under interest are represented in the sample, possible to get ideas of users willingness to pay for some new ITS. Possibility to longitudinal comparison (if repeated same way).

**Disadvantage(s):** gives only a little, if any, explanation to the questions of “why” – especially challenging when investigating new technology of which users don’t have experience. Only subjective (users’ own) estimation of e.g. effects of new technology (on driving behaviour), response rate in questionnaires can be low (and “sample” skewed, especially in internet-based surveys.)

**Other Comments:**

More detailed description of the method/methods, examples of use:

**Information needs of Finnish drivers:**
- Stratified random sample of Finnish drivers, representing whole country.
- Telephone interview conducted by Gallup (agency specialised for surveys), letter including information of the study as well as scales/alternatives for the multiple choice questions were sent to the respondents before the interview.
- Most of the questions close-ended (alternatives or numerical scale for answering)
- Drivers were questioned about their own typical trips: both daily commuting and longer (i.e. holiday) trips. They were reminded to think about their trips throughout the interview.
- Drivers were asked in general level of the importance of each information category (weather, congestion, road work, timetables and routes). If they indicated that a specific category is not important to them, they were not questioned further about the details of that part.
- Drivers were asked to give their opinions of how the information has affected their travelling/driving related decisions.
- Drivers were also asked what sources of information they have used themselves and what would they like to use when searching for travel/traffic related information. In addition, they were asked to estimate their willingness to pay for various ways to get real time traffic information.
- Background variables such as age, gender, education, driving experience, area of residence were also questioned and effects of these on the opinions were tested (statistical analysis) and reported.

**PROS:** gave us a good overview of the importance of a) information categories in general, b) specific details of the information categories, c) possibilities to affect travel decisions with the real-time information, d) overview of the sources of traffic information (in the time of the study, 1996), e) representative sample – possible to analyse results by area of residence

**CONS:** As in general with this kind of quantitative surveys, doesn’t give answer to the questions “why?”. For instance: we found out that even if drivers indicated that a certain piece of information was highly important to them, they still hadn't gotten it when needed. We don’t know if this was due to lack of information, quality of information or the source/easiness to get the information.
Quantitative surveys (questionnaires and interviews) (VTT)
Continued

Other Comments:
Opinions of car and lorry drivers about needs to develop traffic and road conditions in Finland:
- Personal interview: a stratified random sample of car drivers were interviewed at their homes, lorry drivers were interviewed in selected rest areas in different parts of the country.
- Most of the questions close ended: to be answered by using numerical scales
- Drivers were asked (and reminded) to think about their typical trips by car/lorry
- Numerical scales were used to be able to later make factors of the different details of the road environment (i.e. get wider factors such as “traffic safety” by combining several items related to safety)
- Most of the questions concentrated into the needs to develop the physical road infrastructure but included, however, also questions on the information needs and specific questions about the amount of cycling and the means to increase cycling (car drivers) in daily commuting
- Opinions of drivers from different parts of Finland (e.g. Northern/Southern, also countryside vs. cities) were compared to give input for the local needs to develop the infrastructure. Statistical analysis also showed some differences depending on the annual mileage as well as age and gender.

PROS: gave a good overview of the problems in the road infrastructure in different parts of the country. Gave also good insight of the similarities and differences in the opinions of car and lorry drivers. Factor analysis improves reliability of the data.

CONS: (in addition to the general cons of this kind of studies): when the respondents don’t have any “restrictions”, e.g. they don’t have to think about any financial issues, they have a tendency to “want it all”. Therefore, one shouldn’t just look at the answers to an individual aspect – but instead take a look at the order of the importance of the issues.

ITS services – user needs and transport policy goals
- telephone interview for the users (stratified random sample) + workshop for the experts in ITS
- designed to investigate user needs to various information/ITS solutions when driving/travelling, willingness to pay for the ITS, importance of governmental financing of various ITS
- close ended questions using either purely numerical scales or likert-type (strongly disagree,…, strongly agree) to make multivariate statistical analysis possible
- one important new finding compared to the several earlier studies was that ITS for drivers (especially in vehicle devices, personalized services) are widely agreed to be paid by the users – whereas services for public transportation travellers are considered to be “governmentally offered”. (Of course, drivers still want to have road side technology to be free of charge for them)

PROS: including willingness to pay for and willingness to use governmental financing for the development of ITS gives respondents some insight of “restricting” their desires to “have it all”. In addition, the comparison between users and ITS experts gives a good insight not only to the similarities/differences of the opinions but also the need for user awareness enhancement
CONS: as always with telephone interviews, especially concerning new technology, it is not always sure that all the respondents have enough knowledge of all the ITS included into the survey – even if it was explained, not just used the “names” of the systems.

All of the above mentioned studies have partly used the same methodology: questions and scales, to give information of the changes in opinions, awareness as well as changes of the expectations of the ITS in traffic, when repeated.
**Qualitative user studies, i.e. focus groups (VTT)**

**Brief Description:** Focus groups have been used at VTT when designing for new user interfaces and gathering new ideas in the concept development phase.

**Advantage(s):** possible to gather a lot of qualitative data, both individual and group produced, possibility to use paper models, mock-ups etc. of the systems still under development

**Disadvantage(s):** No a real usage situation – users reactions are based on the shown models and their assumptions on future technologies

**Other Comments:**
More detailed description of the method, examples of use:

**Development of traffic information channel (in digital television)**
- Focus groups: drivers and travellers, based partly on their age but also their situation in life (high school students, students, parents of little children, ..., senior citizens). Reason for different (but inside one group homogenous) groups was to a) get opinions from different users but also b) facilitate the discussion inside each group
- In the focus groups: group discussion, individual opinions, opinions on developed mock-up model and Puzzle-method to develop the hierarchy of traffic/travelling information
- In Puzzle, the users need to organize large amount different pieces of traffic related information into the groups (=make a menu hierarchy) as well as naming the made groups
- The mentors of the groups were around during the whole process and collected opinions and explanations of the different choices
- Some differences between groups were found – mostly based on the general “technology orientation”, but also similarities in the menus they made.
- **PROS:** gives good information for the reasons for the opinions. Interactive, one opinion causes more discussion and more opinions. Really fruitful discussion/gathering ideas for additional services for the digital television. Puzzle is a good way to organize several pieces of information. Users’ way to combine pieces of information often differs from “experts” way to do it.
- **CONS:** Time consuming... Success is depending on the skills of the moderators, especially if the group consists of one really talkative member and a couple of really shy ones. Teenagers seemed to be quite reserved to give their opinions in the group. However, their individual answers gave good insights.

**User needs for personal navigation services**
- Focus groups and diaries (also telephone interviews to gather general opinions in the beginning of the project)
- gave good detailed information related to real travelling/driving decisions for both daily commuting as well as for longer trips
- gave possibility to explain more detailed the new services enhanced by location based technology (more that in e.g. phone interviews)
- still challenges to explain the technology and its possibilities to some (not that technically oriented) users

It seems to be so that use of new technology affects not only opinions on that technology but also expectations to the new systems. Therefore, even focus group or similar quantitative studies can give good insight of longitudinal changes.
Driver behaviour in the traffic flow (VTT)

**Brief Description:** Driver behaviour, i.e. speed, headways and lateral position of the vehicle in normal driving conditions (can be before and after installing VMS etc.).

**Advantage(s):** Driver are driving as normally, possibility to before-after –studies as well as comparing different environments, weather etc.

**Disadvantage(s):** no control of the non-measured driving behaviour (e.g. using of controls, in-vehicle systems, mobile phone), no control of driver characteristics (if not stopped and interviewed later)

**Other Comments:**
More detailed description of the method, examples of use:

**Weather related VMS and driver behaviour** (a bunch of related studies, including a PhD Thesis)
- effects of various VMS (variable message signs) have been studied in Finland during the past 10 years. Effects on speeds, (level + variation) as well as headways have been measured. In addition, the recognition and comprehension of the VMS have been investigated – to get more reasoning to the measured changes in speeds as well as find out possible misunderstandings, differences between different driver groups etc. Still, interviews have also conducted to investigate the detection of static traffic signs in the same environment with VMS.
- Speed and headways have been recorded by detector loops in the traffic flow. In addition, the information of the weather and the state of the signs have been logged carefully. Both pre/after studies and trial vs. comparison sites have been used to find out the effect of VMS (not just weather etc.). Possible novelty effect has been taken into account – and final effects have been studied when the system has been active already for a while.

**PROS:** gives both quantifiable, objective as well as subjective data of the effects of VMS. Results can be compared with older ones to find out if there are any differences when VMS are getting more common and drivers are getting used to those.

**CONS:** time consuming, both planning and conducting. Needs to have close co-operation with road authorities (logs, organization of the studies, keeping the sites cleared from other activities such as road work…). Interviews interferes with the traffic (Finnish drivers, however, accepts this quite easily).
User (usability) tests (VTT)

**Brief Description:** User tests in laboratory: users are using a new system of a model of it

**Advantage(s):** Feedback from the users on the user interface (both hardware and software: information ergonomics)

**Disadvantage(s):** The most obvious “mistakes” in the system can be found quite easily. However, since user is using the system without having a primary task (driving), the situation is not as critical (no risk, maybe no need to interrupt the task etc.)

**Other Comments:**
More detailed description of the method, examples of use:

**Development of traffic information channel in digital television**
- users used the real working system in laboratory with the real user interface (remote control as an input device)
- users with different characteristics were included (travelling behaviour, age, experience with digital television)
- users were given various tasks to complete. Errors were observed and listed, as well as task times and opinions/comments during the task. Users were also questioned with the satisfactions of the system, both the user interface as well as the information content.
- Users were also asked to compare how well the system performed compared to other similar traffic related applications. In addition, they were asked about the willingness to pay for the system as it is and/or after modifications.

This kind of quite simple usability tests gives good input for product development – but also gives insight of the differences between users, especially experienced (gadget geeks) and more novice users. Experience of the previous systems has effects on the use of new systems (transfer effect) and therefore could also give some ideas of longitudinal changes.
**Name of Method:** GEM (Group Elicitation Method) session

**Brief Description:** GEM session will be carried out with the user of the system after a usage period. The GEM session is a brainstorming assisted by computers.

**Advantage(s):** to recuperate different point of views and to have a consensus between the users about the advantages and disadvantages of the system.

**Disadvantage(s):** subjective method.

**Other Comments:**
The Group Elicitation Method (Boy, 1996) is a computer-supported knowledge elicitation method and environment that usually gathers 7 participants. It enables the elicitation of viewpoints and concepts on a specific domain. It is based on a multi-platform client/server architecture. It requires a Facilitator for controlling each session. Participants can be in the same place or in different locations. In current practice, we perform GEM sessions in the same place. The GEM session is typically used in any situation where people have to carry out a cooperative work whether it is to design, evaluate, organize, decide or simply brainstorm on a specific topic. The GEM session is a structured environment that nicely accommodates people interactions.

The GEM session supports five steps:
1. Briefing:
The first step called Briefing enables the Facilitator to define precisely
   - the GEM session topic;
   - the definition of a list of participants;
   - the definition of where, when and how the session will take place.
2. Brainwriting:
The second step called Brainwriting enables the Facilitator to initiate the actual generation of viewpoints. Each participant is facing a Brainwriting screen that enables him or her to express viewpoints with respect to the topic. They also can comment (agree or disagree) previously generated viewpoints. The Brainwriting facilitates free and anonymous expression of viewpoints. It enables both intentional and reactive behaviour of participants using a circular permutation. The Brainwriting can be used in a remote-location mode.
3. Concept:
The third step called Concept enables the Facilitator to define concepts based on collected viewpoints and comments. The participants monitor the definition of the processes issued by the Facilitator. The Concept step enables hierarchical structuring of the selected elements (merge, split).
4. Consensus:
The fourth step called Consensus enables the participants to prioritise each concepts. It enables the Facilitator to derive a general average score, and the group to identify other important concepts.
5. Debriefing:
The fifth step called Debriefing enables the participants to co-operatively elicit priority concepts that should be retained or postponed. Decision enables the group to document decisions, associated action plans and the distribution of responsibility. It enables the facilitator to immediately deliver a structured meeting report to appropriate people.
GEM (Group Elicitation Method) session (EURISCO) Continued

Examples of how the method can be used:

The GEM session can be used to measure driver appropriation of ITS. For example, the GEM session was used to elicit current practices of professional drivers and students in telephoning while driving (Barbé, 2005). The GEM approach was chosen to improve our knowledge on these practices in order to identify driver’s appropriation, its needs and identify possible safer solutions for telephony in the car.

For this study, the GEM session questions were:
* How do you use your mobile phone in the car and how do you manage your calls
* What are the problems, the risks and the difficulties that you encountered when telephoning while driving and what are the possible solutions?

We recuperated different point of views and obtained consensus between the participants about their experience, appropriation and advantages or disadvantages concerning telephoning while driving. These results were categorized into concepts. Categorization leads to the clarification of relevant and important concepts by grouping similar and ordered concepts with each other. This categorization enhances our understanding of the current practice of telephoning while driving and the needs of drivers. The results on these practices showed, for example, that it was important for the participants to develop a new technology to assist the driver when she/he uses the mobile phone while driving.

The limit of this method is that the results are subjective but it is possible to combine this method with other objective methods to complete the measure.


Questionnaire and interview (EURISCO)

Name of Method: questionnaire and interview

Brief Description: questionnaire after a period where the system was used

Advantage(s): to recuperate the feedback and feeling of each user about the system used.

Disadvantage(s): subjective method

Other Comments: none
Appendix 3 – Case Studies

Adaptation of secondary task performance by use of ADAS

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Background
In a driving simulator it was examined how the involvement in secondary tasks changes when the drivers are supported by two different kinds of Advanced Driver Assistance Systems (ADAS) which on the one hand support lateral control (lane keeping) or longitudinal control (speed and distance control). On the other hand, one ADAS provides only haptic feedback (lane keeping ADAS) while the other completely takes over control of this part of the driving tasks (speed and distance control). The experiment was conducted within the project S.A.N.T.O.S. A part of this project was done at the Center of Traffic Sciences in Wuerzburg (WIVW), Germany (Würzburger Institut für Verkehrswissenschaften) by PD Dr. Mark Vollrath, Prof. Dr. Hans-Peter Krüger and Dipl.-Psych. Ingo Totzke.

The S.A.N.T.O.S project was managed by BMW Group and Robert Bosch GmbH, sponsored by BmBF, # 19 S 9826 A/B, www.santosweb.de, for an overview, see Mayser, 2002). The main aim of the project was to adapt ADAS towards the driver and the driving situation. The WIVW examined the adaptation of ADAS when secondary tasks like telephoning were executed (see Vollrath & Totzke, 2000).

Method
In a driving simulator with motion simulation two ADAS were examined (see also Vollrath & Lemmer, 2003a,b). Heading Control (HC) is based on a development of the BMW Group. Using a video-based recognition of the lane the position of the centre of the vehicle relative to the centre of the lane is computed. If this deviation from the centre of the lane is larger than a fixed criterion, an additional momentum is given to the steering wheel. Thus, the driver receives additional haptic information about the quality of lane keeping when his performance deteriorates.

Adaptive Cruise Control (ACC) is a radar-based system which determines the distance towards preceding cars and regulates speed to guarantee a specified minimum distance. Without preceding cars a speed selected by the driver is kept. This ADAS is designed as an automatic system that performs a part of the driving task instead of the driver. In the experiment, the ACC system was able to handle all situations given to the driver.

These systems were examined in the motion driving simulator of the WIVW (see Kaussner et al., 2002, Grein et al., 2002). The motion simulation encompasses motion with 6 degrees of freedom and a 180 degree sight of the world. For the experiment with the HC system, a course was designed consisting of a 5.5 km rural road (two lanes, curves 400 to 700 m radius, length 250 to 500 m). Dense oncoming traffic was used to focus the driver’s attention on lane-keeping. This road was driven once with a preceding car which slightly varied speed (between 95 and 105 km/h) and once without a preceding car. For the experiment with the ACC system, a straight course was designed with preceding cars which were introduced at certain points of the course and which drove slower (20, 30 and 50 km/h). Thus, breaking (done by the ACC) was required.

As secondary task a manual operation task was additionally introduced during driving. On an LCD screen a name was shown which was to be found in an electronic address book. To increase the difficulty of this task, for each new name a random entry point of the menu was selected. Thus, subjects had to orientate within the menu, find the address book and then select the name. To perform this task visual and motor resources are necessary.
The HC experiment was conducted with 5 highly trained drivers (2 male, 3 female, mean age 26.2 years) who drove the two courses described above with and without HC and with and without secondary task (2x2 within-subjects design). Both main effects (task and HC) and the interaction are examined using two-way ANOVAS. When significant effects were found, t-tests were used to compare each two conditions.

In the ACC experiment the condition ‘without ACC and without secondary task’ was not done as this condition was too monotonous and fatigue effects would have happened. Thus, in this experiment the effect of ACC (without vs. with ACC) is compared when performing the secondary task, only. The effect of the secondary task (without vs. with task) is compared when driving with ACC, only. Both comparisons were done with t-tests. This experiment was done with 9 experienced drivers (3 female, 6 male, mean age 25.1 years) in a within-subjects design.

In order to analyse performance in the driving task the standard deviation of lane position was computed measuring the precision of lane-keeping. For longitudinal control, the minimum time distance towards the preceding car was computed indicating the time remaining for control actions. Secondary task performance was described by measuring the mean time needed to select one address from the address book. Finally, after each trip drivers were asked to rate how stressful the trip had been (0: not stressful at all, 15: extremely stressful).

Results I: Effects of the Information System HC

Figure 2 gives the effects of HC and secondary task on driving. The standard deviation of lane position increases significantly when conducting the secondary task. When HC is active, the standard deviation decreases. This effect is especially strong when conducting the secondary task. Thus, HC counteracts the negative effects of the secondary task on lateral control. With regard to longitudinal control, the minimum time distance towards preceding cars is increased when engaging in the secondary task when HC is active. Without HC, this effect is not significant. Thus, when doing the secondary task when HC is active, drivers increase the amount of time available to react to sudden speed changes of the preceding car.

Figure 2: Effects of HC on driving with and without secondary task. The lines indicate significant effects (\(\cdot\cdot\cdot\): \(p < 0.1\); \(\ast\ast\ast\): \(p < 0.05\); \(\ast\ast\ast\ast\): \(p < 0.01\)).

Figure 3 shows that when HC is active subjects take significantly longer time to complete one trial. Additionally, driving becomes more stressful when engaging in the secondary task. An effect of HC on subjective stress is not found.
Secondary Task Performance

<table>
<thead>
<tr>
<th></th>
<th>Without HC</th>
<th>HC active</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time needed for one Trial [s]</td>
<td>15</td>
<td>20</td>
</tr>
</tbody>
</table>

Subjective Stress

<table>
<thead>
<tr>
<th></th>
<th>Without HC</th>
<th>HC active</th>
</tr>
</thead>
<tbody>
<tr>
<td>How stressful was the trip? [0..15]</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

**Figure 3: Effects of HC and secondary task on task performance and subjective stress. The line indicate significant effects (, "+": p < 0.1; , "*": p < 0.05; , "**": p < 0.01).**

To summarize the effects of the information system HC:
- HC improves lane keeping.
- The driver increases his time available to react to the preceding car (minimum time distance).
- When HC is active, the drivers take longer time to complete one trial of the secondary task.
- HC does not reduce the stress or workload of the driver.

To put it differently, this means for secondary task performance with heading control:
- When HC is active, the secondary task cannot be performed as well and takes longer as when it is not active.
- It is stressful to perform the secondary tasks while driving.
- HC does not change the stress induced by the secondary task.

Thus, with HC it takes longer for drivers to perform the secondary task while their stress level remains comparable. This can be understood as a protective effect of HC which forces the driver to concentrate on the driving tasks and allocate more attention to it when doing the secondary task concurrently. Thus, from a safety perspective, HC keeps the driver concentrated on the primary task with negative effects for the secondary task performance.

**Results II: Effects of the Automatic System ACC**

Figure 4 gives the effects of ACC on driving. Again, engaging in the secondary task increases the standard deviation of lane position. Moreover, when the ACC system is active, the SD of lane position is also increased, that means ACC reduces the precision of lane keeping. In longitudinal control, the ACC system keeps a larger minimum time distance towards the preceding car than the driver.

Secondary task performance is not changed by ACC (see Figure 5). Subjective stress increases when engaging in the secondary task. ACC reduces subjective stress and thus counteracts the subjective effects of the secondary task.
To summarize the effects of the automatic system ACC:

- ACC increases the available time to react to preceding cars (system parameter).
- ACC decreases the precision of lane keeping.
- ACC enables the driver to engage in the secondary task.
- ACC reduces subjective stress.

From the viewpoint of the secondary task this means:

- The secondary task can be performed with ACC as least as well as without ACC. There is some indication that task can be executed somewhat faster.
- Additionally, the subjective stress induced by doing the secondary task while driving is reduced by the ACC system.

As the ACC system takes over part of the driving task, the driver can concentrate more on the secondary tasks so that the driver’s stress is reduced. This system’s support enables the driver to better perform the secondary task. However, there is some indication that the remaining part of the driving task which has still to be done by the driver is performed worse with ACC and the secondary task (increase in sd of lane position). This could mean that the driver’s attention is withdrawn from the driving task and focused on the secondary task. Thus, if additional attention is required when something critical is happening in the environment, one would predict that drivers performing the secondary task with ACC will not react as adequately as drivers without this system.

Discussion

This example shows that secondary task performance is strongly influenced by ADAS. Moreover, the interaction strategy or level of automation of the ADAS is highly relevant. The HC system which is designed as a warning system effectively draws the attention of the driver to the primary driving task with respective negative effects on secondary task performance.
From a safety point of view this type of ADAS is highly suited to ensure that the driver remains in a safe state even when concurrently engaging in secondary tasks. However, one has to be aware that this may be experienced negatively by the driver whose stress level is high and where it takes longer to complete a task. To examine this question, the drivers were asked after the experiment how much they liked the system (‘how good is the system?’). For this subjective evaluation, data from 10 subjects could be analyzed. For HC, only 5 drivers rated ‘good’ or ‘very good’, 4 drivers rated ‘neither good nor bad’ and one driver ‘not good’. In contrast, 9 of 10 subjects rated ACC as either ‘good’ or ‘very good’. Thus, HC is really evaluated more negatively by the drivers as compared to ACC.

Figure 6: Subjective evaluation of HC and ACC while engaging in a secondary task.

On the other hand, the ACC takes over some part of the driving task and thus reduces the driver’s workload. This enables the driver to engage more in the secondary task and do it somewhat faster. Additionally, subjective stress is substantially reduced. From this viewpoint, this kind of ADAS really supports the driver and he or she can concentrate on the secondary task. This leads to a very positive evaluation by the drivers. However, this may lead to negative consequences with regard to the primary task of driving. One possible solution could be to take over the other parts of driving, too. Perhaps even a warning ADAS for the other parts of the driving task (e.g., an HC for lateral control) could already be beneficial. However, if some critical events happen where the driver has to take over this would probably then take substantially longer. This should be examined in further experiments.

Overall, drivers modify their behaviour even with a very short experience of an ADAS. If an ADAS takes over some part of the driving task, the drivers readily use free resources to engage more in other tasks with possible negative effects on driving. On the other hand, ADAS can also act to keep the driver concentrated on driving with negative effects, however, on secondary task performance. The experiment shows that drivers actively use ADAS and adapt their behaviour according to possibilities which are given them by the ADAS functionality. Thus, when the overall effect of an ADAS is to be evaluated it is not sufficient to examine how driving behaviour is changed with as compared to without ADAS in specific scenarios. One must also create possibilities for the driver to adapt his behaviour so that it can be examined what the overall effect of the ADAS is then.

References


The strategic level of behaviour: Understanding and knowledge
Ralf Risser and Christine Turetschek (FACTUM)

Even if people know about facts that would ask for a change of behaviour this does not mean that they behave according to their knowledge. This is also true for behaviour in traffic, for instance concerning the handling and use of new telematic devices. In addition to the necessary skills for handling a vehicle, people in driving schools also learn about their responsibility and about dangers in traffic. But still risky behaviour like for instance erroneous use or abuse of new IST systems is a frequent phenomenon.

Driving does not only consist of handling the car and safe driving does not only depend on skills in this sense. Safe driving also depends on the motivation of the driver, his/her general life style, his/her experiences and intentions, his/her attitudes towards other road users, etc.. Sometimes, the car is used to compete with others, sometimes to show one’s own performance (where often one’s skills are overestimated), sometimes driving is used for risk seeking and so on. At the same time, people interpret the behaviour of other road users erroneously because for instance they cannot understand the situation of others (e.g., they cannot imagine how it is to be a cyclist in a certain situation as they never experienced cycling themselves), or because they assume wrong reasons for other people’s unsafe behaviour (“He/she is driving 30 km/h instead of 50 because he/she wants to annoy me”).

There are several theories which tackle those issues into account and try to answer the question what the reason for unsafe behaviour is, on a strategical level.

According to the model of Keskinen and Hatakka (Keskinen, 1996 and Hatakka, 1998) the driving task can be described on different levels. Drivers have to learn vehicle manoeuvring, and to master traffic situations. But next to those skills also the goals and the context of driving and the goals for life and skills for living play an important role regarding the driving task and how one accomplishes it.

What people primarily learn in driving schools is to handle the car in a proper way. Recently, at least in Austria, novice drivers also are obliged to attend a Safety Training where they learn to handle difficult and dangerous situations for which the risk mostly is underestimated such as speeding on a wet road. Experienced drivers are supposed to become aware of traffic safety problems through campaigns which refresh the knowledge of what they have learned in the driving school. For many drivers those actions probably are sufficient to make them drive safely.

But for others they obviously do not suffice. Why do people behave in an unsafe way and thus endanger themselves and others? This seems to be quite illogical on the first view but such behaviour becomes understandable if, for example, the theory of constructivism (see wikipedia “Konstruktivismus”) is applied. This theory poses that every person develops a very unique angle of view on the world depending on the surrounding field he or she was born in, grew up in and made experiences in. If we think of a person who has a very important meeting and he/she is late, then there are different possible solutions for him/her, all on the strategic level: Maybe this person would not care about the delay at all because he/she assumes that probably other people will be late as well. Another option could be that this person calls the office and informs his/her colleagues about the delay. But this person also could start speeding in order to make up for the lost time.

According to another theory, the rational choice theory (see wikipedia “rational choice theory”) every human being wants to achieve their goals in the best possible way they can imagine. This does not mean that the most efficient way is chosen, since behaviour depends on the experiences, knowledge, memories of similar solutions at earlier occasions, etc., as said above. To take the example of speeding, this person might have learned that himself/herself usually make it to arrive in time by driving faster.
Moreover, behaving safely also includes the understanding of the possible intentions of others, which may not be obvious in many cases. A driver who turns on the right indicator may have the intention to turn right but he may also be looking for a parking space. In the latter case, deceleration of the car in front may start at an unexpected point of time, leading to problems for the driver behind. A strategic attitude would be not to take one’s own assumptions of other people’s behaviour for granted.

Intentions and motives are key issues in many respects. For instance, if we take the example of persons who seek thrill (as for instance many novice drivers experience speeding as thrilling). For this group a training as described above – where one learns to tackle dangerous situations - may be fatal as it displays to the trainees opportunities to search for thrilling situations, and at the same time provides the feeling that they are now able to tackle such situations. Thus, they will not primarily learn to avoid them, but rather to search them and then to “solve” them. To avoid risky situations is a typical strategic issue and has to be dealt with differently than in the form of training in the field. Education on the strategic level would, in contrast to this, enhance self reflection, make the absurd thing of risking one’s own and others’ lives on the road more transparent, etc..

Not least, strategic issues are influenced by the motives and interests of people. That’s why one has to find out what precisely facilitates the perception of thrill that lies in speeding, for instance. It just might be the bodily feeling at the moment of acceleration, it might be the competition with other car drivers, but it also could be the feeling of having the vehicle under control.

In general it can be stated that it is not enough to teach novice drivers how to handle a car and how to master difficult situations. Back to the model of Keskinen and Hatakka (Keskinen, 1996 and Hatakka, 1998), especially the goals and the context of driving and the goals for life and skills for living must be uncovered, made conscious and subsequently changed, if they cause dangerous behaviour. The goal must be to find those reasons for unsafe and dangerous behaviour that steer behaviour on a strategic, and thus very general, level. In case thrill seeking is very important for a person, one could even discuss where this is possible off the road. But as certain persons obviously nevertheless like to seek thrill in traffic it is necessary to find out what makes traffic such an interesting field in this respect. The question what has to be done to change the behaviour has to be answered as well.

So far there exist quite a lot of different methods to make people behave safely and to teach novice drivers a safe driving style, like the Safety Training. But probably for many those strategies are still not enough. They might need a more individual and a more strategic teaching, where the very personal reasons for unsafe behaviour are made transparent, which is the basis for achieving sustainable changes in behaviour.

References

Keskinen E. 1996, Why do young drivers have more accidents?, BAS, Mensch und Sicherheit, Heft M 52, Bergisch Gladbach

Internet:
http://de.wikipedia.org/wiki/Soziologie
Appendix 4 - How ITS affects safety: Mechanisms of dependancy

(written by VTT 2006 for elimpact project; summary of Draskóczy et al. 1998 paper).

Draskóczy, Carsten and Kulmala (1998)² compiled a list of mechanisms, via which ITS affects safety. The list is the following:

1. Direct in-car modification of the driving task by giving information, advice, and assistance or taking over part of the task. This may influence driver attention, mental load, and decision about action (for example, driver choice of speed).
2. Direct influence by roadside systems mainly by giving information and advice. Consequently the impact of this influence is more limited than of the in-vehicle systems.
3. Indirect modification of user behaviour in many, largely unknown ways. The driver will always adapt to the changing situation. This is often called behavioural adaptation and will often not appear immediately after a change but may show up later and it is very hard to predict. Behavioural adaptation may appear in many different ways (for example, by change of usage of the car, by change of headway in a car following situation, by change of expectation of the behaviour of other road users).
4. Indirect modification of non-user behaviour. This type of behavioural adaptation is even harder to study because it is often secondary. Non-equipped drivers may for example change their behaviour by imitating the behaviour of equipped drivers (for example, driving closer or faster than they should, not having the equipment).
5. Modification of interaction between users and non-users. ITS will change the communication between equipped road users. This change of communication may influence the traditional communication with non-equipped road users. To a large extent this problem may arise in the interaction between drivers and unprotected road users.
6. Modification of road user exposure by for example information, recommendation, restrictions, debiting. This is certainly an area where introduction of ITS will have a large impact for example by changing travel pattern, modal choice, route choice etc.
7. Modification of modal choice by for example demand restraints (area access restriction, road pricing, area parking strategies), supply control by modal interchange and other public transport management measures, travel information systems. Different travel modes have different accident risks, therefore any measure which influences modal choice, has also impact on traffic safety.
8. Modification of route choice by demand restraints by route diversions, route guidance systems, dynamic route information systems, hazard warning systems monitoring incidents. Different parts of the road network, i.e. different categories of roads, have different accident risks, therefore, any measure which influences route choice by diverting traffic to roads of different category, has also impact on traffic safety.
9. Modification of accident consequences by intelligent injury reducing systems in the vehicle, by quick and accurate crash reporting and call for rescue, by reduced rescue time.

Many ITS systems have been developed and implemented for the main purpose of improving road safety by e.g. supporting drivers by advising them to use safe routes and speed, warning them of impeding danger, improving the control of vehicle in critical situations, and alerting assistance after an accident has occurred. Other systems have not had safety as their main concern, but will affect safety due to the changes in the travel and driving behaviour resulting from the use of the system. Table 1 attempts to compile the main safety mechanisms expected to occur with a number of ITS systems.

Table 1. Expected major safety mechanisms of selected ITS systems (+ means improved safety or reduction of fatalities, - means reduced safety or increase of fatalities)

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