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VII	Pereira, M., Beggiato, M., & Petzoldt, T. (submitted 15.06.2014). *Use of adaptive cruise control functions on motorways and urban roads: changes over time in an on-road study*.	6.3.1

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List of Abbreviations

ACC	Adaptive Cruise Control
ACID	Atomicity, Consistency, Isolation, Durability
ADAS	Advanced Driver Assistant System
AIDE	Adaptive Integrated Driver-vehicle interfacE
ANOVA	Analysis Of Variance
BASt	Bundesanstalt für Straßenwesen, Federal Highway Research Institute
BFI	Big Five Inventory
BSSS	Brief Sensation Seeking Scale
DBMS	Database Management System
DLR	Deutsches Zentrum für Luft- und Raumfahrt, German Aerospace Center
GOMS	Goals, Operators, Methods and Selection rules
HUMANIST	HUMAN centred design for Information Society Technologies
FOT	Field Operational Test
GPS	Global Positioning System
NDS	Naturalistic Driving Studies
NLR	Non Linear Regression
OECD	Organization for Economic Co-operation and Development
OLAP	Online Analytical Processing
RMSE	Root Mean Square Error
SA	Situation Awareness
SA-SWORD	Situation Awareness-Subjective Workload Dominance Technique
SAGAT	Situation Awareness Global Assessment Technique
SARS	Situation Awareness Rating Scales
SART	Situation Awareness Rating Technique
SD	Standard deviation
SPAM	Situation Present Awareness Method
SQL	Structured Query Language
SURT	Surrogate Reference Task
UMTRI	University of Michigan Transportation Research Institute
VTTI	Virginia Tech Transportation Institute
ZVT	Zahlenverbindungstest

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Summary

Many functions that at one time could only be performed by humans can nowadays be carried out by machines. Automation impacts many areas of life including work, home, communication and mobility. In the driving context, in-vehicle automation is considered to provide solutions for environmental, economic, safety and societal challenges. However, automation changes the driving task and the human-machine interaction. Thus, the expected benefit of in-vehicle automation can be undermined by changes in drivers' behaviour, i.e. behavioural adaptation. This PhD project focuses on motivational as well as higher cognitive processes underlying behavioural adaptation when interacting with in-vehicle automation. Motivational processes include the development of trust and acceptance, whereas higher cognitive processes comprise the learning process as well as the development of mental models and Situation Awareness (SA). As an example for in-vehicle automation, the advanced driver assistance system Adaptive Cruise Control (ACC) was investigated. ACC automates speed and distance control by maintaining a constant set cruising speed and automatically adjusting vehicle's velocity in order to provide a specified distance to the preceding vehicle. However, due to sensor limitations, not every situation can be handled by the system and therefore driver intervention is required. Trust, acceptance and an appropriate mental model of the system functionality are considered key variables for adequate use and appropriate SA.

To systematically investigate changes in motivational and higher cognitive processes, a driving simulator as well as an on-road study were carried out. Both of the studies were conducted using a repeated-measures design, taking into account the process character, i.e. changes over time. The main focus was on the development of trust, acceptance and the mental model of novice users when interacting with ACC. By now, only few studies have attempted to assess changes in higher level cognitive processes, due to methodological difficulties posed by the dynamic task of driving. Therefore, this PhD project aimed at the elaboration and validation of innovative methods for assessing higher cognitive processes, with an emphasis on SA and mental models. In addition, a new approach for analyzing big and heterogeneous data in social science was developed, based on the use of relational databases.

The driving simulator study investigated the effect of divergent initial mental models of ACC (i.e., varying according to correctness) on trust, acceptance and mental model evolvement. A longitudinal study design was applied, using a two-way (3×3) repeated measures mixed design with a matched sample of 51 subjects. Three experimental groups received (1) a correct ACC description, (2) an incomplete and idealised account omitting potential problems, and (3) an incorrect description including non-occurring problems. All subjects drove a 56-km track of highway with an identical ACC system, three times, and within a period of 6 weeks. Results showed that after using the system, participants' mental model of ACC converged towards the profile of the correct group. Non-experienced problems tended to disappear from the mental model network when they were not activated by experience. Trust and acceptance grew steadily for the correct condition. The same trend was observed for the group with non-occurring problems, starting from a lower initial level. Omitted problems in the incomplete group led to a constant decrease in trust and acceptance without recovery. This indicates that automation failures do not negatively affect trust and acceptance if they are known beforehand. During each drive, participants continuously completed a visual secondary task, the Surrogate Reference Task (SURT). The frequency of task completion was used as objective online-measure for SA, based on the principle that situationally aware driver would reduce the engagement in the secondary task if they expect potentially critical situations. Results showed that correctly informed drivers were aware of potential system limitations and reduced their engagement in the secondary task when such situations arose. Participants with no information about limitations became only aware after first encounter and reduced secondary task engagement in corresponding situations during subsequent trials. However, trust and acceptance in the system declined over time due to the unexpected failures. Non occurring limitations tended to drop from the mental model and resulted in reduced SA already in the second trial.

The on-road study investigated the learning process, as well as the development of trust, acceptance and the mental model for interacting with ACC in real conditions. Research questions aimed to model the learning process in mathematical/statistical terms, examine moments and conditions when these processes stabilize, and assess how experience changes the mental model of the system. A sample of fifteen drivers without ACC experience drove a test vehicle with ACC ten consecutive times on the same route within a 2-month period. In contrast to the driving simulator study, all participants were fully trained in ACC functionality by reading the owner's manual in the beginning. Results showed that learning, as well as the development of acceptance and trust in ACC follows the power law of learning, in case of comprehensive prior information on system limitations. Thus, the major part of the learning process occurred during the first interaction with the system and support in explaining the systems abilities (e.g. by tutoring systems) should therefore primarily be given during this first stage. All processes stabilized at a relatively high level after the fifth session, which corresponds to 185 km or 3.5 hours of driving. No decline was observable with ongoing system experience. However, in line with the findings from the simulator study, limitations that are not experienced tended to disappear from the mental model if they were not activated by experience.

With regard to the validation of the developed methods for assessing mental models and SA, results are encouraging. The studies show that the mental model questionnaire is able to provide insights into the construction of mental models and the development over time. Likewise, the implicit measurement approach to assess SA online in the driving simulator is sensitive to user's awareness of potentially critical situations. In terms of content, the results of the studies prove the enduring relevance of the initial mental model for the learning process, SA, as well as the development of trust, acceptance and a realistic mental model about automation capabilities and limitations. Given the importance of the initial mental model it is recommended that studies on system trust and acceptance should include, and attempt to control, users' initial mental model of system functionality. Although the results showed that also incorrect and incomplete initial mental models converged by experience towards a realistic appreciation of system functionality, the more cognitive effort needed to update the mental model, the lower trust and acceptance. Providing an idealised description, which omits potential problems, only leads to temporarily higher trust and acceptance in the beginning. The experience of unexpected limitations results in a steady decrease in trust and acceptance over time.

A trial-and-error strategy for in-vehicle automation use, without accompanying information, is therefore considered insufficient for developing stable trust and acceptance. If the mental model matches experience, trust and acceptance grow steadily following the power law of learning – regardless of the experience of system limitations. Provided that such events are known in advance, they will not cause a decrease in trust and acceptance over time. Even over-information about potential problems lowers trust and acceptance only in the beginning, and not in the long run. Potential problems should therefore not be concealed in over-idealised system descriptions; the more information given, the better, in the long run. However, limitations that are not experienced tend to disappear from the mental model. Therefore, it is recommended that users be periodically reminded of system limitations to make sure that corresponding knowledge becomes re-activated. Intelligent tutoring systems incorporated in automated systems could provide a solution. In the driving context, periodic reminders about system limitations could be shown via the multifunction displays integrated in most modern cars. Tutoring systems could also be used to remind the driver of the presence of specific in-vehicle automation systems and reveal their benefits.

Zusammenfassung

Viele Aufgaben, die ehemals von Menschen ausgeführt wurden, werden heute von Maschinen übernommen. Dieser Prozess der Automatisierung betrifft viele Lebensbereiche von Arbeit, Wohnen, Kommunikation bis hin zur Mobilität. Im Bereich des Individualverkehrs wird die Automatisierung von Fahrzeugen als Möglichkeit gesehen, zukünftigen Herausforderungen wirtschaftlicher, gesellschaftlicher und umweltpolitischer Art zu begegnen. Allerdings verändert Automatisierung die Fahraufgabe und die Mensch-Technik Interaktion im Fahrzeug. Daher können beispielsweise erwartete Sicherheitsgewinne automatisch agierender Assistenzsysteme durch Veränderungen im Verhalten des Fahrers geschmälert werden, was als Verhaltensanpassung (behavioural adaptation) bezeichnet wird. Dieses Dissertationsprojekt untersucht motivationale und höhere kognitive Prozesse, die Verhaltensanpassungen im Umgang mit automatisierten Fahrerassistenzsystemen zugrunde liegen. Motivationale Prozesse beinhalten die Entwicklung von Akzeptanz und Vertrauen in das System, unter höheren kognitiven Prozessen werden Lernprozesse sowie die Entwicklung von mentalen Modellen des Systems und Situationsbewusstsein (Situation Awareness) verstanden. Im Fokus der Untersuchungen steht das Fahrerassistenzsystem Adaptive Cruise Control (ACC) als ein Beispiel für Automatisierung im Fahrzeug. ACC regelt automatisch die Geschwindigkeit des Fahrzeugs, indem bei freier Fahrbahn eine eingestellte Wunschgeschwindigkeit und bei einem Vorausfahrer automatisch ein eingestellter Abstand eingehalten wird. Allerdings kann ACC aufgrund von Einschränkungen der Sensorik nicht jede Situation bewältigen, weshalb der Fahrer übernehmen muss. Für diesen Interaktionsprozess spielen Vertrauen, Akzeptanz und das mentale Modell der Systemfunktionalität eine Schlüsselrolle, um einen sicheren Umgang mit dem System und ein adäquates Situationsbewusstsein zu entwickeln.

Zur systematischen Erforschung dieser motivationalen und kognitiven Prozesse wurden eine Fahrsimulatorstudie und ein Versuch im Realverkehr durchgeführt. Beide Studien wurden im Messwiederholungsdesign angelegt, um dem Prozesscharakter gerecht werden und Veränderungen über die Zeit erfassen zu können. Die Entwicklung von Vertrauen, Akzeptanz und mentalem Modell in der Interaktion mit ACC war zentraler Forschungsgegenstand beider Studien. Bislang gibt es wenige Studien, die kognitive Prozesse im Kontext der Fahrzeugführung untersucht haben, unter anderem auch wegen methodischer Schwierigkeiten in diesem dynamischen Umfeld. Daher war es ebenfalls Teil dieses Dissertationsprojekts, neue Methoden zur Erfassung höherer kognitiver Prozesse in dieser Domäne zu entwickeln, mit Fokus auf mentalen Modellen und Situationsbewusstsein. Darüber hinaus wurde auch ein neuer Ansatz für die Analyse großer und heterogener Datenmengen im sozialwissenschaftlichen Bereich entwickelt, basierend auf dem Einsatz relationaler Datenbanken.

Ziel der der Fahrsimulatorstudie war die systematische Erforschung des Effekts von unterschiedlich korrekten initialen mentalen Modellen von ACC auf die weitere Entwicklung des mentalen Modells, Vertrauen und Akzeptanz des Systems. Eine Stichprobe von insgesamt 51 Probanden nahm an der Studie teil; der Versuch wurde als zweifaktorielles (3x3) gemischtes Messwiederholungsdesign konzipiert. Die 3 parallelisierten Versuchsgruppen zu je 17 Personen erhielten (1) eine korrekte Beschreibung des ACC, (2) eine idealisierte Beschreibung unter Auslassung auftretender Systemprobleme und (3) eine überkritische Beschreibung mit zusätzlichen Hinweisen auf Systemprobleme, die nie auftraten. Alle Teilnehmer befuhren insgesamt dreimal im Zeitraum von sechs Wochen dieselbe 56 km lange Autobahnstrecke im Fahrsimulator mit identischem ACC-System. Mit zunehmendem Einsatz des ACC zeigte sich im anfänglich divergierenden mentalen Modell zwischen den Gruppen eine Entwicklung hin zum mentalen Modell der korrekt informierten Gruppe. Nicht erfahrene Systemprobleme tendierten dazu, im mentalen Modell zu verblassen, wenn sie nicht durch Erfahrung reaktiviert wurden. Vertrauen und Akzeptanz stiegen stetig in der korrekt informierten Gruppe. Dieselbe Entwicklung zeigte sich auch in der überkritisch informierten Gruppe, wobei Vertrauen und Akzeptanz anfänglich niedriger waren als in der Bedingung mit korrekter Information. Verschwiegene Systemprobleme führten zu einer konstanten Abnahme von Akzeptanz und Vertrauen ohne Erholung in der Gruppe mit idealisierter Beschreibung. Diese Resultate lassen darauf schließen, dass Probleme automatisierter Systeme sich nicht zwingend negativ auf Vertrauen und Akzeptanz auswirken, sofern sie vorab bekannt sind. Bei jeder Fahrt führten die Versuchsteilnehmer zudem kontinuierlich eine visuell beanspruchende Zweitaufgabe aus, die Surrogate Reference Task (SURT). Die Frequenz der Zweitaufgabenbearbeitung diente als objektives Echtzeitmaß für das Situationsbewusstsein, basierend auf dem Ansatz, dass situationsbewusste Fahrer die Zuwendung zur Zweitaufgabe reduzieren wenn sie potentiell kritische Situationen erwarten. Die Ergebnisse zeigten, dass die korrekt informierten Fahrer sich potentiell kritischer Situationen mit möglichen Systemproblemen bewusst waren und schon im Vorfeld der Entstehung die Zweitaufgabenbearbeitung reduzierten. Teilnehmer ohne Informationen zu auftretenden Systemproblemen wurden sich solcher Situationen erst nach dem ersten Auftreten bewusst und reduzierten in entsprechenden Szenarien der Folgefahrten die Zweitaufgabenbearbeitung. Allerdings sanken Vertrauen und Akzeptanz des Systems aufgrund der unerwarteten Probleme. Erwartete, aber nicht auftretende Systemprobleme tendierten dazu, im mentalen Modell des Systems zu verblassen und resultierten in vermindertem Situationsbewusstsein bereits in der zweiten Fahrt.

Im Versuch unter Realbedingungen wurden der Lernprozesses sowie die Entwicklung des mentalen Modells, Vertrauen und Akzeptanz von ACC im Realverkehr erforscht. Ziele waren die statistisch/mathematische Modellierung des Lernprozesses, die Bestimmung von Zeitpunkten der Stabilisierung dieser Prozesse und wie sich reale Systemerfahrung auf das mentale Modell von ACC auswirkt. 15 Versuchsteilnehmer ohne ACC-Erfahrung fuhren ein Serienfahrzeug mit ACC insgesamt 10-mal auf der gleichen Strecke in einem Zeitraum von 2 Monaten. Im Unterschied zur Fahrsimulatorstudie waren alle Teilnehmer korrekt über die ACC-Funktionen und Funktionsgrenzen informiert durch Lesen der entsprechenden Abschnitte im Fahrzeughandbuch am Beginn der Studie. Die Ergebnisse zeigten, dass der Lernprozess sowie die Entwicklung von Akzeptanz und Vertrauen einer klassischen Lernkurve folgen – unter der Bedingung umfassender vorheriger Information zu Systemgrenzen. Der größte Lernfortschritt ist am Beginn der Interaktion mit dem System sichtbar und daher sollten Hilfen (z.B. durch intelligente Tutorsysteme) in erster Linie zu diesem Zeitpunkt gegeben werden. Eine Stabilisierung aller Prozesse zeigte sich nach der fünften Fahrt, was einer Fahrstrecke von rund 185 km oder 3,5 Stunden Fahrzeit entspricht. Es zeigten sich keine Einbrüche in Akzeptanz, Vertrauen bzw. dem Lernprozess durch die gemachten Erfahrungen im Straßenverkehr. Allerdings zeigte sich – analog zur Fahrsimulatorstudie – auch in der Realfahrstudie ein Verblassen von nicht erfahrenen Systemgrenzen im mentalen Modell, wenn diese nicht durch Erfahrungen aktiviert wurden.

Im Hinblick auf die Validierung der neu entwickelten Methoden zur Erfassung von mentalen Modellen und Situationsbewusstsein sind die Resultate vielversprechend. Die Studien zeigen, dass mit dem entwickelten Fragebogenansatz zur Quantifizierung des mentalen Modells Einblicke in Aufbau und Entwicklung mentaler Modelle gegeben werden können. Der implizite Echtzeit-Messansatz für Situationsbewusstsein im Fahrsimulator zeigt sich ebenfalls sensitiv in der Erfassung des Bewusstseins von Fahrern für potentiell kritische Situationen. Inhaltlich zeigen die Studien die nachhaltige Relevanz des initialen mentalen Modells für den Lernprozess sowie die Entwicklung von Situationsbewusstsein, Akzeptanz, Vertrauen und die weitere Ausformung eines realistischen mentalen Modells der Möglichkeiten und Grenzen automatisierter Systeme. Aufgrund dieser Relevanz wird die Einbindung und Kontrolle des initialen mentalen Modells in Studien zu automatisierten Systemen unbedingt empfohlen. Die Ergebnisse zeigen zwar, dass sich auch unvollständige bzw. falsche mentale Modelle durch Erfahrungslernen hin zu einer realistischen Einschätzung der Systemmöglichkeiten und -grenzen verändern, allerdings um den Preis sinkenden Vertrauens und abnehmender Akzeptanz. Idealisierte Systembeschreibungen ohne Hinweise auf mögliche Systemprobleme bringen nur anfänglich etwas höheres Vertrauen und Akzeptanz. Das Erleben unerwarteter Probleme führt zu einem stetigen Abfall dieser motivationalen Faktoren über die Zeit.

Ein alleiniges Versuchs-Irrtums-Lernen für den Umgang mit automatisierter Assistenz im Fahrzeug ohne zusätzliche Information wird daher als nicht ausreichend für die Entwicklung stabilen Vertrauens und stabiler Akzeptanz betrachtet. Wenn das initiale mentale Modell den Erfahrungen entspricht, entwickeln sich Akzeptanz und Vertrauen gemäß einer klassischen Lernkurve – trotz erlebter Systemgrenzen. Sind diese potentiellen Probleme vorher bekannt, führen sie nicht zwingend zu einer Reduktion von Vertrauen und Akzeptanz. Auch zusätzliche überkritische Information vermindert Vertrauen und Akzeptanz nur am Beginn, aber nicht langfristig. Daher sollen potentielle Probleme in automatisierten Systemen nicht in idealisierten Beschreibungen verschwiegen werden – je präzisere Information gegeben wird, desto besser im langfristigen Verlauf. Allerdings tendieren nicht erfahrene Systemgrenzen zum Verblassen im mentalen Modell. Daher wird empfohlen, Nutzer regelmäßig an diese Systemgrenzen zu erinnern um die entsprechenden Facetten des mentalen Modells zu reaktivieren. In automatisierten Systemen integrierte intelligente Tutorsysteme könnten dafür eine Lösung bieten. Im Fahrzeugbereich könnten solche periodischen Erinnerungen an Systemgrenzen in Multifunktionsdisplays angezeigt werden, die mittlerweile in vielen modernen Fahrzeugen integriert sind. Diese Tutorsysteme können darüber hinaus auch auf die Präsenz eingebauter automatisierter Systeme hinweisen und deren Vorteile aufzeigen.

1 Introduction

In-vehicle automation has become increasingly ubiquitous in modern vehicles. Advanced driver assistance systems (ADAS) aim to increase comfort and safety through automation of driving tasks. Depending on system and manoeuvre types, estimates of potential ADAS safety benefits in terms of avoidable accidents involving personal injury range from 2% to 45% for cars, 2% to 12% for trucks and 1% to 15% for buses (Hummel, Kühn, Bende, & Lang, 2011). However, to fully harness this safety potential, it is necessary that drivers use ADAS adequately for the intended purpose, calibrate trust, accept the systems and use them on a regular basis. The expected safety benefit of ADAS can be undermined by changes in drivers' behaviour, following the introduction of changes to the road-vehicle-user. These behavioural changes may create an increase or decrease in safety and are defined as behavioural adaptation (OECD, 1990).

Present work was conducted in the Marie Curie Initial Training Network ADAPTATION. The main aim of ADAPTATION was the investigation of drivers' behavioural adaptation and its underlying processes over time in response to the use of ADAS. A total of ten PhD projects and two postdoctoral projects focussed on a broader view of adaptation processes, including not only observable behaviour but as well changes in energetic, motivational and higher cognitive processes. Energetic processes include attention, mental workload and effort management, motivational processes comprise intentions, perceived risk and attitudes such as trust and acceptance, whereas higher cognitive processes include SA, mental models and information processing (Krems, Brusque, & Stevens, 2014).

This PhD project focuses on motivational as well as higher cognitive processes when interacting with in-vehicle automation. A driving simulator as well as an on-road study has been conducted. Both of the studies used a repeated-measures design and investigated the development of trust, acceptance and the mental model of novice users when interacting with ACC as an example for in-vehicle automation. In addition, real-time SA was assessed in the driving simulator study and the learning process was modelled in the on-road study, based on the power law of learning. The driving simulator study mainly investigated how different initial mental models of ACC affect system trust and acceptance over time as well as how a user's mental model evolves with experience. The on-road study was a continuation of the driving simulator study, focussing on the learning process as well as the development of trust, acceptance and the mental model under realistic conditions and over a longer period of time.

The section on the theoretical background in chapter 2 introduces the conceptual framework for the studies. Chapter 2.1 defines and explains behavioural adaptation and presents an integrative model of influencing factors. These factors were either controlled or experimentally manipulated in the studies. Chapter 2.2 introduces the concept of automation, discussing levels of automation as well as the functionality and degree of automation of ACC. Chapter 0 defines mental models and discusses psychological theories on the mental model construction and update. An overview of existing assessment methods highlights pros and cons of different techniques and requirements for new approaches. Based on this, principles of the mental model questionnaire developed in this PhD project are presented. Chapter 2.4 defines SA as well as the relationship between mental models and SA and reports recent psychological theories including related research. Again, existing assessment tools for SA are discussed and the online-measurement technique used in the driving simulator study is presented. Motivational processes and related research are discussed in chapter 2.5, including trust in automation, acceptance and the power law of learning. An overview of the research questions for both of the studies is presented in chapter 3. The overall-methods section of chapter 4.1 discusses advantages and drawbacks of driving simulator studies and on-road-tests. In order to store and analyze the huge amount of data produced in both studies, a database-framework for data storage and analysis has been set up. Chapter 4.2 presents advantages and use-cases for databases in research, the structure of tools and data within the framework as well as challenges and experiences in teaching social scientists to work with databases. The empirical section starts with the detailed description of the driving simulator study in chapter 5, including the results on the development of trust, acceptance, the mental model of ACC as well as SA. Chapter 6 presents a detailed description of the on-road study with results on changes in ACC usage, trust, acceptance, the mental model as well as the subjectively reported learning process. A general discussion and conclusion section can be found in chapter 7, including theoretical, practical and methodological implications. The final chapter 7.3 discusses limitations as well as directions for future research.

2 Theoretical background

2.1 Behavioural adaptation and higher cognitive processes

ADAS aim to support drivers by automating driving subtasks such that comfort and safety are enhanced. However, the positive effects of these systems may be diminished or even inverted by unintentional changes in user behaviour. Behavioural adaptation, which is induced by the use of ADAS, is a well-known phenomenon and defined by the Organisation for Economic Co-operation and Development (OECD; 1990) as “those behaviours which may occur following the introduction of changes to the road-vehicle-user system and which were not intended by the initiator of the change” (p. 23). However, results are heterogeneous regarding conditions, influencing factors and direction of changes. Therefore, further research is required to understand the factors underlying these phenomena (Cacciabue & Saad, 2008).

Within the ADAPTATION project, higher cognitive processes mainly include information processing, mental models (i.e., synonymous to mental representation) and SA. These processes are thought to influence behavioural adaptation (e.g. Kazi, Stanton, Walker, & Young, 2007; Rudin-Brown & Parker, 2004; Saad, 2007; Stanton & Young, 2005). A dynamic qualitative model for behavioural adaptation was presented by Rudin-Brown and Noy (2002, as cited in Rudin-Brown & Parker, 2004, p. 61; Figure 1). The model takes into account the iterative process introducing a feedback loop from the object-level to the driver and the behaviour-level. The personality factors locus of control and sensation seeking are considered to contribute to behavioural adaptation. Driver with an internal locus of control rely more on their own skills and are supposed to maintain a more direct involvement with the driving task than driver with external locus of control. High sensation seekers may show behavioural adaptation because of their preference for a higher level of risk. These personality factors influence the mental model of ADAS and this process is considered to be mediated by trust in the system. The mental model influences driving behaviour on strategic, tactical and operational level. The behaviour changes the vehicle-road-environment system on the object level, which feeds back to the behaviour as well to the driver level.

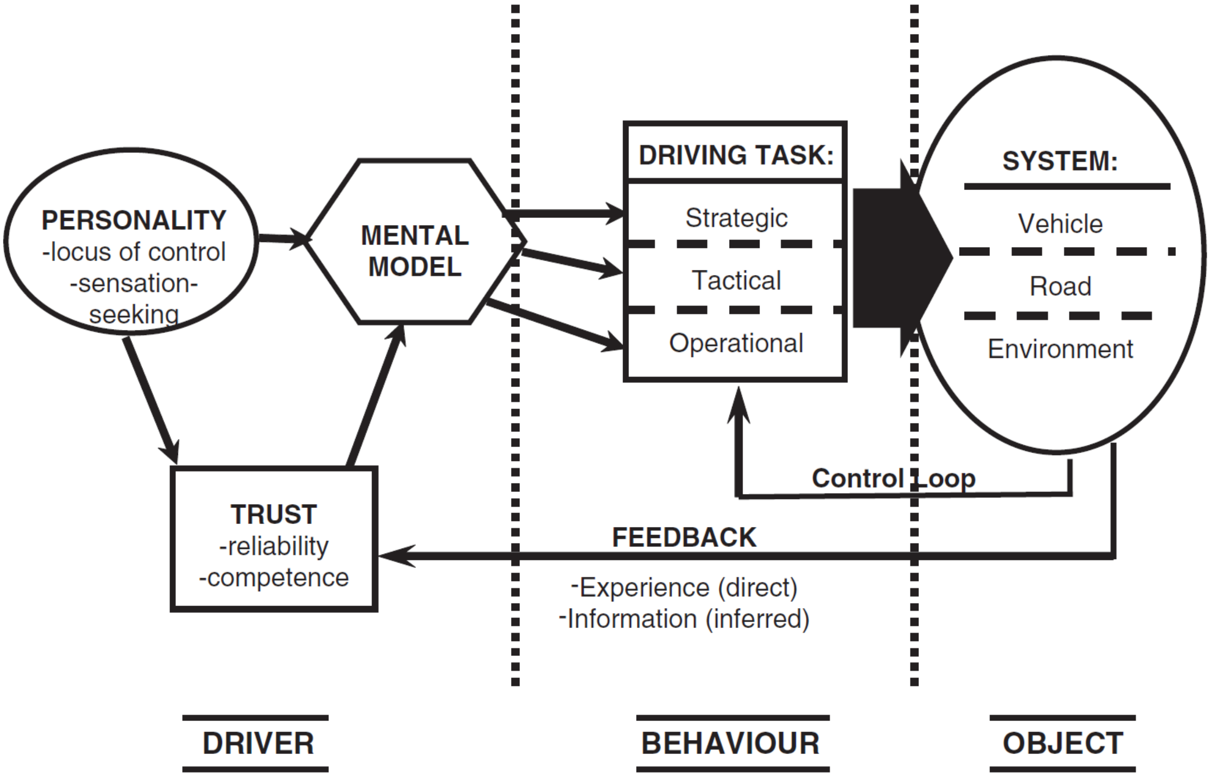


Figure 1. Qualitative model of behavioural adaptation (Rudin-Brown & Noy, 2002, as cited in Rudin-Brown & Parker, 2004, p. 61; reprinted with permission).

A model that integrates and extends previous theories (e.g. Rudin-Brown & Noy, 2002; Weller & Schlag, 2004) is the driver appropriation model developed in the HUMANIST project (Cotter & Mogilka, 2007, p. 14; Figure 2). The model collects and organizes relevant factors, which are descriptive of behavioural changes occurring with ADAS use. These factors were either controlled or experimentally manipulated in the studies presented in this thesis. The broader definition of "driver appropriation" includes cognitive, regulatory and motivational processes underlying observable behaviour, as well as temporal interaction.

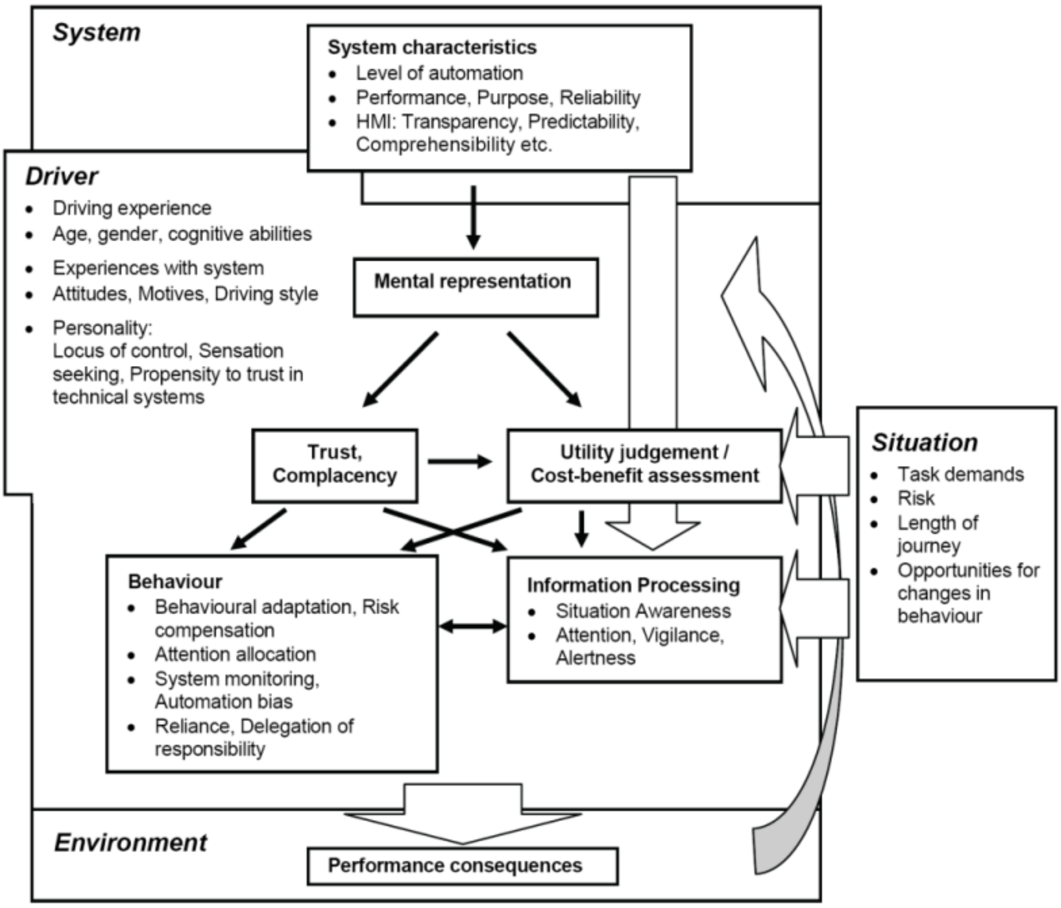


Figure 2. A conceptual model of driver appropriation (adapted from Cotter & Mogilka, 2007, p. 14).

The driver appropriation model comprises three main interacting factors: the system, the situation and the driver. The driver employs higher cognitive processes in creating a mental representation of the system, which is continuously elaborated and refined by experience. Comprehensibility, transparency and predictability of a system support the development of an accurate mental representation, which in turn leads to an appropriate calibration of trust. Trust and complacency, which form attitudes towards the system, mediate information processing as well as observable behaviour. Furthermore, system characteristics are assumed to have a direct influence on information processing mechanisms, such as SA, attention, vigilance and alertness. Observable behaviour, that is, reliance, system monitoring, attention allocation and behavioural adaptation, is mediated by these cognitive processes. The consequences of a specific behaviour occurring in a certain situation will feed back into and revise mental representations accordingly. All of these processes are influenced by driver characteristics, such as personality, sociodemographic factors and driving experience. Despite several studies addressing the connection between mental models and changes in driving behaviour in response to ADAS use (e.g. Cahour & Forzy, 2009; Kazi et al., 2007; Rajaonah, Tricot, Anceaux, & Millot, 2008; Rudin-Brown & Parker, 2004; Xiong, Boyle, Moeckli, Dow,

& Brown, 2012), knowledge of the relation between the appropriateness of mental models, system trust and behavioural changes over time is lacking (Saad, 2007). Therefore, this PhD project aimed at the elaboration and validation of innovative methods for assessing higher cognitive processes, with an emphasis on SA and mental models. The development principles of a mental model questionnaire are described in chapter 2.3.4 and the approach for assessing SA in real time is presented in chapter 2.4.5. Both methods were applied in the studies – results can be found in chapters 5 and 6.

2.2 Vehicle automation and Adaptive Cruise Control

Many functions that at one time could only be performed by humans can nowadays be carried out by machines, especially computers. This development impacts many areas of life including work, home, communication and mobility. Automation can be defined as "the full or partial replacement of a function previously carried out by the human operator" (Parasuraman, Sheridan, & Wickens, 2000, p. 287). Full or partial replacement implies that automation can vary between different levels and should not be considered as all or none. Therefore several models were developed for describing levels of automation. Parasuraman et al. (2000) proposed a 10-stage model based on the work of Sheridan and Verplank (1978), starting from manual control at level one until full automation at level ten (Table 1).

Table 1. Levels of Automation (Parasuraman et al., 2000; based on Sheridan & Verplank, 1978).

HIGH	10.	The computer decides everything, acts autonomously, ignoring the human
	9.	informs the human only if it, the computer, decides to
	8.	informs the human only if asked, or
	7.	executes automatically, then necessarily informs the human, and
	6.	allows the human a restricted time to veto before automatic execution, or
	5.	executes that suggestion if the human approves, or
	4.	suggests one alternative
	3.	narrows the selection down to a few, or
	2.	The computer offers a complete set of decision/action alternatives, or
LOW	1.	The computer offers no assistance: human must take all decisions and actions

The distinction between assistance and automation in this continuum of automation levels is fuzzy. Hauß and Timpe (2000) proposed to talk about assistance if the level of automation is below or equal than 5, whereas automation ranges from 6 to 10. In terms of concept, assistance means that the driver remains the central element in the control loop and is supported by the systems, whereas automation partly or completely bypasses the driver in the control loop by automating driving tasks

(Kompass, Huber, & Helmer, 2012). A specific model for describing assistance and degrees of vehicle automation was proposed by the BASt-Expert-Group (Gasser et al., 2012):

5) Full automation: The system takes over longitudinal and lateral control completely and permanently. In case of a takeover request that is not followed, the system will return to the minimal risk condition by itself.
4) High automation: The system takes over longitudinal and lateral control; the driver is no longer required to permanently monitor the system. In case of a take-over request, the driver must take-over control with a certain time buffer.
3) Partial automation: The system takes over longitudinal and lateral control, the driver shall permanently monitor the system and shall be prepared to take over control at any time.
2) Driver Assistance: The driver permanently controls either longitudinal or lateral control. The other task can be automated to a certain extent by the assistance system.
1) Driver Only: Human driver executes manual driving task

Vehicle automation is considered to provide solutions for environmental, economic, safety and societal challenges such as reduction of emissions through optimization of traffic flow and fuel consumption, adaption to demographic change by enhancing mobility of elderly and reducing driving stress by supporting unconfident drivers, economic competitiveness through technical innovations and higher product attractiveness as well as road safety enhancement by avoidance of human errors (Meyer & Deix, 2014). However, automation changes the driving task and especially the human-machine interaction. The role of the driver changes from active operator towards a supervisor of automation (Vollrath & Krems, 2011). These changes evoke new problems due to automation, which have been observed in other domains such as aviation or manufacturing and become relevant as well in transportation. Bainbridge (1983) described such "ironies of automation" including the loss of skills, reduced vigilance because of monotony, mistrust or overreliance, reduced SA and misuse of automation. These psychological issues with respect to vehicle automation are still less investigated (Vollrath & Krems, 2011) and the present work aims at these research gaps. Human-machine interaction issues are considered the most important future research topic in the area of vehicle automation (Gasser, 2012).

ACC is one example for an advanced driver assistance system, which is located at the border between assistance and automation. In combination with lane departure warning, ACC is considered the most relevant functionality for highly automated driving (Meyer & Deix, 2014). ISO 15622 (2002) defines ACC as "an enhancement to conventional cruise control systems, which allows the subject vehicle to follow a forward vehicle at an appropriate distance by controlling the engine and/or power train and potentially the brake." ACC adjusts automatically vehicle's velocity in order to provide a specified distance to the preceding vehicle. In absence of a preceding vehicle, ACC maintains a user set velocity such as conventional cruise control.

Recent ACC Stop and go systems operate on the full speed range, can decelerate to a complete standstill and follow automatically if the vehicle in front restarts (Winner, Danner, & Steinle, 2012). Longitudinal vehicle control can thereby completely be taken over by ACC. However, the driver turns the system on and off, sets the desired speed and distance and has to monitor the systems operation. Hence, ACC can either be seen as automation, located on level seven according to the classification of Parasuraman et al. (2000), whereas according to the definition of Gasser (2012) it is classified as driver assistance. Continuous monitoring is still required as ACC is not yet operative in every situation due to sensor limitations. Problems in detecting objects ahead can, for instance, occur at narrow bends, in adverse weather conditions, as well as with stationary or small vehicles. Therefore, drivers need to acquire a realistic mental model of these limitations in order to use the system in a safe and adequate manner (Rajaonah, Anceaux, & Vienne, 2006; Seppelt & Lee, 2007). A comprehensive and systematic review on the development of ACC as well as research achievements can be found in Xiao and Gao (2010).

2.3 Mental models

2.3.1 Definition

Mental models have been studied to understand how humans make decisions, perceive, know, and construct behaviour in a variety of environments. In the Human-machine-interaction domain, mental models can be conceptualized as ...a rich and elaborate structure, reflecting the user's understanding of what the system contains, how it works, and why it works that way” (Carroll & Olson, 1987, p. 12). Durso and Gronlund (1999) define a mental model more precisely as a long-term memory knowledge structure, that is, “... a representation of the typical causal interconnections involving actions and environmental events that influence the functioning of the system” (pp. 297–298). The latter authors point out that mental models, in the context of complex dynamic systems, differ from mental models of static objects or abstract syllogism. In transportation research, mental models are considered fruitful for explaining relevant cognitive processes (e.g. Bellet, Bailly-Asuni, Banet, & Mayenobe, 2009), and a correct mental model of ADAS functionality is considered fundamental to adequate use of these systems (Kazi et al., 2007; Itoh, 2012; Rajaonah et al., 2006). Empirical evidence shows that many ACC users are not aware of system limitations: Jenness, Lerner, Mazor, Osberg, and Tefft (2008) reported in a survey study of 370 ACC owners that 72% were not aware of manufacturers’ warnings about system limitations. Therefore, they overestimated the ACC’s helpfulness in scenarios where system technology has not been proven completely effective: approximately 25% of users reported that ACC works fairly well or perfectly, when following a vehicle on a curvy road or in stop-and-go traffic, and 43% when encountering a stopped vehicle in the lane ahead. The most frequent methods for learning how to use ACC were the vehicle owner’s manual (67%) and on-road experience (54%), where 15% reported on-road experience as sole learning method. Mehlenbacher, Wogalter, and Laughery (2002) reported similar tendencies on reading the owner’s manual for automotive vehicles: Approximately four of ten users did not read the manual at all and the rest read about half of the manual. Larsson (2012) found that ACC users have difficulties understanding system limitations, especially at the beginning. Hence, it cannot be assumed that all ACC users acquire a comprehensive mental model of ACC before initial use.

2.3.2 Mental model construction and update

Estimating effects of incomplete or incorrect mental models requires a theoretical concept of how mental models are constructed and updated. Durso, Rawson, and Girotto (2007) distinguish between mental models and situation models. While the former is considered a general long-term memory knowledge structure, the latter is formed in a particular situation and is built by environmental input (bottom up) in connection with top-down knowledge structures. One mental model can therefore give rise to several situation models associated with particular situational characteristics. When using an ADAS, a correct mental model of the system functionality is considered crucial for the construction of an adequate situation model in real road situations (Cotter & Mogilka, 2007; Seppelt & Lee, 2007). On the one hand, incorrect mental models can lead to the misinterpretation of environmental input, and on the other hand, experience updates and corrects the mental model. Theories from text comprehension research elaborate on the cognitive processes underlying the interpretation and comprehension of a given situation (Baumann & Krems, 2007; Durso et al., 2007; Krems & Baumann, 2009). The Construction–Integration Theory (Kintsch, 1998) assumes two stages in the comprehension process: In the first construction-related phase, environmental input activates knowledge stored in long-term memory (nodes) that is linked to the perceived information. Activation in this first stage is considered rather diffuse and general. In the second integration phase, bottom-up information is used to specifically select corresponding knowledge structures: compatible elements within the activated knowledge network are activated, while incompatible nodes are suppressed. Highly interconnected nodes accumulate activation while less activated nodes lose activation. As a result, less-well-connected nodes may disappear from the knowledge network over time (Durso et al., 2007). Through these inhibitory and excitatory processes, a coherent situation model is formed. After the integration phase, the remaining network is restored in long-term memory and retrieved in future processing cycles. However, updating the mental model requires cognitive effort. The processing-load hypothesis (Zwaan, Radvansky, Hilliard, & Curiel, 1998) assumes that the fewer aspects that are shared between an event and its mental model, the more difficult it is to incorporate the event in the knowledge structure. Research in text and film comprehension (Durso & Sethumadhavan, 2008) shows empirical evidence for this hypothesis. Thus, a more comprehensive reorganisation of the mental model of ACC is expected to augment processing load, and influence trust and acceptance negatively due to the mismatch between mental model and experience (Lee & See, 2004).

2.3.3 Discussion of existing measures

Different tools and measures have been established to assess users' mental models of ADAS. The summary listed below describes pros and cons of selected techniques used in transportation research and is mainly based on research performed in the AIDE project (Cherri, Nodari, & Toffetti, 2004):

- Focus groups are moderated group discussions that proceed according to a specific topic and goal. Users can, for instance, discuss problems and experience with ADAS. The resulting statements are usually recorded and a qualitative analysis is carried out. This method is a cheap and fast way to assess users' understanding of a system. However, finding a representative user group and ensuring good moderation are needed to ensure efficiency.

- In-depth interviewing, which is another qualitative method, invites users to talk freely about important topics from their own point of view. A pre-defined topic-structure is used to guide user–interviewer communication, but a natural conversation is sought for analysis. This method helps researchers understand users' mental models, thoughts, needs, desires, doubts, motivations and issues related to resistance in a very free and individualized manner. Skilled interviewers are required and data analysis can be expensive and challenging due to the high amount of unstructured data.
- Self-reported diaries require users to regularly report in writing about their experience during a certain period of time. Behavioural data related to system–user interaction is typically recorded with the purpose of assessing the impact in everyday life. Diaries permit the acquisition of data with high external validity over a long period of time. However, this data is highly subjective and should be complemented by logger data or video recordings.
- Questionnaires are the most frequently used tool to assess the mental model of ADAS. Because of the generality of application, they can be applied in every phase of system development and evaluation. Answer formats may be free, single/multiple choice or rating scales. Standardized questionnaires can be used across different systems, conditions or experimental groups and can be easily administered to a high number of subjects. However, topics and items must be designed and tested carefully beforehand to ensure that they are self-explanatory.
- Task analysis involves the identification of system tasks that a user is willing to perform and how efficiency can be optimized. The aim of this analysis is to identify cognitive and action processes needed to achieve a task. Whole-system analysis can be performed, for example, by mission/scenario analysis, function-flow diagrams or function allocation. User's activities can be assessed by operational sequence diagrams, timeline analysis, hierarchical task analysis or GOMS models (Goals, Operators, Methods and Selection rules). Error analysis techniques include event trees, fault trees and effect analysis.
- Decision trees facilitate the decision-making process by displaying a decision problem in the form of a tree with several branches and endpoints. This format helps system designers ensure that all possible decisions can be made correctly, and permits adequate user interaction.
- Card sorting is used to identify how users potentially group and name items to arrange them in an optimal way (e.g., icon positioning, menu structure). Card sorting is easy to conduct, identifies potentially misleading terminology and optimum structure from a user's point of

view. Major drawbacks are that it does not depend upon a user's task and it can become difficult to administer and analyse when the item number increases.

- The "potato head" technique invites user's to build their own instrumentation, for example, select shape, dimension, colour, labelling and position of elements. It can be used, for example, to design vehicular instrumentation.

Task analysis, decision trees, card sorting and potato head techniques primarily focus on the optimal user-centred design of concrete systems. These techniques identify the most favourable design configurations for optimizing user–system interaction, avoiding misleading terminology and analyzing decision processes while performing tasks. Therefore, they work best in the design and evaluation process of ADAS. However, it is difficult to apply these methods in a more general research environment due to the very specific configurations of particular systems. Furthermore, most of these techniques are costly, complex and time-consuming in terms of development, setup and analysis.

Focus groups, in-depth interviews and diaries are primarily qualitative methods. They allow for a detailed, flexible and individualized assessment of mental models. On the one hand, these techniques are useful in exploring mental models, particularly in describing and explaining individual experience and relationships. On the other hand, data analysis is mostly complex and time consuming. Direct comparisons between or within subjects as well as statistical calculations are difficult due to lack of standardization.

2.3.4 Development of the mental model questionnaire

A key objective of this PhD project is the development of new tools for assessing mental models in the context of behavioural adaptation. Because behavioural adaptation is considered as a process, the assessment tool should be able to track changes of the mental model over time. Moreover, it should be possible to quantify how the mental model has changed, for example, due to interaction with a system. In addition to within-subjects measurement, a comparison should also be possible between subjects. This allows for statistical tests between groups with different characteristics, for example, experimental groups. Furthermore, the tool should be based on a theoretical concept and be amenable to adaptation to different ADAS. In sum, the development, administration and analysis procedures should be as simple as possible.

To fulfil these requirements, a standardized questionnaire approach was chosen, based on the mental model definitions stated in chapter 2.3.1: A user's understanding of a system is intended as the representation of causal interconnections between situational characteristics and system functioning. Accordingly, questionnaire items were developed, focusing on concrete system functionality in specific situations. A mental model questionnaire for ACC was developed and tested at Chemnitz University of Technology. The first version of the questionnaire included 37 items, all focusing on ACC functions in specific situations. Subjects answered questions using a 6-point Likert scale ranging from 1 (totally disagree) to 6 (totally agree), for example: “The system maintains a predetermined speed in an empty lane”, “The system reacts to pedestrians in the traffic lane” or “The system works during night time”. A pretest was done with 12 students at Chemnitz University of Technology. They received a one-page description of ACC with different versions of information about the system. Three distinct system descriptions contained either correct, incomplete or incorrect information (see Chapter 5.2.5 for details). After reading the description, all participants answered the mental model questionnaire and gave feedback regarding the item’s comprehensibility. Pretest results showed that the questionnaire was able to distinguish between the three groups. Two items were removed due to ambiguity.

The final mental model questionnaire consisted of 35 items. Five items focused on differences between the incomplete information group and both of the other groups, for example, “The system works with motorbikes”. The differences between the incorrect group and other two groups were assessed by another four items, for example, “The system reacts to lead vehicles in the same lane that are white”. The remaining 26 questions acted as distractor items focusing on common ACC functionality, for example, “The system is overruled by depressing the brake pedal”. Further to functioning as distractors, the latter items were also used to make sure that all participants fully understood the general information about ACC. The complete questionnaire can be found in Appendix 9.1 and results of the driving simulator study, where the questionnaire was administered, are reported in chapter 5.3.1. The application of the questionnaire in a real driving context is presented in chapter 6. This study assessed how users interpret statements given in the car manufacturer’s manual concerning ACC, and how the interpretation changed over time due to experience. Therefore, the mental model questionnaire used in the driving simulator study was slightly adapted to the statements in the user’s manual. The full questionnaire used in the on-road study can be found in Appendix 9.4.

2.4 Situation Awareness

2.4.1 Definition

The concept of SA originated in aviation research in the 1980s and became widespread among several disciplines and work environments, such as power plant operations, anaesthesiology, military activity, and automobile driving (Durso & Sethumadhavan, 2008). Increasing automation of the driving task shows similarities with previous developments in other domains, such as aviation or air traffic control, thus rendering the SA concept fruitful in connection with research of the effects of automation in driving (Popken & Krems, 2011). Although the concept of SA is considered well established in the study of human factors in complex environments (Rousseau, Tremblay, & Breton, 2004), the literature shows a broad variety of definitions (see e.g., Breton & Rousseau (2001) for a systematic classification of 26 SA definitions). The most common and widely used definition is from Endsley (1988): "Situation awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (p. 792). Based on this definition she developed a model with three levels of SA (Figure 3, Endsley, 1995, p. 35).

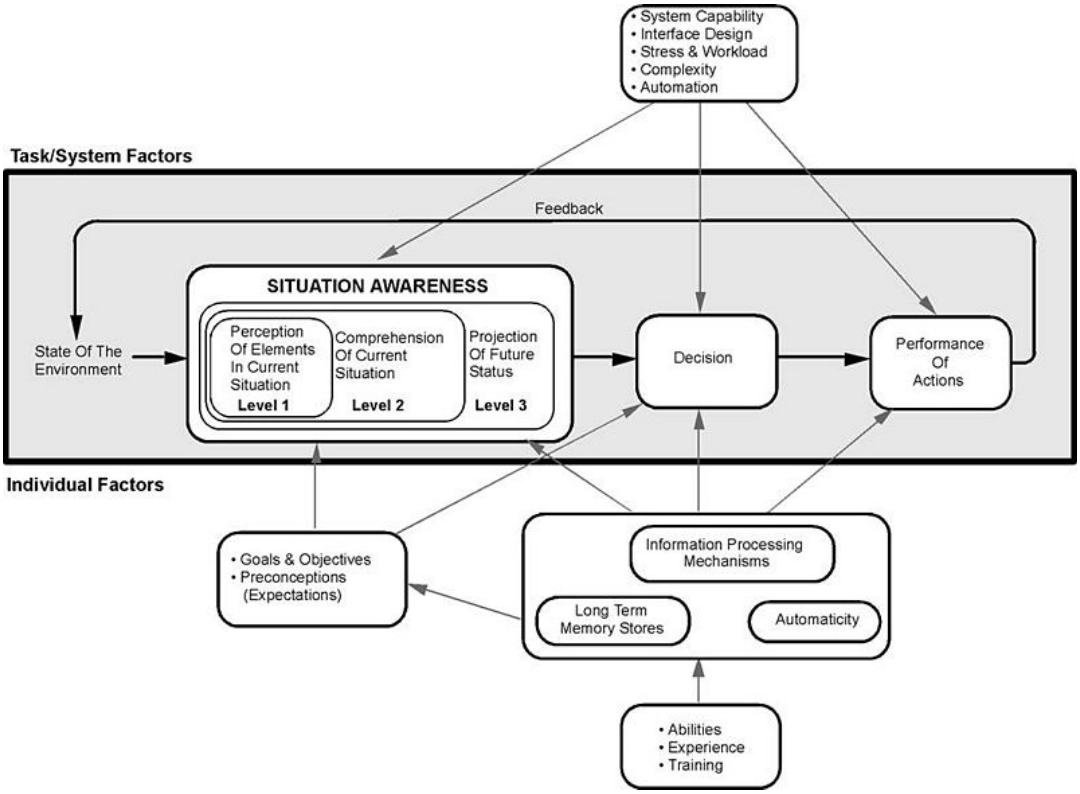


Figure 3. Situation Awareness model (Endsley, 1995, p. 35; reprinted with permission).

- Level 1. Perception: The perception of status, attributes and dynamics of relevant elements in the environment is fundamental to acquiring a correct picture of a situation. For example, a car driver has to perceive the status and dynamics of other vehicles, his/her own vehicle and surroundings obstacles.
- Level 2. Comprehension: Perceived elements on Level 1 need to be integrated into a holistic picture of a situation. That is, an awareness of elements must be complemented by an understanding of their significance in, and relationship to, a specific context. A driver, for example, needs to understand that red lights displayed by a leading vehicle signal that the car is braking.

- Level 3. Projection: Perception and comprehension form the basis of projecting future actions of elements in the environment. The highest level of SA allows for anticipating future events and timely decision making. If a driver, for example, perceives and understands the blinking light of a leading car, he can predict a turning manoeuvre.

SA influences decision making, and subsequent actions change the state of the environment, which in turn begins a new cycle of perception starting with Level 1. The whole process is influenced by task/system characteristics as well as individual factors.

2.4.2 Relationship between mental models and Situation Awareness

The relationship between SA and mental models is conceptualized by Endsley (2000, p. 62) as depicted in Figure 4. In her definition, “Mental models embody stored long-term knowledge about these systems that can be called upon to direct problem solving and interaction with the relevant system when needed” (p. 61). Mental models represent rather static knowledge about system functionality, which however grow and evolve with experience. In contrast, a situation model is considered “... very dynamic, representing the human’s knowledge and understanding of the present state of the system” (Endsley, 2000, p. 62). As described in Chapter 4.1, Durso et al. (2007) make the same distinction between mental model and situation model. Endsley (2000) uses situation models and SA synonymously as the levels of perception, comprehension and projection of future states. Situation models are considered largely influenced by a person’s mental models, which guide attention to specific aspects of a situation, influence how this information is interpreted and therefore affect projections about future states.

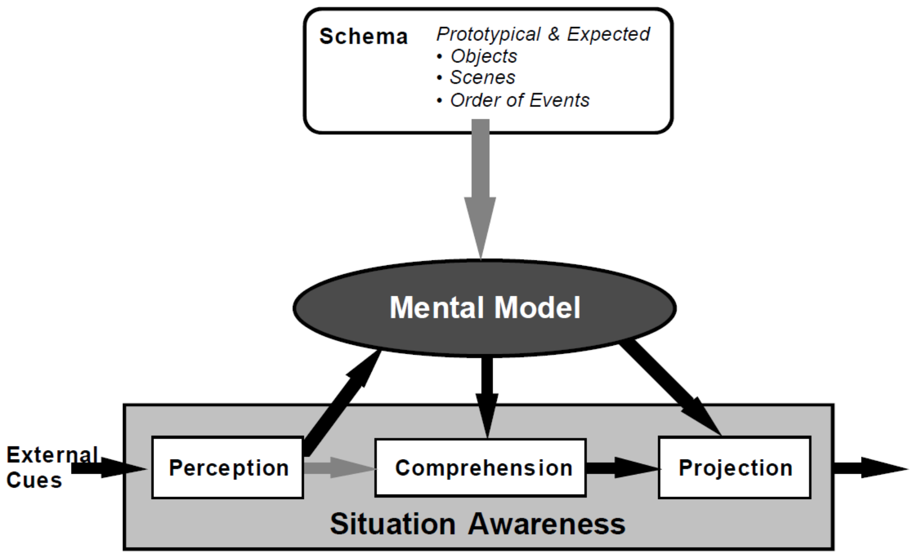


Figure 4 Relationship between mental model and Situation Awareness (Endsley, 2000, p. 62; reprinted with permission).

2.4.3 Situation Awareness as comprehension process

Recent approaches define SA as a comprehension process, analogous to theories of reading comprehension (Baumann & Krems, 2007; Durso et al., 2007; Krems & Baumann, 2009). In these examples, further to Endsley's model, cognitive mechanisms underlying the construction of SA are specified in detail. In particular, the perception of new elements in a situation (bottom-up processes) activates associated knowledge structures in long-term memory (top-down processes), according to the two-stage Construction–Integration Theory by Kintsch (1998). This process forms the actual "mental situation model", which triggers the activation of coherent actions, which in turn effects change in the situation, and subsequently demands updating the situation model. As the amount of available information exceeds the capacity of working memory, an additional mechanism is postulated: long-term working memory stores the excess information, but provides it immediately when it becomes relevant. The schemata stored in long-term memory encodes experience of different driving situations and therefore also knowledge about the functions of assistance systems. Analogous to findings in reading comprehension research (Zwaan, Magliano & Graesser, 1995), an inappropriate mental model hinders and delays the comprehension process. Moreover, experience that demand reorganisation of the mental model due to the addition of new information should result in higher cognitive load (processing-load hypothesis, Zwaan et al., 1998).

2.4.4 Discussion of existing measures

SA measurement techniques have mainly been developed and applied in aviation research. There are several proposed classifications of SA assessment methods, including Durso and Gronlund (1999), who propose three general approaches: subjective measures, query methods and implicit performance measures.

1) <u>Subjective measures:</u> Subjective measures are based on self-reports from system operators. One of the most often used techniques is the Situation Awareness Rating Technique (SART; Taylor, 1990). Operators indicate their demand on the dimensions attentional resources, attentional supply and understanding. A comprehensive SA score can be calculated from the three dimensions. Several studies have been carried out to investigate the validity and sensitivity of the SART scale (for an overview see Jones, 2000). Other subjective measures are, for example, the Situation Awareness-Subjective Workload Dominance (SA-SWORD; Vidulich & Hughes, 1991) technique, and the Situation Awareness Rating Scales (SARS; Waag & Houck, 1994) technique.
2) <u>Query methods:</u> The most prominent query method is the Situation Awareness Global Assessment Technique (SAGAT, Endsley, 1990). This technique only works in simulation: At random points the simulation is stopped, all information is removed and operators are asked

questions about the situation. In aviation, these questions focus, for example, on the location, speed, altitude, etc. of other planes whereas in driving the questions focus, for example, on the position and behaviour of other vehicles or traffic rules in the driving context. A driving version of SAGAT was developed by Gugerty (1997).

3) Implicit performance measures: Using performance-based measures, researchers make inferences on SA based on actions of the operator. SA performance measures in driving include, for example, lane keeping and responsiveness to critical events (Ward, 2000). However, this procedure requires specifically designed situations, where optimal and poor SA can be distinguished (Pritchett & Hansman, 2000). Event-based SA measures require subject reactions in the face of predefined events (Gugerty, 2011). Speed and accuracy of the responses indicate the evaluative quality of the SA. The Situation Present Awareness Method (SPAM; Durso, Bleckley, & Dattel, 2006) uses a procedure similar to the SAGAT method, where a simulation freezes at unpredictable times. In contrast to the SAGAT, however, the scenario remains visible. Operators respond to one or two questions and response time is an implicit performance measure of SA.

The main criticism of subjective measures is that operators cannot possibly be aware of their own SA (Jones, 2000). Operators report what they perceive and know, and this may differ from a real-life situation. Furthermore, subjective SA ratings are highly influenced by self-assessment of performance. Finally, errors and systematic bias in human judgement and memory undermine self-reported results. However, subjective measures provide insights into underlying cognitive processes involved in SA ratings and provide an indication of an operator's confidence level regarding his SA. The latter is considered an important aspect of an operator's job satisfaction and performance (Durso & Gronlund, 1999).

Query methods remove the problem of collecting SA data after task completion as they are applied in the situation itself. Furthermore, tools such as SAGAT are subject to numerous validation studies and directly assess SA using objective and unbiased data. However, query methods require simulators and therefore, cannot be applied in the field or in real time. Further, freezing a simulation is artificial and intrudes on the primary task; that is, questions posed could affect what aspects of the situation that operators look for. Finally, query methods, as well as subjective methods, focus on conscious and explicit knowledge, whereas implicit aspects cannot be assessed. This is critical in the driving domain, as many processes are skill-based and therefore automated and unconscious.

The major drawback of implicit performance measures is the indirect measurement approach. In particular, this approach may not reflect actual SA level, as poor performance can result from factors other than low SA and vice versa. The main advantage of performance measures is that they can be collected objectively and non-intrusively. Moreover, implicit knowledge of a situation is brought into the SA evaluation. Furthermore, the transfer of knowledge into concrete behaviour can be assessed in terms of timing and appropriateness.

2.4.5 Development of the Situation Awareness measurement technique

To assess SA in connection with behavioural changes when using ADAS, several requirements have been established for the PhD project: The measurement technique should not be based on subjective ratings of operators, because users' awareness of changes in their own behaviour is incomplete. Query methods require a freeze in simulation, which presumably has an impact on behavioural adaptation. In particular, simulation freezing could guide users' attention to certain aspects of a situation and, as noted for subjective ratings, thereby only report explicit and conscious knowledge. Therefore, the SA assessment technique should focus on implicit behavioural measures. This approach seems to best suit the needs as it is non-intrusive, covers implicit knowledge, assesses changes in behaviour over a longer time period, and can be applied in real-time in the dynamic domain of driving.

The approach chosen is largely based on and extends the work of Rauch, Gradenegger, and Krüger (2009), where a secondary task is used to assess SA. The central assumption is that "Situationally aware drivers are able to decide in accordance with the demands of the actual driving situation if execution of a secondary task is safely possible or not." (Rauch et al., 2009, p. 4). Thus, prioritisation of the driving task or secondary task is used as an indicator for SA. The decision to execute a secondary task involves processes of perception, comprehension and prediction in a given situation. Rauch (2009) differentiates the SA concept from related concepts such as anticipation, hazard perception and workload: Anticipation usually requires stable and unambiguous laws, whereas driving is highly dynamic, circumstances change frequently and situations can be ambiguous. Hazard perception focuses solely on critical situations, whereas SA implies a more general process of action planning and execution, which is also active in non-critical situations. And finally, in contrast to the concept of workload, SA enables drivers to reduce or avoid future workload by prioritizing tasks in advance. Tsang and Vidulich (2006) argue that "Workload is primarily a result of the limited attentional resources of humans, whereas SA is a cognitive phenomenon emerging from perception, memory, and expertise" (p. 262).

Rauch et al. (2009) used two different secondary tasks in their driving simulator studies: The first was a highly standardized, externally paced task, where drivers had to read a sequence of numbers displayed on a central console (Schömig, Metz, & Krüger, 2011). The second study was self-paced, interruptible and consisted of navigating according to instructions, using a realistic menu system (Metz, Schömig, & Krüger, 2011). For both tasks, drivers were given the opportunity to perform a task at predetermined points of the route, cued by a question mark appearing in the overhead display. Within a given amount of time, drivers decided whether or not to accept the offer by pushing a button on the steering wheel. Results show that drivers adapted their interaction with secondary tasks depending on the predicted demands of the situation; this was used as indicator for SA (Rauch et al., 2009).

The measurement approach used in the present PhD project is based on the same principles, but differs in the type of secondary task used. The secondary task is continuously present and participants are instructed to solve as many of these tasks as possible, while driving safely. The opportunity to complete a secondary task is always present, and thus allows continuous and sensitive measurements for the duration of a simulator trial by calculating the frequency of solved tasks within a certain time period. To obtain a sufficient number of responses, a relatively easy task must be chosen that can be processed continuously and quickly. The Surrogate Reference Task (SURT, Mattes, & Hallén, 2009) meets these requirements. Details about the setup can be found in chapter 5.2.3. Based on the definition of SA given in the beginning of this chapter, the frequency of secondary tasks solved should decrease with an increase in the demands of a situation.

2.5 Learning, acceptance and trust in automation

2.5.1 Power law of learning

ACC cannot handle every situation due to sensor limitations and the driver is required to take over manual control. In order to use ACC in a safe manner, drivers need to know these limitations and learn how to handle these situations (Seppelt & Lee, 2007; Rajaonah et al., 2006). A psychological theory for describing learning phenomena as a quantitative relation between the amount of practice and task performance is the "power law of practice", also referred to as the "power law of learning", developed by Newell and Rosenbloom (1981). Task performance is not conceptualized as a linear function of the number of learning trials, but as an asymptotic power curve where performance steeply increases in the beginning and subsequently levels out into a performance plateau. The general equation of the power law is given by

$$P(N|a, b, c) = a + bN^{-c}$$

The predicted performance, P, at session, N, is a function of the three free parameters, a, b and c. The parameter "a" represents the asymptote (stabilized performance at the end of the learning process), "b" is the amplitude at the beginning of the training (difference between initial performance and asymptote), and "c" is the curvature which corresponds to the learning rate (Lacroix & Cousineau, 2006). The power law of learning has been applied to numerous learning phenomena such as perceptual-motor skills, memory, perception, decision, motor behaviour and problem solving (see overview in Lacroix & Cousineau, 2006). In the driving context, the power law has been applied to model the learning process when using regenerative breaking in electric vehicles (Cocron et al., 2013). Jahn, Krems, and Gelau (2009) fitted the power law to describe skill acquisition in operating in-vehicle information systems. In the current on-road study, the power law of learning is applied to model the learning process, as well as the development of acceptance and trust in ACC.

2.5.2 Acceptance

Acceptance is considered a precondition for ADAS to achieve the benefits they claim (Martens & Jenssen, 2012; Najm, Stearns, Howarth, Koopmann, & Hitz, 2006). Recent acceptance models such as e.g. the Automation Acceptance Model (Ghazizadeh, Lee, & Boyle, 2012) highlight the mutual relation between attitudes towards automated systems and actual use. Despite numerous studies on acceptance of driver assistance systems, neither a common definition nor a standardized measurement procedure is available. Definitions of acceptance range from attitude approaches to observable behaviour in terms of actual use (Adell, 2010). In this PhD project, acceptance is defined as an individual's direct attitude towards the system, following the approach of Van der Laan, Heino, and De Waard (1997). A common ground in acceptance research is the fact that human behaviour is not primarily determined by objective factors, but by subjective perceptions (Ghazizadeh et al., 2012). Hence, acceptance is based on individual attitudes, expectations and experience as well as the subjective evaluation of expected benefits (Schade & Baum, 2007). As a result, personal importance is considered to have a greater effect on acceptance than the degree of technological innovation (Ausserer & Risser, 2005). The user-centered design approach represents a product design philosophy where human factors are of central concern within the design process. This means that user acceptance, requirements, goals, and user tasks are incorporated as early as possible into the design of a system, when the design is still relatively flexible and changes can be made at least cost (Czaja & Nair, 2012). Assessing user acceptance at different stages of the product development process is considered a precondition for creating successful products. As long as customers' opinions are not integrated in the development process, maximum market success can hardly be reached (Adell, 2010).

2.5.3 Trust in automation

Trust is considered a key variable for reliance on, and misuse/disuse of automated systems (Lee & See, 2004; Kazi et al., 2005). Whereas reliance means concrete observable behaviour, trust is defined here as "...the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability" (Lee & See, 2004, p. 51). Studies by Muir (1994) and

Muir and Moray (1996) concluded that experience and practice improve trust in automated systems and trust varies as a function of systems reliability. Accordingly, substantial empirical evidence shows that a decline in trust is caused by faults in automation (Lee & See, 2004). The effect of such faults depends mainly on its predictability than on its magnitude. Therefore, a discrepancy between the operator's expectations and the behaviour of the automated system can undermine trust even when the system performs well (Lee & See, 2004). However, the results regarding trust development and ACC reliability are inconsistent: In a driving simulator study, Rajaonah et al. (2008) did not find any relationship between ACC use and different kinds of trust. Similarly, Stanton and Young (2005) concluded that trust was unaffected by ACC use. Kazi et al. (2005) reported no significant differences between the reliability of driving trials and trust in ACC. Furthermore, reliability of automation did not influence drivers' developing a correct mental model of ACC, and therefore, the authors recommend driver training and education. In a subsequent 10-day longitudinal driving simulator study (Kazi et. al, 2007) with three ACC reliability conditions (100%, 50%, 0%), results showed an influence of automation reliability on trust. Trust increased over time for the reliable group, but the other groups showed inappropriate trust in relation to reliability level. Additionally, drivers developed inaccurate mental models of ACC that were consolidated in a short time. Similar findings were reported in the test-track study of Rudin-Brown and Parker (2004), where drivers' trust in ACC increased after using the system, despite a simulated system failure. The present PhD project proposes that drivers' initial mental model of ACC may be a possible explanatory variable for the diversity of results.

2.5.4 Related research on learning, acceptance and trust in ACC

Weinberger, Winner, and Bubb (2001) carried out a field test with ACC over four weeks to assess the learning process. Participants reported that they were familiar with ACC controls and displays after about two weeks or 2,800 km of driving. After one to two weeks or 2,000 km of driving, participants felt confident in handling take-over situations. In general, the greatest learning progress was observed in the first two weeks, stabilizing afterwards. However, the ACC usage rate has not been controlled and the assessment rate of the learning parameters was rather low (once per week). Moreover, the study sample of 15 participants consisted of only male persons between the ages of 30 and 62 driving luxury class cars with a relatively high driving mileage of 1,400 km per week. One aim of the present on-road study is to validate these results with a sample of younger drivers, balanced in gender and with less mileage. Simon (2005) carried out a similar field test to assess ACC learning and acceptance. Five participants with no ACC-experience drove a test vehicle outfitted with ACC and recording equipment for an average period of 16 days (mean driving distance = 2,800 km, mean ACC usage/km = 60%). Retrospective data on the learning process collected after the conclusion of the experiment revealed that users were familiar with ACC functionality after a period of two days and reported a “seamless collaboration with ACC” after approximately four days of use. However, the strength of these results is limited due to the low number of participants and potential bias in retrospective data after long time periods. Similar results on the learning process are reported by Ojeda and Nathan (2004). A sample of eight participants drove a test vehicle equipped with ACC on a predefined itinerary once a week during a total period of four weeks. After a steady growth in drivers’ self-reported knowledge and understanding of ACC in the beginning, parameters stabilized after approximately 360 km of driving. Comfort and ease-of-use ratings show an increasing trend across all four trips. The findings of this study are limited due to the rather small sample size and the limited number of trials. A theoretical “satisfaction index” during the period of ACC-usage is proposed by Winner, Barthenheier, Fecher, and Luh (2003). Users with no prior ACC-experience would try the system with a certain amount of scepticism in the beginning. When discovering the functionality and benefits in the first minutes of use, a peak of satisfaction is reached. However, after about half an hour of use, a sharp decline of satisfaction below the initial level is expected due to the experience that the system cannot handle all situations. Afterwards, satisfaction is expected to increase steadily over hours of usage until reaching a plateau. However, empirical data in support of this theoretical index is lacking.

3 Overall research questions

Based on the identified knowledge gaps in current research, both the driving simulator study and the on-road study carried out in this PhD project focussed on the development of trust, acceptance and the mental model of novice users when interacting with ACC. In addition, real-time SA was assessed in the driving simulator study and the learning process was modelled in the on-road study, based on the power law of learning.

The driving simulator study answers the following research questions: What is the effect of different initial mental models of ACC when experiencing the same situations? How are trust and acceptance affected by either a correct, incomplete and incorrect ACC description? How do trust, acceptance and the mental model evolve over time in these groups? What is the price of acquiring a realistic mental model of ACC by trial and error? How is SA affected by the initial mental model in situations where automation failures occur due to ACC limitations? How does SA evolve given this experience?

The on-road study is a continuation of the driving simulator study under realistic conditions, answering these research questions: How do trust and acceptance develop under real conditions when having full information from the owner’s manual? Do trust and acceptance increase continuously or do they decline after an initial peak? Does trust and acceptance eventually stabilize and at what point does this occur? How can the learning process be described? Does the learning process correspond to the power law of learning that has been observed in other domains? When does learning end in terms of stabilization? How appropriate is the mental model of ACC functionality that is created as a result of reading the owner’s manual? Which aspects of the mental model change due to experience? How does objective ACC usage evolve?

4 Overall methodological considerations

4.1 Driving simulator studies and on-road tests

Driving simulator studies as well as on-road studies offer the opportunity to assess changes in behaviour and attitudes as a result of ADAS use. In order to depict the most suitable approach, it is important to know more about each method, contrasting the methodological approaches in regard to utility, potential research questions, data collection, validity, advantages, and disadvantages. The following chapter points out the advantages and disadvantages of realistic driving settings and simulator studies for the investigation of behavioural change. The information on realistic methods is mainly based on the report of Lietz et al. (2011). Realistic and simulated settings can be seen as ends of a continuum from naturalistic driving to laboratory experiments. The continuum can be characterized roughly by the degree of experimental control, realism and amount of technology used (Figure 5).

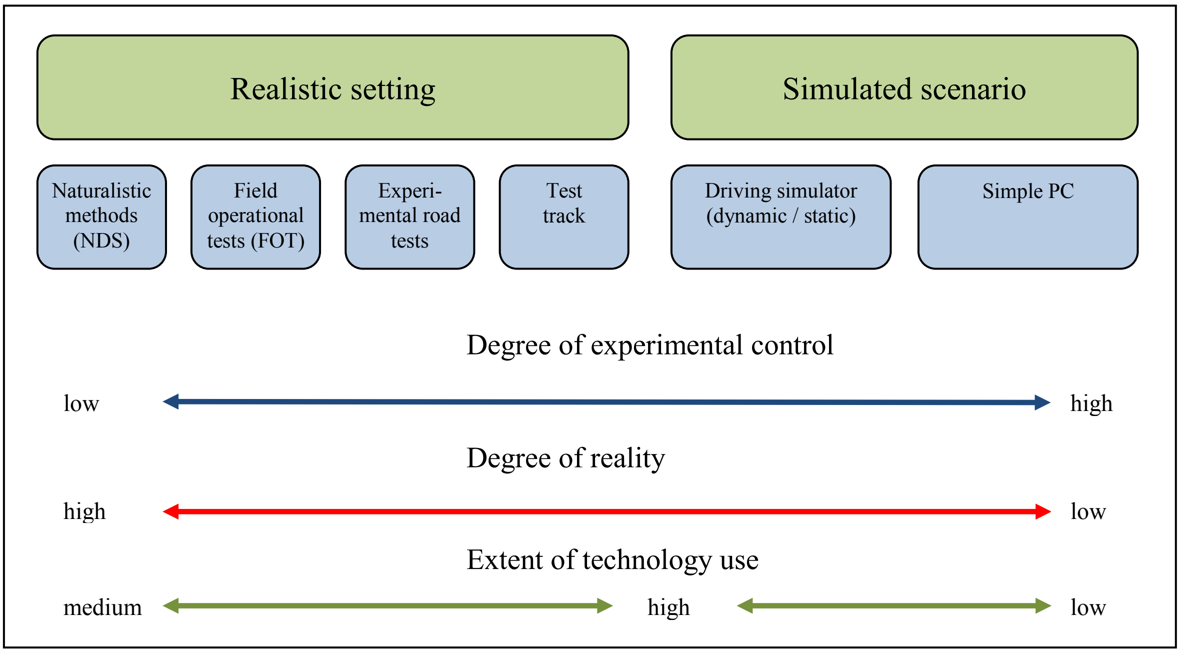


Figure 5. Degree of experimental control, realism and technology use in different research settings (adapted from Lietz et al., 2011).

Simulated scenarios are programmed in driving simulators, which can either be

1) simple PC's with one or more monitors and a minimal mock-up that reproduces driver seat and controls,
2) fixed-based driving simulators without any simulation of acceleration and deceleration movements,
3) or dynamic simulators with simulated acceleration and deceleration movements.

In contrast to simulated scenarios, realistic settings require participants to drive a real car. Realistic settings can be divided into four types:

1) Naturalistic driving studies (NDS): Participants usually drive an instrumented car for a certain period of time on their usual routes without any limiting instructions. Data is recorded continuously.
2) Field operational tests (FOT): In contrast to an NDS, an FOT aims to investigate the effect of one or more independent variables (e.g., assistant systems, different groups, different conditions, etc.) on driving behaviour. Natural driving behaviour is recorded continuously such as in the NDS. The experimental design of an FOT allows for limited hypothesis testing and manipulation of conditions.
3) Experimental road tests: These tests concern experimentations carried out with instrumented cars in real traffic conditions on a predefined test route. In order to cover different experimental conditions, participants often have to drive the same test route several times.
4) Test tracks: In contrast to the three former tests, participants of test track studies drive the car on specifically designed and usually not public roads. This allows for higher control over the route and testing of for example infrastructure measures. Although the conditions are more artificial than in an NDS or FOT, the real road setting provides greater external validity than simulator studies.

One major advantage of driving simulator studies over realistic settings is the high controllability, reproducibility and standardisation. This allows for specific experimental manipulation of conditions, including the possibility of simulating critical situations. Data acquisition is cheaper and easier than data collection under realistic conditions. Driving simulator studies also admit a broader range of measurements with good data quality. Possible disadvantages are low fidelity, simulator sickness and lacking validity. On the other hand, realistic settings are characterized by a naturalistic and realistic driving experience ensuring high external validity and allowing for the assessment of naturalistic driving behaviour. Especially for assessing long term behavioural changes, naturalistic methods offers advantages as several participants can unobtrusively drive instrumented vehicles in parallel for a longer period of time, that is, months or even years. Continuous recording of different behavioural data allows for detailed analysis of gradual changes over a longer period of time. However, one challenge of naturalistic methods is to handle and especially filter the huge amount of data in order to extract meaningful indicators. This issue is connected to one of the major drawbacks of naturalistic methods, i.e. missing experimental control. Under naturalistic driving conditions, many factors such as road type, weather conditions, traffic density, etc. may influence driver behaviour and can neither be controlled nor completely assessed. Therefore conclusions drawn from post-hoc analysis are rather limited to a mainly explorative character in contrast to hypotheses-driven experimental studies.

One methods' inherited inconvenience is the other methods advantage, making both methods complimentary, an aspect to keep in mind when assessing behavioural changes effectively and efficiently on different levels. Understanding the benefits and drawbacks of each method will ensure experimental designs that go beyond the capabilities provided by each method individually and provide useful insights into behavioural changes.

4.2 Database-framework for data storage and analysis

In order to store and analyze the huge amount of data resulting from the simulator and on-road study performed in this PhD project, a storage and analysis framework has been set up (Figure 6). The core component is the relational open-source database management system (DBMS) PostgreSQL 9.1. All tools for data pre-processing as well as the analysis tools access the DBMS using the Structured Query Language (SQL). SQL is standardized by the ISO 9075, which allows for a common access procedure using various software products.

In comparison to classical analysis tools in social science such as SPSS, Excel, R or STATA, relational databases offer some advantages (Mahrt, 2006):

- Minimal data redundancy due to separate tables and relations between tables
- Improved data consistency due to the guarantied database-principle of reliable "transactions", founded on the ACID-properties (Atomicity, Consistency, Isolation, Durability)
- Improved data accessibility due to the client-server-principle, permitting parallel access by multiple users and sophisticated rights management
- Program-data independence, allowing access using various software products
- Amount of data only limited by hardware resources
- Only one server needs extended hardware resources for executing queries; clients send requests and receive the results
- All data is stored in one place, which simplifies backup and avoids confusion regarding most recent data

These database features are especially useful when dealing with large, heterogeneous and related datasets, such as sensor data with different frequency, questionnaires, video and interview data collected in one study.

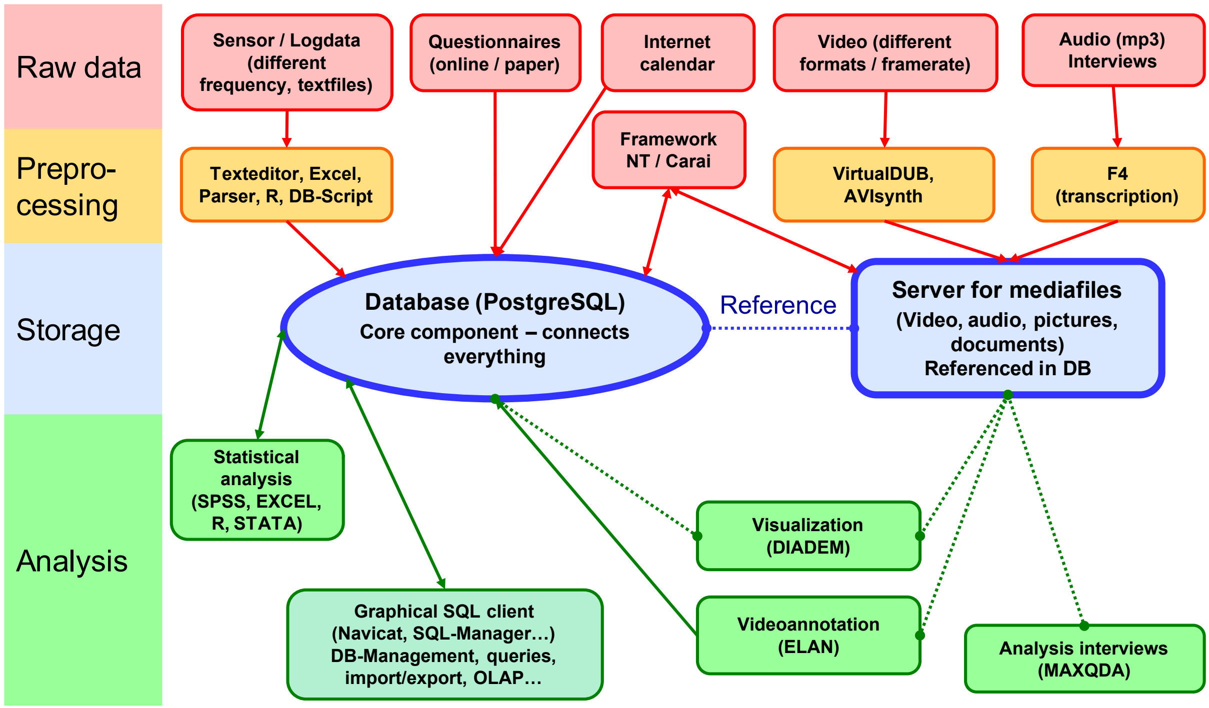


Figure 6. Database-framework for data storage and analysis.

The decision to use PostgreSQL as DBMS is based on a previous work at Chemnitz University of Technology (Lietz et al., 2008), where PostgreSQL 8.2 was tested and compared to Microsoft SQL Server 2005, Oracle 10 and MySQL 5.0 for the use-case of naturalistic driving studies. PostgreSQL resulted as the most stable and fastest DBMS in executing queries on large datasets, it is free and easy to install on various operating systems, documentation is comprehensive and the included geospatial database extension PostGIS offers excellent opportunities for analyzing geographical data such as GPS data. In addition to these test results, recent PostgreSQL versions starting from 9.0 include as well extended OLAP-functionalities such as common table expressions and window functions (it-novum GmbH., 2011). These functionalities provide powerful tools for structuring and aggregating data and were used for analyzing secondary task engagement in the simulator study, ACC usage patterns in the on-road test and in general for identifying, extracting and analyzing sequences of behaviour (e.g. glance sequences before lane changes, see Beggiato & Krems, 2013c). In line with previous experience from UMTRI (LeBlanc et al., 2006) and VTTI (Dingus et al., 2006) regarding the optimal data structure, media files such as video, pictures or audio are not stored entirely inside the database. These files are located on a separate fileserver and the database tables only contain a reference, e.g. the filename and frame number for each video. This structure allows for keeping the database size smaller and therefore faster, whereas the link to the media files is always present.

Despite of all advantages listed above, databases do not replace classical analysis tools but extend them. In the data analysis process, databases cover the storage and retrieval parts (Figure 7), whereas statistical analysis is still performed by common tools. The main operations inside the database concern structuring and aggregating data, which indeed is the main analysis step for large and heterogeneous datasets. The use of a database is especially indicated when dealing with large datasets (i.e. more than 1 million records), with relational data, when data sharing or parallel access is required, for persistent storage and when complex retrieval procedures are needed.

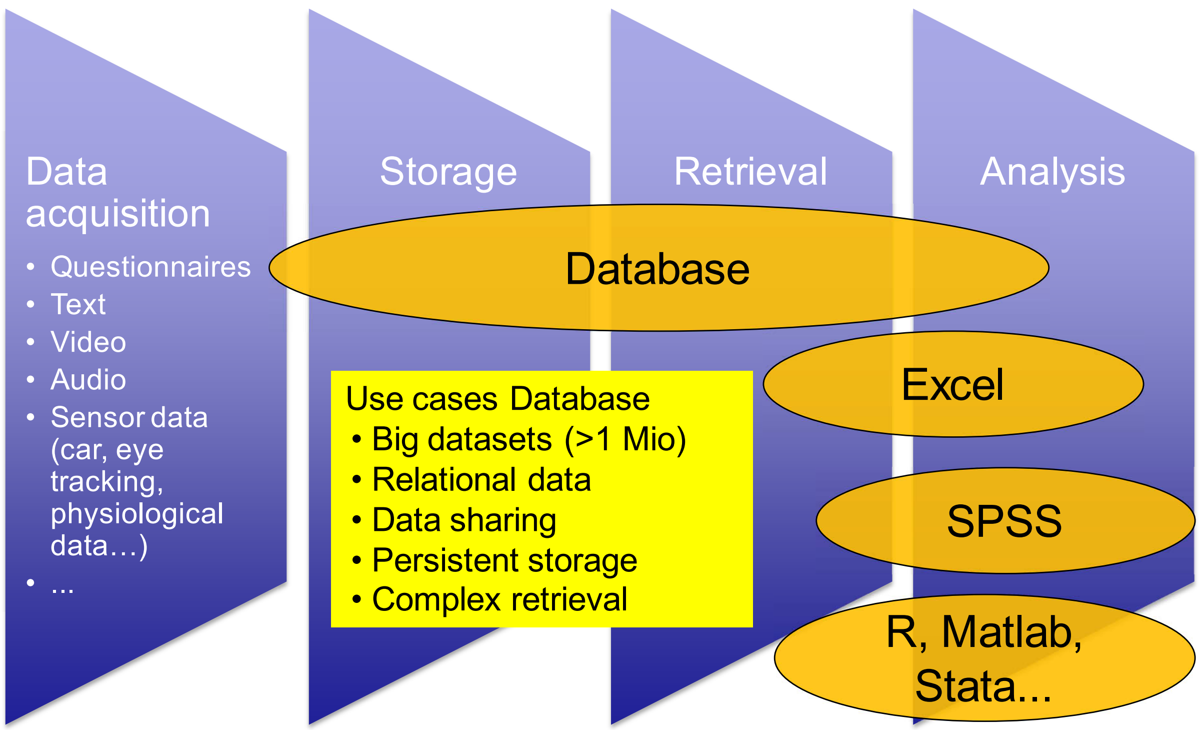


Figure 7. Use cases and positioning of databases in the research process.

Alongside the benefits of a database, new challenges arise for social scientists. Firstly, the complexity of the data structure increases due to several related tables. However, this fact is mainly related to the inherent complexity of the studies, e.g. when using different assessment methods such as video, interviews and multiple sensors. Databases help to deal with data complexity and do not create it. Secondly, installation and management of the DBMS is required. Due to the client-server principle, the DBMS runs on one server and it is not installed on every researcher's computer. Installation and management including rights management, backup strategy, failsafe hardware configuration... etc. should preferably be carried out by one specialized person, i.e. a computer scientist. However, as a third challenge, researchers need to acquire knowledge about the database, especially about querying the database using SQL. This task should preferably not be sourced out to computer scientists, because

1) researchers should have direct and immediate access to the data,
2) knowing the extended analysis potential of databases (e.g. OLAP-functions) offers new opportunities for data analysis,
3) researchers know their data best and should be able to explore, check and "play" with the data without restrictions and
4) due to the constant and irreversible growth of measurement data in research (e.g. physiological data, eye-tracking data, video, GPS, web-logfiles... etc.), social scientists should acquire analysis competence for this type of data to be ready for future research challenges.

To face this challenge of enabling social scientists to use databases, a database for storage and analysis of behavioural data has been setup and tested within the ADAPTATION Project (Pereira, Lietz & Beggiato, 2014). The aim was to develop and implement an easy access to a specifically designed database to facilitate the storage, joint access, analysis and integration of different data types collected in the various studies. For this purpose, a PostgreSQL database has been implemented in combination with an easy-to-use graphical web-interface providing the most important SQL-functionalities such as data selection, create/modify, filter and search functions along with upload/download features. Several user tests took place showing that the researchers were generally favourable about the concept and were able to deal with the database. However, it required additional time to transform data in order to fit into the database structure and the web interface allowed for only limited data upload/download and restricted SQL-functionalities.

This experience led to a change in the strategy. Instead of developing tailor-made, use-case specific and therefore necessarily restricted tools for interacting with the DBMS, a new and more general approach has been adopted. Researchers should be enabled to use existing tools for directly accessing the DBMS including an easy access to the full range of SQL-features. This strategy allows for using all database functionalities without restrictions, starting from the creation of appropriate data structures, data import and immediate access to the creation of analysis queries. There are several open-source as well as commercial SQL-management tools available for PostgreSQL, providing a graphical user interface (overview at https://wiki.postgresql.org/wiki/Community_Guide_to_PostgreSQL_GUI_Tools). After testing various tools, the commercial Software NAVICAT premium (www.navicat.com, see Figure 8) performed best for several reasons: It provides an easy and well-designed graphical interface, several assistants for importing and exporting data, a graphical SQL-builder and the possibility to simultaneously connect to MySQL, MariaDB, SQL Server, Oracle, PostgreSQL, and SQLite databases from a single application. The latter feature offers a future-proof way for interacting with different DBMS and has already been used in a project with the German Aerospace Center (DLR) in Braunschweig for accessing their Oracle database.

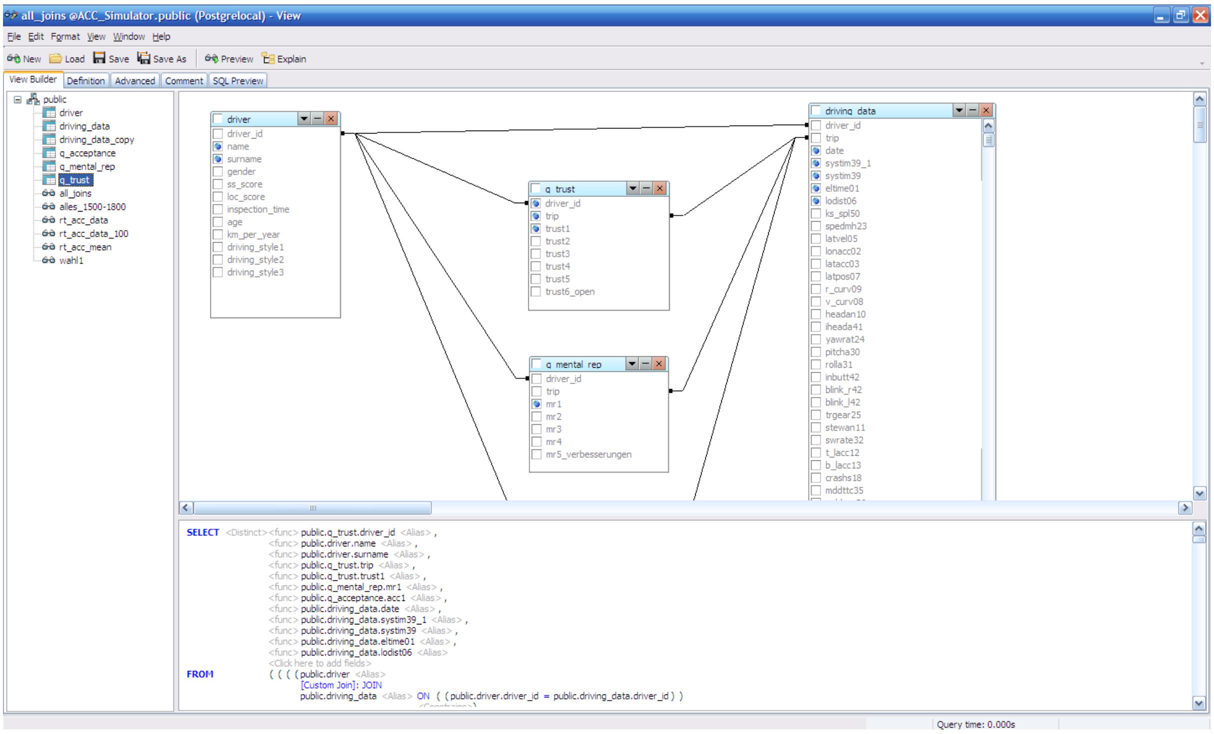


Figure 8. Graphical SQL-management tool NAVICAT premium.

However, this new approach needs more effort in learning how to use the SQL-management tool. To systematically train social scientists, a 4-day-seminar has been developed and carried out twice at the Professorship of Cognitive and Engineering Psychology (a detailed description of the seminar contents can be found in Appendix 9.5). The seminar includes all necessary steps from deciding if a database is needed to the installation procedure, structure design, data import, simple to complex queries and exporting/accessing aggregated data from other analysis tools. All tasks are immediately trained by working with the real database of the driving simulator experiment presented in chapter 5. This seminar formed the basis for other researchers and students to perform secondary data analysis of already collected data with new research questions. Data from the driving simulator study and the field test presented in this thesis has been reused for additional multidisciplinary publications with a different focus (Schmidt, Beggiato, Hoffmann, & Krems, 2014) as well as for several master's and bachelor's theses (Göbel, 2012; Grieger, 2013; Klamroth & Winkler, 2013; Metzner, 2012; Schmidt, 2012; Schwarzwäller, 2013). Currently, data of seven studies is stored in the database framework with a total of more than 200 million records.

5 Driving simulator study

5.1 Aims and research questions

The driving simulator study systematically investigates the effect of divergent initial mental models of ACC (i.e., varying in correctness), using the same system in identical situations. The main research questions focus on how different initial mental models of ACC affect system trust and acceptance over time and how a user's mental model evolves with experience. Possible confounding effects related to driver characteristics are controlled for using a matched sample approach. Preliminary information is used to induce a distinct initial mental model by stating a different number of potential system limitations. All participants drive the same simulator track using the same ACC system three times, within a 6-week period; however, initial information differs in each of the three scenarios. Regarding the development of a mental model it is hypothesized that:

- The provision of distinct preliminary information induces a correspondingly different mental model about system functionality, prior to using an ACC system for the first time.
- With experience, a user's mental model converges towards a realistic view of system capabilities. According to construction–integration theory (chapter 2.3.2), expected but not experienced limitations become less activated in the mental model network, and therefore, tend to be forgotten over time. Conversely, unexpected but experienced limitations have the greatest impact due to the need for restructuring the existing mental model.

For trust and acceptance it is assumed that:

- The more initial information given about potential system problems, the lower initial trust and acceptance of the system after reading the description.
- For the group presented with the correct system description, trust and acceptance increase steadily due to the correspondence of mental model and experience. The same trend is assumed when drivers are presented with information about potential problems that do not actually occur during driving. Due to the expected weaker impact of expected but not-experienced problems, trust and acceptance should reach almost the same level over time as in the correct group; however, starting from the lowest initial level (see previous hypothesis).
- When omitting preliminary information about potential problems that later actually occur during driving, trust and acceptance are expected to decrease steadily over time. The trial-and-error strategy alone, without accompanying explanation of system limitations, is insufficient for the recovery of trust and acceptance.

5.2 Method and material

5.2.1 Sampling and participants

To control for relevant confounding factors, the study was designed using a matched sample approach, based on the model of Cotter and Mogilka (2007, chapter 2.1). All participants drove on the same simulator track using the same ACC system; therefore, the model factors “situation” and “system” were controlled. To match relevant driver characteristics, a two-step sampling procedure was applied. In a first phase, participants younger than 30 years possessing a valid driver’s license could apply for the study by completing an online questionnaire about ADAS knowledge and experience, driving experience and demographic information. In a second step, 51 out of 396 applicants were selected by excluding participants with ACC experience or extensive system knowledge, and balancing gender, age and driving experience to obtain a homogeneous sample. A second online questionnaire was sent to the 51 candidates, assessing sensation seeking (BSSS, Hoyle et al. 2002), locus of control (driving internality–externality scale, Montag & Comrey, 1987), driving style (Popken, 2009) and a short 10-item version of the Big Five Inventory (BFI-10, Rammstedt & John, 2007). Upon arrival at the driving simulator, a paper-and-pencil perceptual speed test (ZVT “Zahlenverbindungstest”; Oswald & Roth, 1986) was conducted. Finally three experimental groups were created with 17 participants each, balanced in all confounding variables. The final sample consisted of 25 male and 26 female students showing no statistical differences between the three groups (Table 2, *p* ranging from .454 to .951).

Table 2. Sample characteristics and results of the matching process.

Variable	Mean	SD	Between-group comparison	Statistical significance (*p*)
Gender			χ^2 (2, 51)=.157	.925
Age (years)	24	2.37	$F(2,48) = .145$	.865
Total km driven	52,255	47,329	$F(2,48) = .076$	.927
IQ perceptual speed (ZVT)	119	13.41	$F(2,48) = .278$	.759
Sensation seeking	2.99	.63	$F(2,48) = .392$	.678
Driving style 1 “carefulness”	3.95	.80	$F(2,48) = .662$	.520
Driving style 2 “routine”	2.65	.86	$F(2,48) = .802$	.454
Internal locus of control	3.06	.55	$F(2,48) = .139$	.871
External locus of control	3.07	.52	$F(2,48) = .257$	.774
BFI-10 Extraversion	3.28	.96	$F(2,48) = .096$	.908
BFI-10 Agreeableness	3.25	.81	$F(2,48) = .050$	.951
BFI-10 Conscientiousness	3.30	.71	$F(2,48) = .460$	.634
BFI-10 Neuroticism	2.87	.82	$F(2,48) = .372$	.691
BFI-10 Openness	3.66	.92	$F(2,48) = .138$	.871

5.2.2 Research design and procedure

The study was planned as a two-way (3×3) repeated measures mixed design. Three distinct system descriptions formed the between-subjects factor (correct, incomplete, incorrect) and three consecutive trials formed the within-subject factor (Figure 9). Participants were paid, and as cover story were told that the study aimed to test a new driver assistance system called “DriveFree”. The terms “ACC” or “Adaptive Cruise Control” were never used to prevent information search.

Upon arrival at the driving simulator, subjects signed the consent form and read a one-page written description of the ACC system (Appendix 9.2). To ensure that the description was well understood, participants were required to answer seven questions about the system’s functionality, orally. Subsequently, participants completed a questionnaire related to mental model, trust and acceptance. To become accustomed to the driving simulator, the ACC system and the secondary task, all subjects drove a 5-km city route, accompanied by a researcher. Thereafter, the trial on a 56-km two-lane highway started. Participants were instructed to use the ACC in such a way that they could complete as many secondary tasks as safely possible. After each trial, a semi-structured interview was conducted and subjects filled in the same questionnaire about mental model, acceptance and trust as given at the beginning of the trial. The same questionnaires were used after subjects completed Trials 2 and 3; additionally the mental model questionnaire was applied before these trials to check for interim changes. The system description was only shown before Trial 1. Within the 6-week study, the average time interval between the trials was 13 days, ranging from 7 to 24 days.

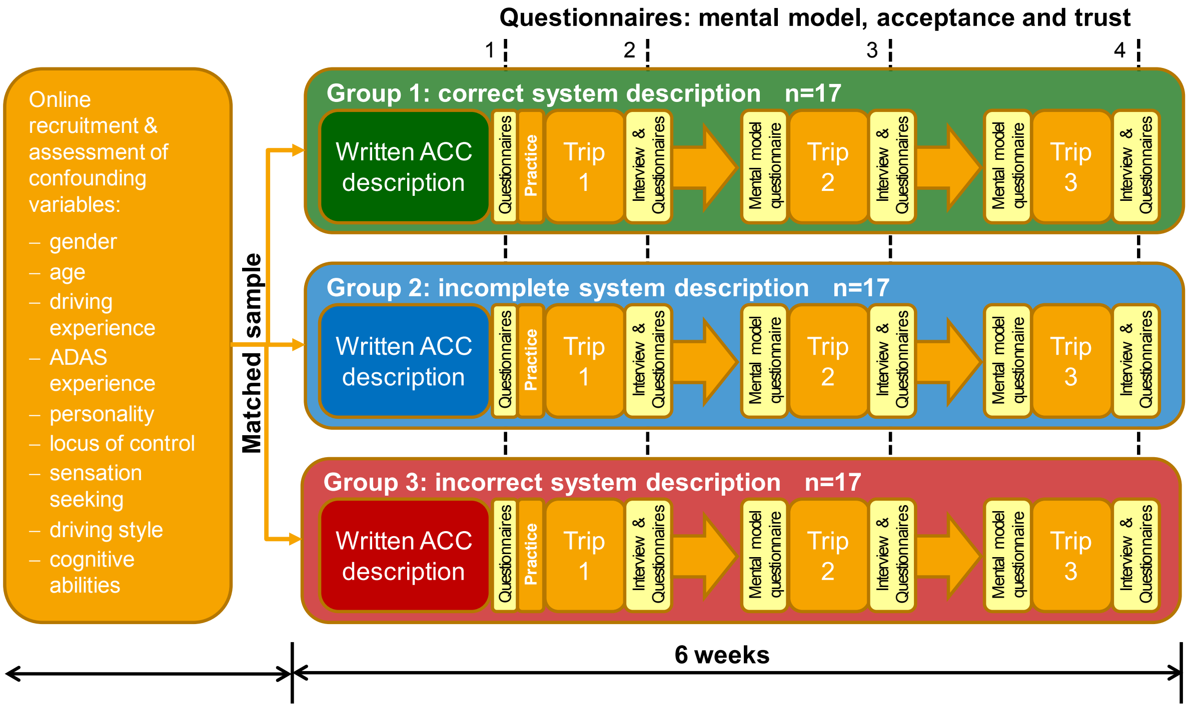


Figure 9. Design and procedure of the matched-sample driving simulator study.

5.2.3 Facilities and driving simulator track

Driving simulator and ACC: A fixed-base driving simulator (STISIMDrive 100w) at Chemnitz University of Technology was used for the study. It provided a 135° horizontal field of view and was composed of a BMW 350i driving cab with automatic transmission (Figure 10). The ACC was integrated in the simulation software and allowed specific manipulation of functionality in defined driving situations. In general, the ACC worked at every driving speed, and included stop-and-go functionality. During the entire simulation, ACC headway time was set to 2 s and speed to 100 km/h. To maintain constant conditions, participants were not allowed to change these settings during driving or turn off the system. Depressing the accelerator or brake pedal temporarily disabled the ACC; when the pedals were released, ACC functions were immediately reactivated. No ACC alarms were implemented to simulate critical situations without prior warning. The system was programmed to recognise all leading vehicles except motorbikes. In three defined situations (i.e., two narrow bends and one episode of heavy fog), recognition of the lead vehicle was disabled temporarily to simulate system failure.

Simulator track: The simulator track was comprised a 56-km long two-lane highway with an average driving time of 35 min and 32 s. With the exception of a 100-km/h speed limit in construction zones, simulator speed limit was set to 120 km/h. The route consisted of five consecutive base modules of 11 km each and 1 km of straight road at the end (see Appendix 9.3 for a detailed overview). Every base module included:

- two left bends and one right bend
- a cut-in situation from the left after 4.7 km: A vehicle overtakes on the left side, cuts-in directly in front of the own vehicle and slows down to 80 km/h
- a construction zone from 8.5 to 11 km, where only the right lane could be used and a lead car with a constant speed of 80 km/h set the driving pace
- an approach situation involving queuing at the beginning of the construction zone

However, the five base modules differed as follows:

- weather conditions (good weather / light fog / heavy fog)
- cut-in vehicle (normal car / motorbike / white car)
- last car in the queue (normal car / white truck)
- lead car in the construction zone (normal car / white truck)
- tracking lost (heavy fog / narrow bends)

The first base module represented a baseline for good weather conditions and no system failure. The second module was identical but included light fog conditions. During the third module, a motorbike was used for the cut-in situation, resulting in failure of the ACC to react and requiring the driver to intervene. Moreover, the last car in the queue was a white truck. During the fourth module a white car was used for the cut-in situation and tracking was lost in the final narrow left bend. In the fifth module, heavy fog conditions resulted in lost tracking on two occasions, one again in a narrow bend.

5.2.4 Secondary task SURT

As a secondary task, participants had to continuously solve the SURT (Mattes & Hallén, 2009). The software was kindly provided by the German Aerospace Center (DLR) in Braunschweig. The visual search task consisted of 50 randomly arranged circles presented on a 10-inch touch screen on the central console (see Figure 10). Test subjects had to select one circle with an approximately one-third-greater radius and touch it with their right hand. Therefore, the SURT requires visual perception combined with a manual response. Immediately after touching the screen, a green light appeared if the participant selected the right half of the screen and a red light, if the wrong half of the screen was chosen. After a delay of 0.5 s, a new task with randomly arranged circles was presented. The 49 small circles had a diameter of 0.8 cm, and the bigger circle 1.05 cm.

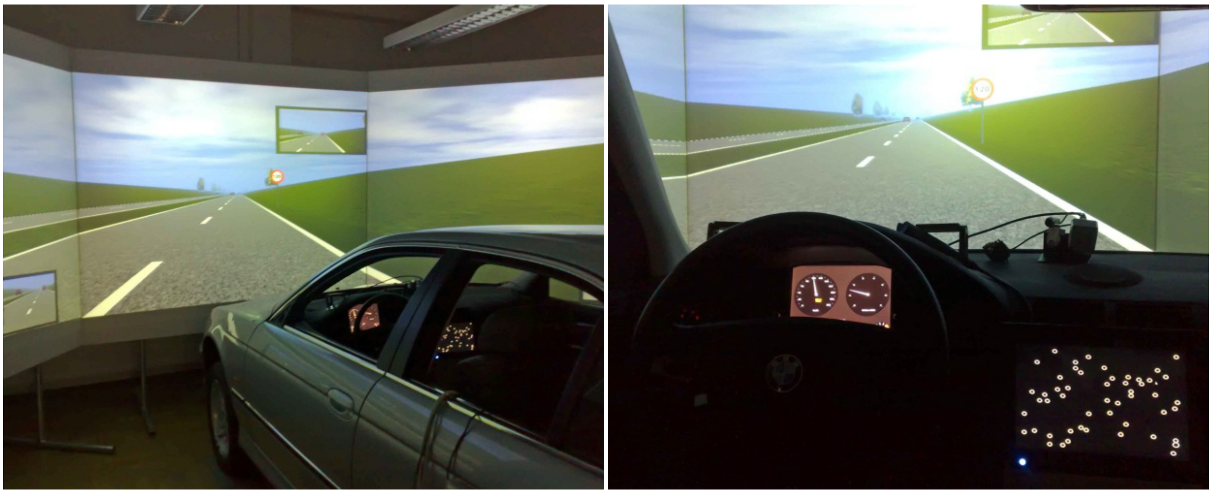


Figure 10. Driving simulator setup and SURT.

5.2.5 System description

A one-page system description was designed to induce different initial mental models of ACC in the three experimental groups (see Appendix 9.2 for the original documents). First, for all three groups, the description dealt with general system functionality including an explanation of longitudinal control automation, speed and time headway settings, temporary deactivation via brake or accelerator pedal, and information regarding reactivity of the system (i.e., non-reactive to oncoming traffic, pedestrians, traffic signs and traffic lights). In subsequent parts of the description, there were differences between the three groups (Table 3). The correct group was informed about system problems that would actually occur at narrow bends, in adverse weather conditions, and involving small vehicles. The incomplete group, on the other hand, did not receive this information, and therefore received idealised information. The incorrect group was provided with the same information as the correct group, but were over-informed about potential system problems with large vehicles and white/silver cars. The latter problems, however, never occurred during driving.

Table 3. Initial ACC information in the three experimental groups.

Initial information about the ACC	Group 1 correct infor-mation	Group 2 incomplete infor-mation	Group 3 incorrect information	Events occurred during driving
General information on system functions	X	X	X	
No reaction for traffic signs, pedestrians, oncoming traffic and traffic lights	X	X	X	
Potential problems at narrow bends	X		X	Yes
Potential problems in adverse weather conditions	X		X	Yes
Potential problems with small vehicles, such as motorbikes	X		X	Yes
Potential problems with big vehicles, such as buses or trucks			X	No
Potential problems with white or silver cars due to reflection			X	No

5.2.6 Dependent variables trust, acceptance and mental model

Trust was assessed by a 12-item unidimensional scale for trust in automated systems (Jian, Bisantz, & Drury, 2000; see Appendix 9.1). Subjects answered questions such as "I can trust the system" or "I am confident in the system" using a seven point Likert scale ranging from 1 (fully disagree) to 7 (fully agree). Reliability analysis showed good-to-excellent Cronbach's alpha values between .854 and .911 for all times of measurement. The mean of the twelve single items was used as overall trust score.

The 5-point rating scale developed by Van der Laan et al. (1997) was used as acceptance indicator (Appendix 9.1). A total of nine items resulted in the two acceptance dimensions usefulness and satisfaction. Both dimensions showed acceptable-to-good reliability scores: Cronbach's alpha for usefulness ranged from .728 to .865 and for satisfaction from .741 to .896.

Users' mental model of ACC was assessed by a self-developed and pretested standardized questionnaire consisting of 35 items (Appendix 9.1). Although there are well-known methods to investigate mental models such as card sorting, task analysis, focus groups or in-depth-interviews (Cherri et al., 2004), these mainly qualitative approaches have certain drawbacks. While they allow for a detailed, individualized and flexible assessment of mental models, statistical calculations and direct comparisons are difficult due to the lack of standardization. However, a major focus of this study was to develop an assessment method for mental models that is able to transform the subjective interpretation of real-world statements (e.g. from user manuals) such as "problems at narrow bends can occur" into numbers. This allows for comparisons between the experimental groups as well as the quantification of changes in the mental model over time, both of which made qualitative approaches appear impractical. Based on the mental model definition in chapter 1.1, all 35 questionnaire items focused on knowledge about ACC functions in specific situations. Subjects answered questions using a Likert scale ranging from 1 (totally disagree) to 6 (totally agree). Five items focused on differences between the incomplete group and both of the other groups, e.g., "The system works with motorbikes". The differences between the incorrect group and other two groups were measured by another four items, e.g., "The system reacts to white cars driving ahead in the same lane". The remaining 26 questions acted as distractor items focusing on common ACC functionality, e.g., "The system is overruled by pressing the brake pedal".

5.2.7 Contrast analysis

Contrast analysis was used to statistically test the hypotheses regarding trust and acceptance. A standard analysis of variance (ANOVA) reflects all possible differences between group means (omnibus test). Contrast analysis, on the other hand, permits focused questions to the data by testing specific data patterns. Statistical power is therefore higher compared to standard ANOVA and effect sizes can be directly computed (Rosenthal, Rosnow, & Rubin, 2000). Contrast analysis is especially useful when comparing specific patterns of means in three or more groups. Hypotheses are translated in contrast coefficients which reflect the predictions. The correlation between the contrast coefficients and observed group means indicates the similarity between predictions and empirical data (Abdi & Williams, 2010). Due to the correlation procedure, only the relation between the contrast weights is important, not the absolute values.

According to the hypotheses for trust and acceptance, a steady increase is predicted for the correct group. Therefore, the contrast weights 0, 1, 2, 3 are assigned for the four times of measurement (after reading the system description, and after Trials 1–3). For the incomplete group a steady decrease is predicted, starting from the highest level. The contrast weights 1, 0, –1, –2 are therefore assigned. The incorrect/over-informed group is expected to show the lowest trust and acceptance level in the beginning and almost reach the level of the correct group by the end. Therefore, the contrast weights 4, –2, 0, 2 are assigned.

5.3 Results

5.3.1 Mental model

To assess the changes in mental models of ACC, the questionnaire was presented immediately after reading the description and after each of the three trials. Figure 11 shows the profiles for the three groups and the nine questionnaire items that distinguish the groups.

Immediately after reading the description, Items 1–5 highlight the differences between incomplete and both of the other groups, whereas Items 6–9 distinguish between the incorrect group and the other two groups. According to the different initial ACC description, the incomplete group reported almost no problems in all of the nine question items. The incorrect as well as the correct group were aware of potential problems at curvy roads, with motorbikes, and in rain and fog. In addition, the incorrect group suspected potential problems with trucks, buses, white cars and silver tank lorries. As a manipulation check it can therefore be concluded that the different preliminary ACC information led to the desired distinctive mental model within the three groups.

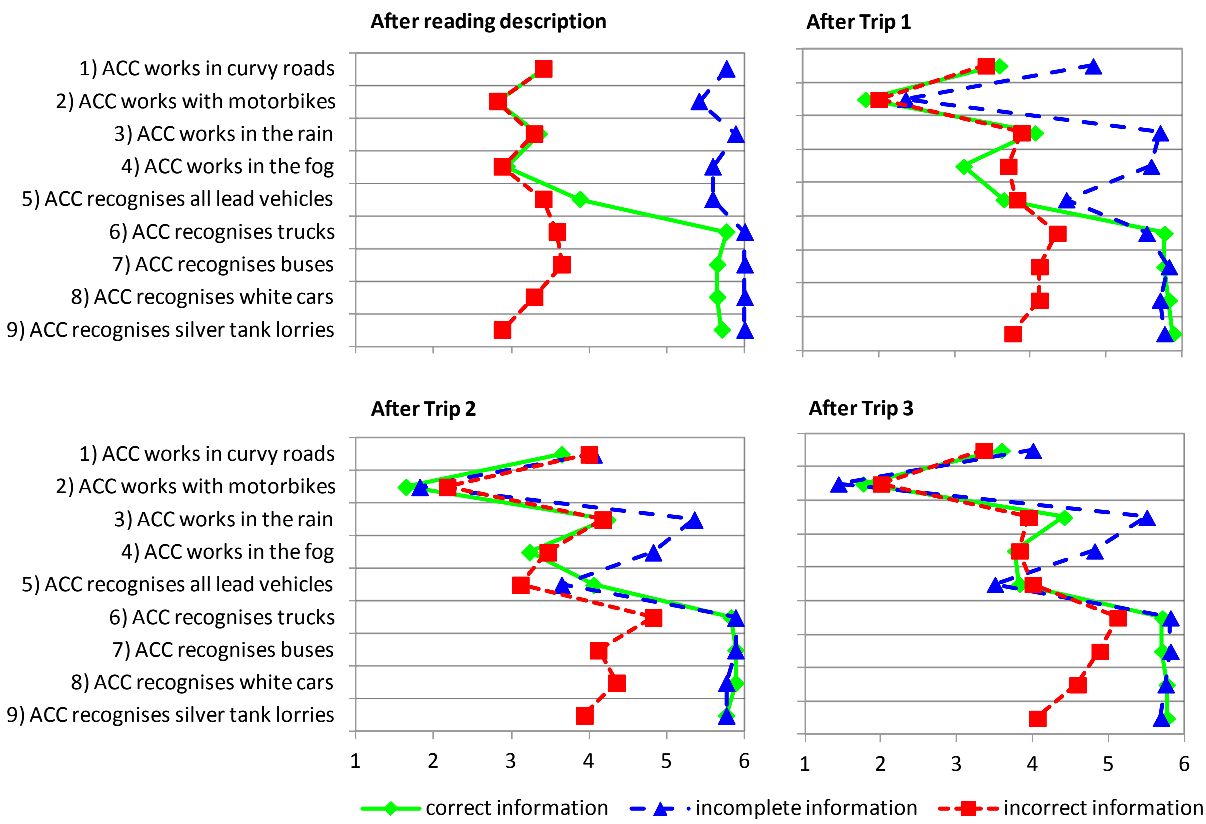


Figure 11. Development of ACC mental model (1 = *totally disagree*, 6 = *totally agree*).

After completing the first trial in the driving simulator, mental model profiles shifted towards the correct profile. To estimate the profile distance, the sum of absolute differences between the means of the correct group and both of the other groups was calculated (city-block-metric: distance = $|\bar{x}_{correct} - \bar{x}_{incomplete}| + |\bar{x}_{correct} - \bar{x}_{incorrect}|$). Table 4 shows the distances for every item and trial, and as well the average distance of all nine questions. Over all items, mean profile distance from the correct group decreased from 2.56 after reading the description to 1.71 after Trial 1. The incomplete group, in particular, became aware of problems with motorbikes (Item 2), curvy roads (Item 1), and problems due to ACC's failure to recognize all leading vehicles (Item 5).

With further practice, mental model profiles converged towards the correct group: Mean distance decreased from 1.71 after Trial 1 to 1.35 after Trial 2, and finally to 1.00 after Trial 3. For the expected, but non-occurring failures questioned in Items 6–9, a continuous shift towards the correct group was observed for the incorrect group. This effect is reflected in the steady decrease of profile distance for these four items from 2.65 after reading the description to 1.15 after Trial 3 (average of Items 6–9). Negative interaction in terms of unexpected but experienced failures (i.e., with motorbikes, curvy roads, fog) led to a faster and stronger shift in the mental model than the experience of expected, but non-occurring failures (i.e., with trucks, buses, white cars).

Table 4. Mental model profile distance between correct and incomplete/incorrect groups.

	Absolute distance between correct and other two groups distance = $|\bar{x}_{correct} - \bar{x}_{incomplete}| + |\bar{x}_{correct} - \bar{x}_{incorrect}|$			
	After reading description	After Trial 1	After Trial 2	After Trial 3
1) ACC works in curvy roads	2.35	1.41	0.76	0.65
2) ACC works with motorbikes	2.59	0.71	0.71	0.56
3) ACC works in the rain	2.59	1.82	1.18	1.56
4) ACC works in the fog	2.71	3.06	1.82	1.11
5) ACC recognises all lead vehicles	2.18	1.00	1.35	0.50
6) ACC recognises trucks	2.41	1.65	1.06	0.69
7) ACC recognises buses	2.35	1.71	1.76	0.93
8) ACC recognises white cars	2.71	1.82	1.65	1.19
9) ACC recognises silver tank lorries	3.12	2.24	1.82	1.78
Mean distance of all 9 items	2.56	1.71	1.35	1.00

5.3.2 Trust and acceptance

Trust in ACC developed according to the contrast model for the hypotheses with a medium effect size, $r(203) = .288$, $p < .001$. Immediately after reading the system description, the incorrect group, with the highest amount of critical information in the initial system description, showed the lowest level of trust (Fig. 4). A sharp increase can be observed for the incorrect group after Trial 1 where trust grows steadily until almost reaching the level of the correct group after Trial 3. Trust scores of the incomplete group decrease steadily over time from the highest level in the beginning to the lowest level after Trial 3. The correct group showed a slightly lower trust score than the incomplete group after reading the description. Trust rose steadily for the correct group until Trial 2, with a slight drop occurring from Trial 2 to Trial 3.

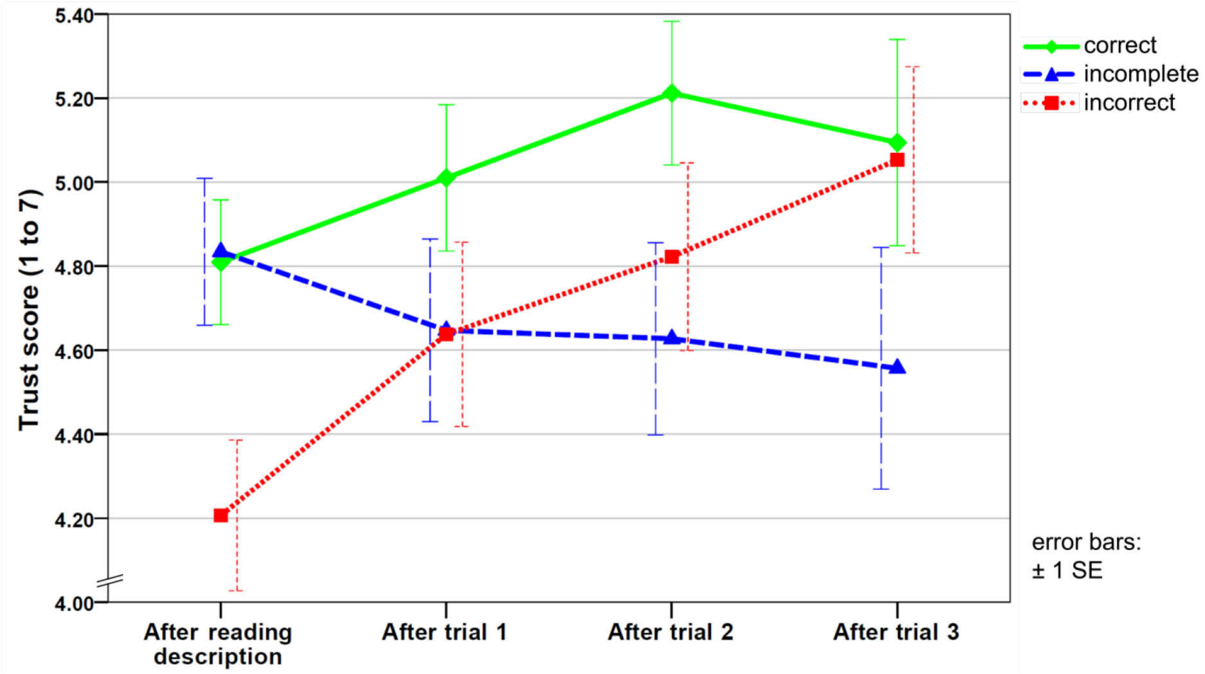


Figure 12. Evolvement of trust in ACC.

For acceptance, the contrast model showed small to medium effect sizes for the two acceptance subscales “usefulness”, $r(203) = .181$, $p = .005$, and “satisfaction”, $r(203) = .199$, $p = .002$. For both of the subscales a similar development as for trust in the system could be observed (Fig. 5). For the incorrect group, usefulness and satisfaction showed an increasing trend starting from the lowest acceptance level and ending at almost the level of the correct group after Trial 3. A decrease in both of the acceptance indicators was observed for the incomplete group, whereas the correct group showed an increasing tendency in acceptance scores over time.

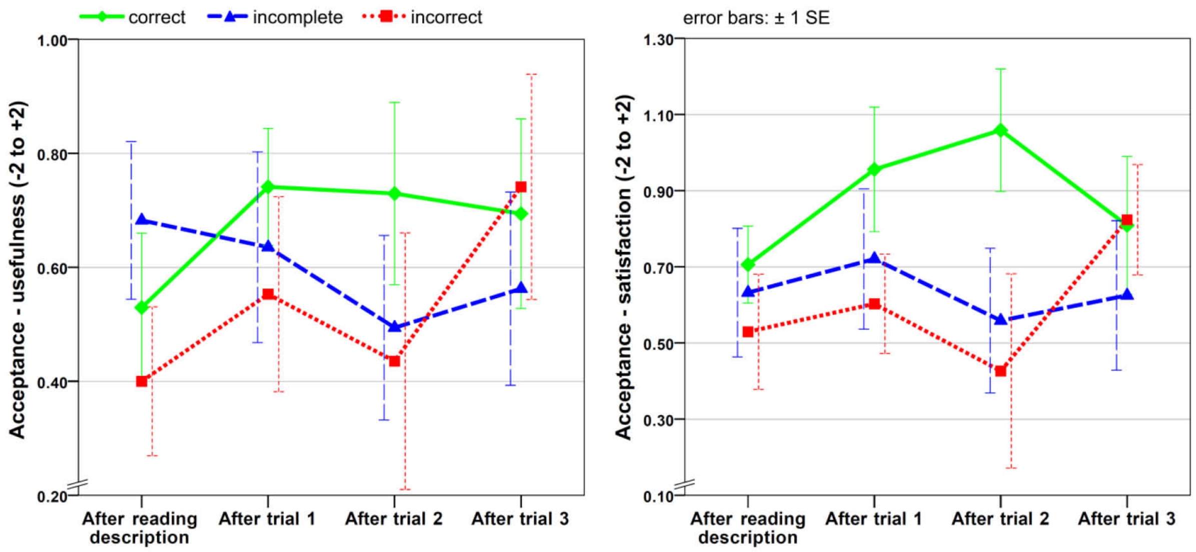


Figure 13. Evolvement of acceptance scores.

5.3.3 Situation Awareness

The frequency of the continuously presented secondary task (SURT) was used as an indicator for SA. On average, participants solved 543 SURT tasks per trip (range: 115–1,082, SD = 219.14), corresponding to an average frequency of 0.252 Hz (range: 0.003–1.753 Hz, SD = 0.214). As the task can be completed quickly (i.e., theoretical maximum 2 tasks per s), SURT completions can be displayed as frequency over time. This allows for exploratory analysis in combination with the synchronized video file. Figure 14 shows exemplarily the queue situation with the white truck leading. The left picture shows the first trip of one driver. Red spikes display SURT reactions and blue lines show frequency of SURT reactions in Hz. The x-axis shows elapsed time in s and the gray vertical line marks the current position. In this exploratory view it can be seen that the driver stops his engagement in the secondary task as the white object becomes visible. The right picture shows the same situation during the first trip with averaged SURT frequency data for the three experimental groups. It is clearly visible that the incorrect group (red line) reduce the secondary task engagement when approaching and following the white truck, whereas the correct (green line) and incomplete group (blue line) restart SURT-completion immediately. Analysis software, such as DIADEM from National Instruments (www.ni.com/diadem/), can display synchronized driving data and video in real-time and permits easy data exploration. This exploratory analysis is a powerful tool for identifying and visualizing situations associated with drops in SURT frequency.

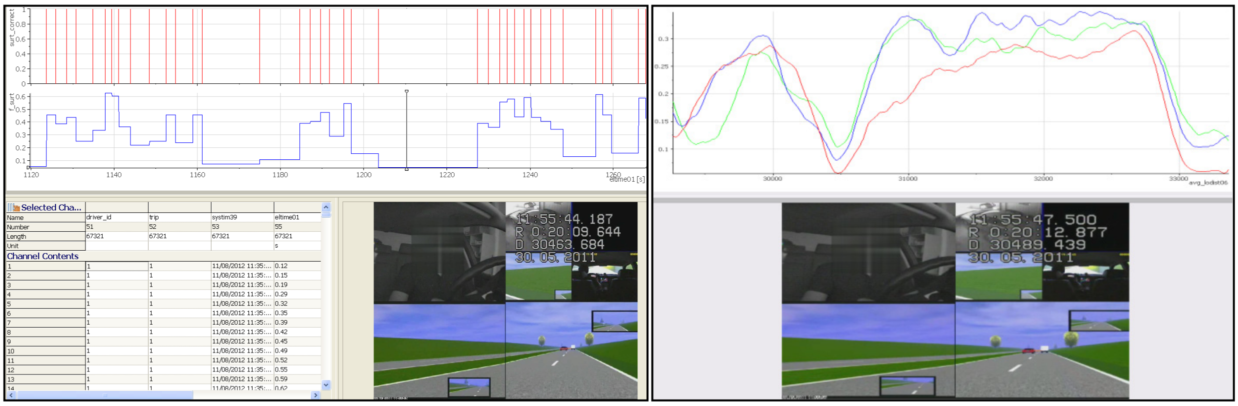


Figure 14. Exploratory analysis of secondary task frequency for a single trip (left) and averaged for the three experimental groups (right).

In order to check the effects of different initial mental model on SA as well as the development of SA in these situations over time, changes in SURT completions are assessed as an indicator for SA in these specific situations. SA is expected to show a similar development as the mental model (chapter 5.3.1), shifting towards a more realistic situation model because of previous experience. Exploratory analysis showed a broad range of absolute SURT completions per person. Therefore, relative completion rates were used in terms of percent of SURT completions within a certain section of the simulator track. Figure 15 shows the average percentage of solved SURT tasks per group for the construction zone, ranging from 30,500 m to 33,000 m. A white truck was placed in standstill at the beginning of the one-lane construction zone. Once the time headway between the own vehicle and the white truck went below four seconds, the truck started and drove constantly with 80 km/h as lead vehicle throughout the complete construction zone. The correct and incomplete group showed a constant linear growth in SURT completion from the beginning to the end of the section and for all the three trips (Figure 15). The incorrect group was informed about potential problems with white and big vehicles. Thus, a statistically significant drop in SURT completions was observed when approaching the white truck during the first trip (p < .05 between 30,830 m and 31,410 m). At approximately 31,150 m, SURT completion frequency was again in line with the other two groups. In accordance with the mental model results, a slight but statistically not significant drop in SURT-frequency for the incomplete group was visible in this approach situation for trips two and three. The same effects resulted for the cut-in situation with the white passenger car. During the first trip, the incorrect group was aware of potential problems and reduced the secondary task engagement compared to the other two groups ($F(1, 43) = 5.50$, $p = .024$, $\eta_p^2 = .113$ at the moment of cut-in). This effect disappeared at trip two and three.

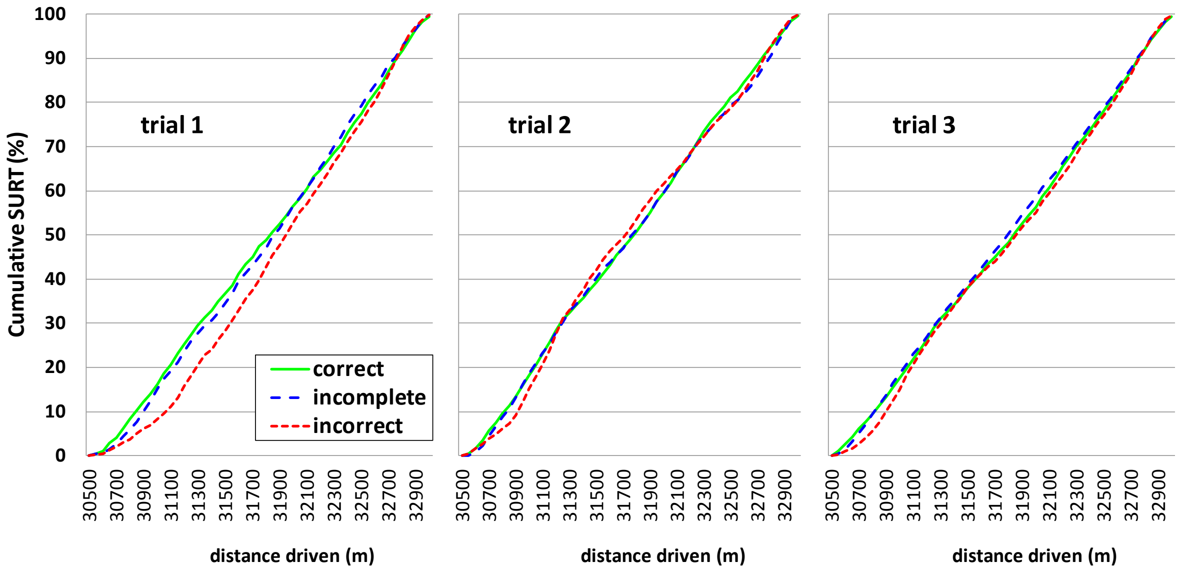


Figure 15. Percentage of SURT-tasks solved during the construction zone with the white truck leading.

SURT completion showed a similar trend in the cut-in situation with the motorbike (Figure 16), in line with the mental model development. The x-axis shows the meter driven before and after the moment at 0 m, when the motorbike passed the centre line from the left to right lane. On first encounter during trip one, both the correct and incorrect group reduced the secondary task engagement already before the cut-in at 0 m, visible through the flattening of the curves. Both of the groups were aware of a potential danger, whereas the incomplete group continued the secondary task engagement. Only approximately 40 m after the cut-in, the incomplete group slowly reduced SURT completion. In line with the mental model results, SURT completion rates became similar over the three experimental groups during trips two and three. All groups reduced the secondary task engagement already before the motorbike passed the centre lane.

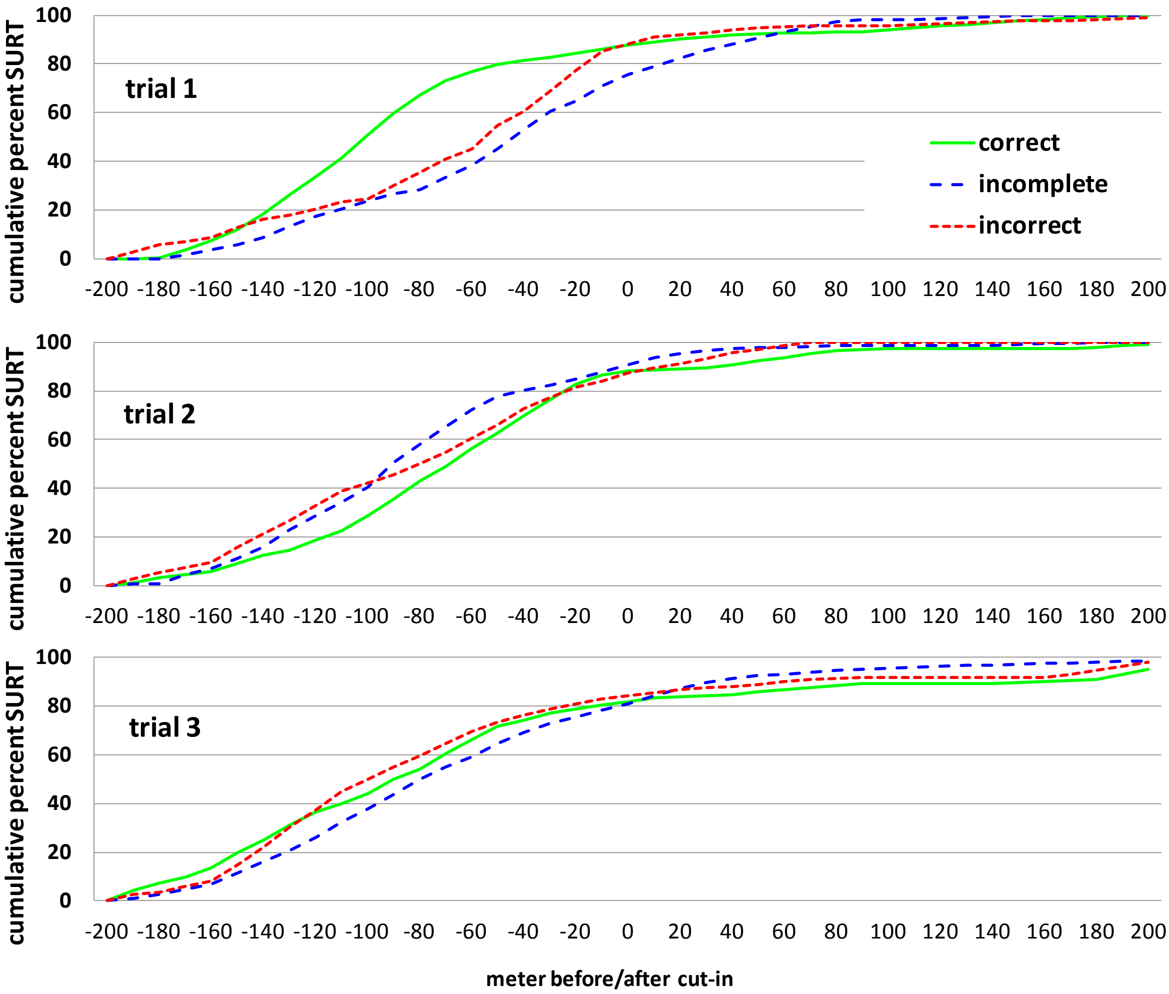


Figure 16. Percentage of SURT-tasks solved during the cut-in situation with the motorbike.

During the situations in narrow curves where ACC lost tracking of the car ahead, no differences in secondary task engagement were observed between the three groups. An explanation may be that the sudden acceleration of the own car due to the lost tracking was so apparently that all groups stopped SURT completion immediately. However, driving parameters showed a difference between the groups in handling this situation, which can be explained by the different initial mental model. The first brake reaction during the first trip after the onset of tracking failure at 53,420 m occurred significantly later in the incomplete group which had no information about this potential problem than in both of the other groups (Figure 17, delay of 80 m, X^2 (1, N = 50) = 7.815, p = .005). These differences in brake reaction disappeared during trips two and three. The same pattern for the first brake reaction appeared as well for the first situation with ACC tracking lost at 42,420 m, where the first brake reaction of the incomplete group occurred 68 m later compared to both of the other groups (X^2 (1, N = 48) = 4.607, p = .032).

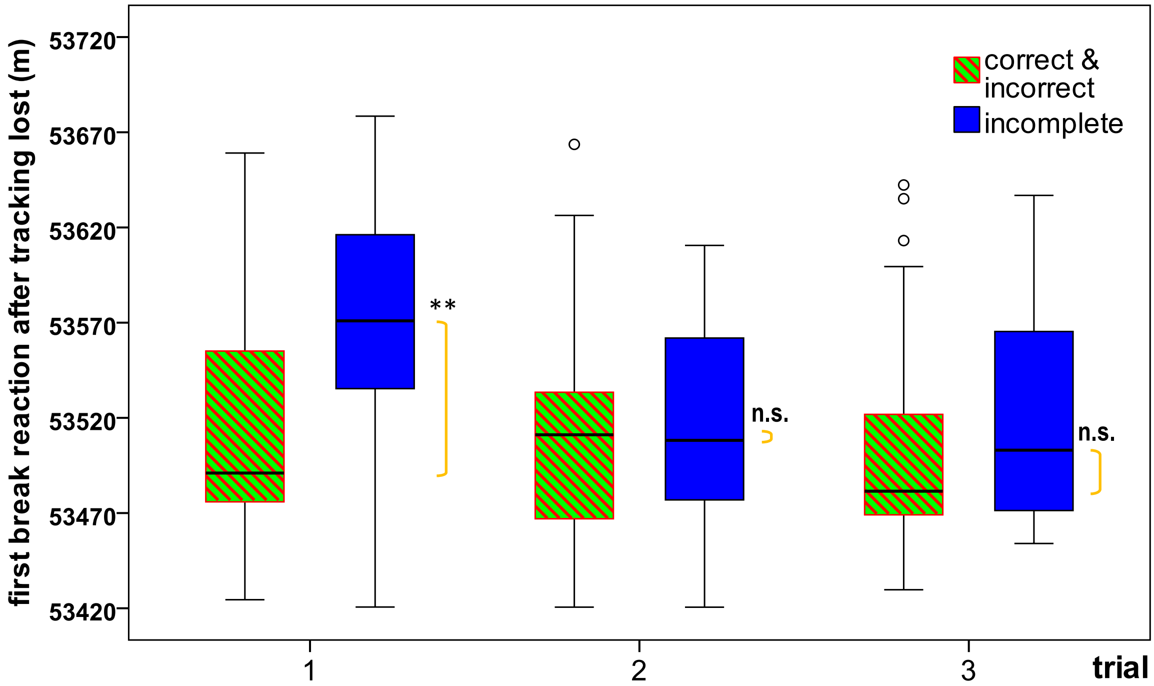


Figure 17. First brake reaction after ACC tracking lost (*p < .05, ** p < .01, ***p < .001, n.s. p > .05).

No differences in secondary task engagement appeared during the two situations with heavy fog, where ACC track lost was simulated for 3,500 m. This may be a result of the relatively long section without necessarily critical situations. Participants usually overtook slower vehicles driving in front and therefore the tracking problems were not noticed.

5.4 Discussion

The driving simulator study focuses on the effect of preliminary ACC information on the evolution of mental model, trust, acceptance and SA. Due to the matched sample, the results can be considered unbiased by relevant confounding factors listed in the model from Cotter and Mogilka (2007). The two-step sampling procedure ensured that the experimental groups were balanced according to gender, age, driving experience, ADAS experience, driving style, cognitive ability, locus of control, and sensation seeking, as well as the five BFI factors extraversion, agreeableness, conscientiousness, neuroticism and openness.

Results of the mental model questionnaire show a clear distinction between the three groups after reading the description. Therefore, participants entered the simulator trials with different expectations about system functionality, according to prior information given. As hypothesized, based on construction–integration theory (Kintsch, 1998), mental model profiles converge over time towards the profile of the correct group. Experiencing the functionality of the system in concrete situations (bottom-up information) updates the mental model (top-down information) accordingly. Inhibitory and excitatory processes change the activation of mental model nodes stored in long-term memory and make the updated knowledge network available for further processing cycles (Durso et al., 2007). Results show both a faster and greater impact of unexpected critical situations (e.g., failures in detecting the motorbike) on the mental model in comparison to expected, but non-experienced failures (i.e., trucks, buses, white cars). Expected, but non-experienced failures comprised less activated nodes. The loss of activation is depicted by a shift in mental model profile towards the "non-problem" values. This trend suggests that these nodes may drop out the network over time if they are not activated by experience. Potential problems could be forgotten over time in the absence of periodic re-activation of these knowledge nodes. As the tendency to drop out the network is already visible in the relatively short period of this study, more dangerous consequences can be expected over longer time. The results of Jenness et al. (2008), showing that 7 of 10 ACC users are not aware of manufacturers' warnings about system limitations, could be interpreted from this point of view. It might explain why "Surprisingly, at higher levels of experience respondents are more likely to say that their system works 'fairly well' or 'perfectly' to help them avoid a collision in these situations [...] where ACC is not likely to work well and they are usually included as warnings in the vehicle owner's manual" (Jenness et al., 2008, p. 23). Results of the online SA assessment using the SURT completion frequency are substantially congruent with the results on the mental model development. Not previously known system limitations are learnt relatively fast and change the behaviour in consequent similar situations towards better SA. Drivers with correct initial information on system limitations recognize potentially critical situations already before they actually arise. This awareness of the situation is measurable by the reduction in secondary task engagement at the onset of such scenarios. As a result, more attentional resources are allocated to monitor the system and faster reaction can occur in case an intervention is required.

Results concerning trust and acceptance of the system show an effect of initial information: The more potentially critical situations presented in preliminary information, the less the initial trust and acceptance of the system is, after reading the description. Accordingly, while the over-informed incorrect group shows the lowest scores for trust and acceptance in the beginning, the incomplete group tends to trust and accept the ACC the most, initially. According to the processing load hypothesis (Zwaan et al., 1998), updating the mental model is expected to create the most cognitive effort for the incomplete group, less for the incorrect group and the least effort for the correct group. Higher cognitive effort to adjust the mental model in turn lowers trust and acceptance of the system over time, due to a mismatch of expectations and experience. The results support this hypothesis, showing an increasing trend in trust and acceptance for the correct group having the highest correspondence of mental model and experience. Actually occurring system failures do not affect trust and acceptance in a negative way if they are known beforehand. These results are in line with the findings of Lee and See (2004), where the predictability, not the magnitude, of faults is considered the major impact factor on trust. Trust and acceptance decline steadily in the incomplete group with the greatest demands of reorganizing the mental model resulting from non-expected failures. Even though the mental model of the incomplete group becomes more realistic, trust and acceptance do not recover within three trials. These results partly diverge from the findings of Kazi et al. (2007) and Rudin-Brown and Parker (2004), where trust did not decline as much as predicted in the unreliable/failure condition. An explanation for the constantly decreasing trust in this study could be the higher amount of cognitive effort required to restructure the mental model of ACC. The incomplete group experienced several unexpected problems, which could have had a stronger impact than single or less frequent failures. However, further research is needed to investigate how the development of mental model, trust and acceptance evolve, after more than three trials. As hypothesized, the expected but non-occurring failures in the incorrect group do not affect trust and acceptance in a negative way over time. These nodes become less activated and require less cognitive effort to reorganize the mental model. As a result, trust and acceptance increase steadily until almost reaching the level of the correct group. Providing over-information about potential problems lowers trust and acceptance in the beginning only without causing long-lasting negative effects.

6 On-road study

6.1 Aims and research questions

The on-road study investigates the development of trust, acceptance, learning and the mental model of novice users when interacting with the automated in-vehicle system ACC. An exploratory repeated-measures study design with ten consecutive on-road trips allows for assessment of the learning and integration process until the point of stabilization. The primary research questions focus on modelling this process in mathematical/statistical terms and the identification of the point at which trust, acceptance, learning and the mental model of the system stabilize. Hence, the study design is exploratory and aims to answer the following research questions: How do trust and acceptance develop under real conditions when having full information from the owner's manual? Do trust and acceptance increase continuously or do they decline after an initial peak? Does trust and acceptance eventually stabilize and at what point does this occur? How can the learning process be described? Does the learning process correspond to the power law of learning that has been observed in other domains? When does learning end in terms of stabilization? How appropriate is the mental model of ACC functionality that is created as a result of reading the owner's manual? Which aspects of the mental model change due to experience? How does objective ACC usage evolve?

6.2 Method and material

6.2.1 Research design and procedure

To assess the development and stabilization process, an on-road field test with a repeated measurement design was utilized. Fifteen drivers without ACC experience drove a BMW525d vehicle with ACC ten consecutive times on the same route within a 2-month period (November and December). Participants were required to complete the ten sessions on different days, and it was not possible to complete more than two sessions per week. The first session lasted approximately 90 minutes and the other nine not more than 60 minutes. During the first session, participants drove without using the ACC to familiarize themselves with the car, the route, and the navigation instructions. A researcher accompanied the drivers during the first session in case help was needed. In subsequent sessions, participants performed the trial alone and were instructed to use the ACC system whenever possible. The decision to use the system was entirely up to participants, that is, when they felt sufficiently safe and comfortable using it. Drivers were paid for their participation. During the first session, participants received training on ethics and safety procedures. After familiarization with the car, they received a copy of the ACC section of the BMW owner's manual and were instructed to read it before the next trial. By the second session, researchers confirmed that everyone had read the manual. Participants completed the questionnaires on mental model, trust, acceptance and learning before driving with ACC (subsequently labelled as session 1) and after driving with ACC (subsequently labelled as session 2). The mental model questionnaire was administered again after sessions 3, 5 and 10 and all other questionnaires were administered after each consecutive session.

6.2.2 Sampling and participants

Participants were selected in a two-step procedure. In an initial online questionnaire, interested candidates were given the opportunity to apply for the study. The questionnaire covered demographic information and driving experience, as well as knowledge and experience with assistance systems. Specific requirements were established for participant selection: Drivers must have a valid driver license, a minimum of 50,000 km of total driving experience, as well as no experience with or detailed knowledge of ACC. Due to contractual obligations regarding the car insurance, participants had to be at least 25 years old and employees of the University. Fifteen novice ACC users were selected to take part in the study. The age of the 8 males and 7 females ranged from 25 to 32 years with a mean age of 28 years (SD = 1.82). On average, participants reported driving 14,666 km (SD=8,094) in the last 12 months prior to the experiment.

6.2.3 Facilities and apparatus

Test vehicle and ACC: The test vehicle was a standard BMW525d with automatic transmission and ACC with stop-and-go function. The ACC system is able to automatically maintain a set cruising speed, and reduce it when approaching a slower vehicle that travels on the same lane, while always maintaining a driver-specified distance from the vehicle immediately ahead. When following a vehicle that reduces its speed to a complete stop, the stop-and-go function allows the driver's car to do the same, reducing its speed until a standstill. Once active, the system is able to be deactivated or switched to standby mode by pressing the brake or accelerator pedals respectively. Visual feedback of system status is shown in the vehicle's control panel, located behind the steering wheel. Due to sensor limitations, ACC cannot handle every situation and the driver is required to assume manual control. Participants acquired an initial mental model of the ACC functionality by reading the ACC-section of the owner's manual. The following system limitations were described in the manual:

- Detection problems may occur with small vehicles, such as motorbikes or bicycles.
- Automatic braking may not function in short-distance cut-in situations or when deceleration of the leading vehicle occurs too rapidly.

- The system does not react to stationary objects in front (e.g. stationary vehicles at traffic lights).
- In situations involving swerving vehicles, the other car can only be detected at the moment of entering the lane ahead.
- Detection can be delayed or even fail in sharp bends, due to limited sensor range. Moreover, vehicles in adjacent lanes may be detected.
- Obstructions on the sensor, such as dirt, snow, ice or heavy rain, can restrict the detection of vehicles.

All changes have a corresponding visual tell-tale sign and in specific cases of system failure, an auditory tone is sounded.

Route: The 37 km route was the same in every trial to ensure valid comparisons between sessions and participants. Located in the vicinity of Chemnitz, the route was composed of three connected road types ranging from urban to arterial to motorway (Figure 18). The approximately 2.5 km stretch of urban roadway had a speed limit of 50 km/h. This was followed by the arterial road, approximately 5 km in length and with a speed limit of 70 km/h. The motorway road stretch was approximately 11 km long and had no legally imposed speed limit. To complete the entire route, participants drove back on the same roads to return to the starting point: motorway (11 km), arterial road (5 km), and urban road (2.5 km). In order to ensure that all participants completed the exact same route, the course was saved in the car's built-in navigation system. Mean driving time per trip was 38 min and 48 seconds, ranging from 26:40 to 1:04:05.

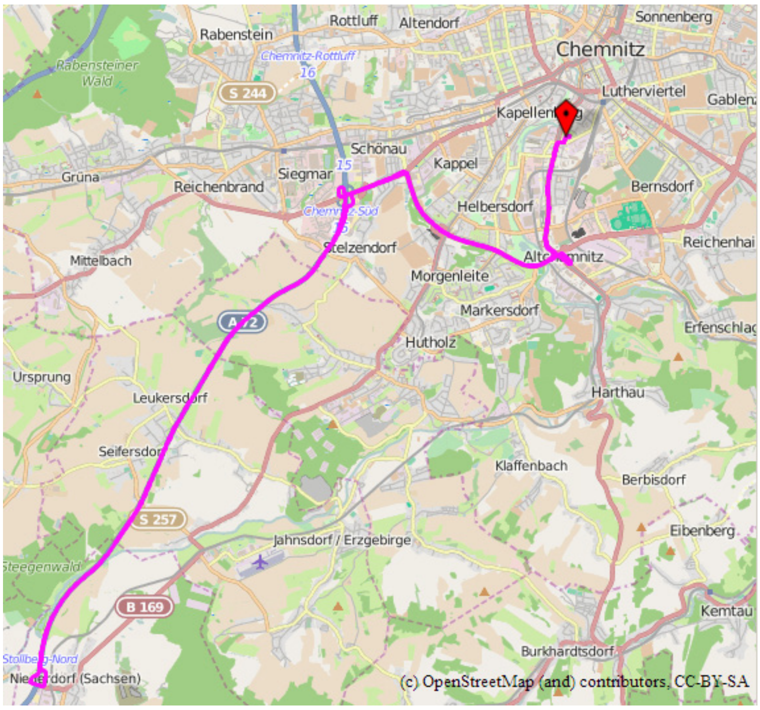


Figure 18. Route driven during every session (OpenStreetMap contributors, 2014).

Data acquisition system: The car was equipped with a video data acquisition system, capable of recording the interior of the car and the road ahead (Figure 19). This system was composed of four cameras connected to a central computer, which recorded images at a frequency of 50 Hz. The following images were captured: 1) face of the driver; 2) pedals; 3) ACC display on the control panel; 4) road ahead. In addition, another camera (Smarty BX 1000 Plus from D-TEG; camera: 1/4" CMOS Digital Sensor 310K pixels), with a 170° view angle (H: 131°; V: 96°) was used, incorporating a GPS and G sensor. This camera was placed on top of the front passenger seat to record events inside the vehicle cockpit. Images were recorded at a frequency of 15 Hz, and the GPS and G-sensor signals were collected at 1 Hz.

Figure 19. Experiment vehicle with video cameras and data acquisition system.

6.2.4 Dependent variables mental model, trust, acceptance, learning and ACC usage

The mental model questionnaire included 32 questions on ACC functionality in specific situations with a 6-point Likert scale ranging from "totally agree" to "totally disagree". The full questionnaire can be found in Appendix 9.4; the development principles are described in chapter 2.3.4. Questions covered general ACC functionality (e.g. "ACC maintains a predetermined speed in an empty lane") as well as system limitations described in the owner's manual (e.g. "ACC detects motorcycles"). Trust was assessed using a 12-item unidimensional scale for trust in automated systems (Jian et al., 2000). Participants answered questions such as "I can trust the system" or "The system is reliable" using a 7-point Likert scale ranging from 1 ("fully disagree") to 7 ("fully agree"). Internal consistency reliability was good, Cronbach's alpha values ranged between .722 and .831 for all sessions. The 5-point bipolar rating scale developed by Van der Laan et al. (1997) was used for assessing acceptance. A total of nine items were factor-analyzed and found to load onto one acceptance dimension. The resulting acceptance scale ranges from -2 to 2 where higher values correspond to greater acceptance.

Reliability is good, with Cronbach's alpha values ranging from .732 to .917. Self-reported learning progress was assessed using five items focusing on different aspects of the users' interaction with the ACC (see chapter 6.3.3 for details). Ratings were given on a percentage scale. Objective ACC usage has been coded manually using the video on ACC display on the control panel. Due to technical problems, only 128 out of 150 trials could be used for coding the ACC usage rate, whereas all 150 trips are included in the analysis of trust, acceptance, mental model and learning.

6.3 Results

6.3.1 ACC usage

This variable indicates the percentage of kilometres driven while ACC. As it can be seen in Figure 20, on the motorway the number of km driven with ACC was always higher along all trials (motorway: M= 78.3%; urban road: M= 50.0%).

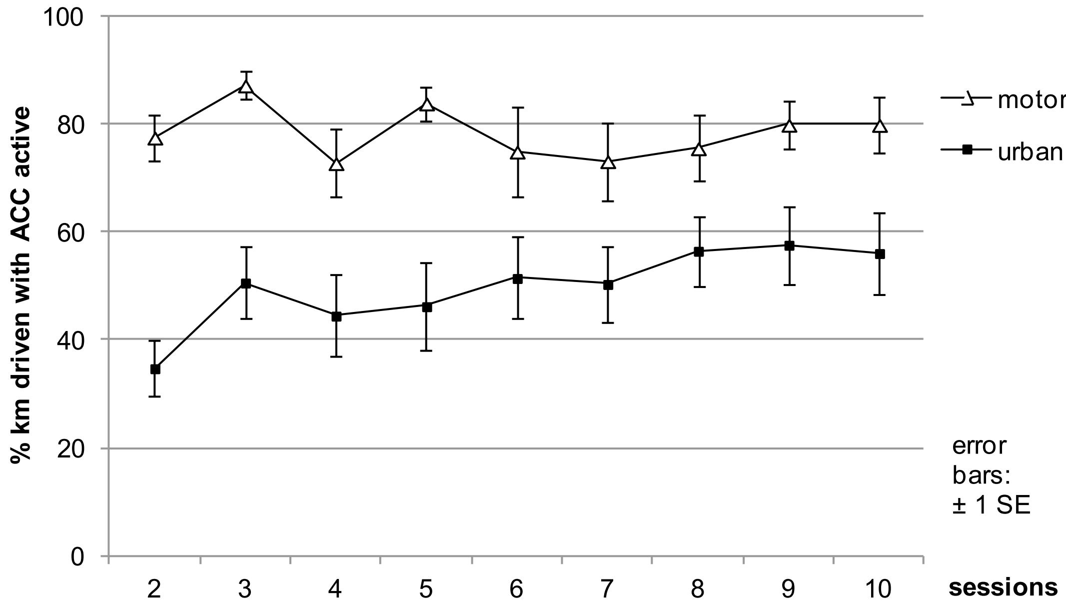


Figure 20. ACC usage rate in percentage of kilometres with standard error bars.

Repeated-measures ANOVA indicated no main effect of experience (F(3.26, 45.7) = 2.23, p = .093, η_p^2 = .14). However, when taking into account exclusively the urban environment, an effect of experience is verified (F(8, 112) = 3.05, p = .004, η_p^2 = .18). Contrasts showed a significant difference between the first and the second trial (F(1, 14) = 13.34, p = .003, η_p^2 = .44), and between the first and the fifth and following trials (respectively, fifth trial F(1, 14) = 7.38, p = .017, η_p^2 = .35; sixth trial F(1, 14) = 10.59, p = .006, η_p^2 = .43; seventh trial F(1, 14) = 17.85, p = .001, η_p^2 = .56; eighth trial F(1, 14) = 18.94, p = .001, η_p^2 = .57; ninth trial F(1, 14) = 10.12, p = .007, η_p^2 = .42). A main effect of road environment was also registered ($F(1, 14) = 24.0$, $p < .001$, $\eta_p^2 = .63$). This means that participants used the ACC system to a larger proportion when driving on the motorway. An increase in ACC percentage of use was observed only for the urban road. Thus, the effect of experience was shown to be dependent on the road environment.

6.3.2 Trust and acceptance

To assess the development of trust and acceptance over time, both questionnaires were presented after reading the ACC description (session 1) and after each drive (session 2 through 10). Figure 21 shows mean trust scores and the fitted power law curve. Trust evolved according to a power function, growing steeply in the first sessions and levelling off after approximately the fifth session. The score stabilized at a relatively high level of M = 5.84, (SD = 0.39, mean values from session 5 to 10), which corresponds to 81% of the trust scale range. The fitted power function explained 44% of the variance in the data ($R^2 = .443$, see Table 5).

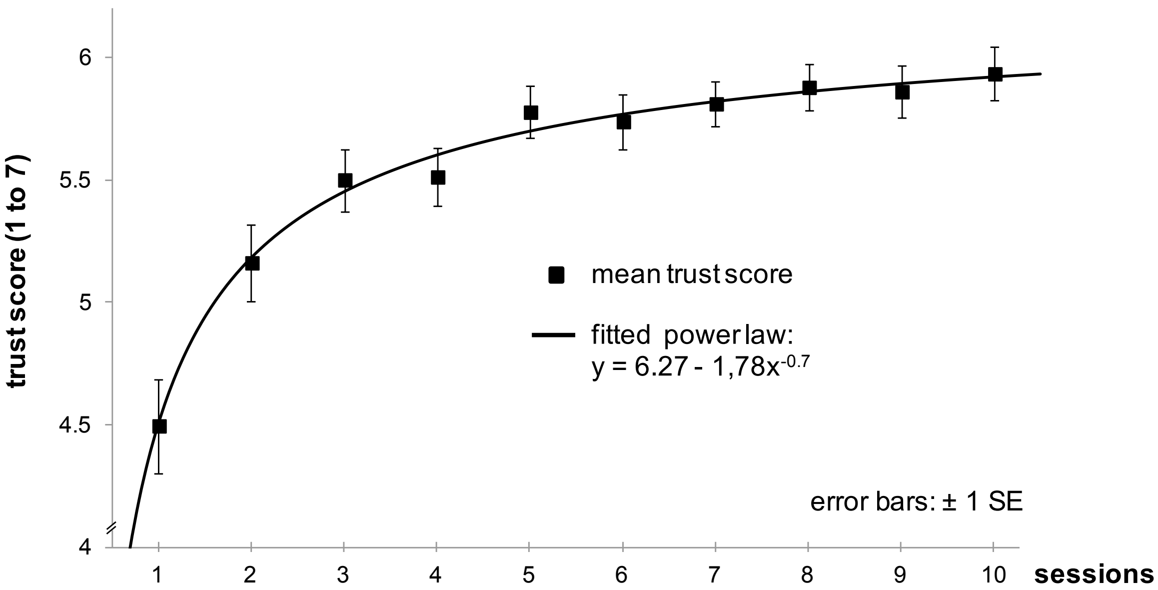


Figure 21. Development of trust in ACC and fitted power law.

Acceptance climbed dramatically after the first drive with ACC and remained rather stable for the remaining sessions (Figure 22). Stabilization occurred at a relatively high level (M = 1.16, SD = 0.45 between session two and ten), corresponding to 79% of the acceptance scale range. However, greater error bars indicate more variance in the acceptance scores, which led to a lower fit of the power function (14% of explained variance, see R^2 in Table 5).

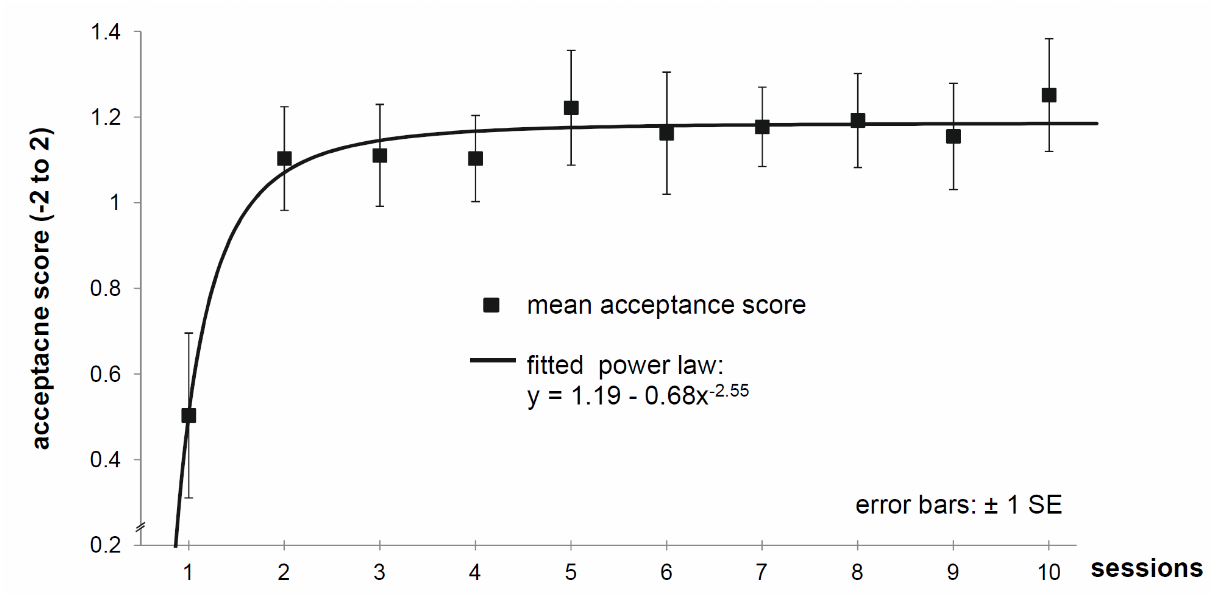


Figure 22. Development of ACC acceptance and fitted power law.

6.3.3 Learning

Learning progress was assessed using five items covering ACC operations (learning1), the meaning of displayed ACC messages (learning2), manual override situations (learning3), overall ACC functionality (learning4) and confidence in using the ACC (learning5). During every session, participants estimated their learning level by answering the statement on a percentage scale. Figure 23 shows mean percentage values for each session as well as the fitted power laws. Except for learning4 (overall ACC functionality), all items showed a rapid rise at the beginning followed by a period of deceleration and stabilization. Accordingly, power functions for learning1, 2, 3, and 5 showed a good fit with an explained variance between 42% and 73% (R^2 in Table 5). For learning4 on the overall ACC functionality, participants indicated a rather high knowledge level (80%) after reading the owner's manual. Therefore, the learning progress was not as steep as for the other items and the power law showed a relatively poor fit of 13% variance explained (R^2 in Table 5). A general tendency of stabilization for all learning curves could be observed approximately after the fifth session with an overall mean level of 96% between sessions 5 and 10.

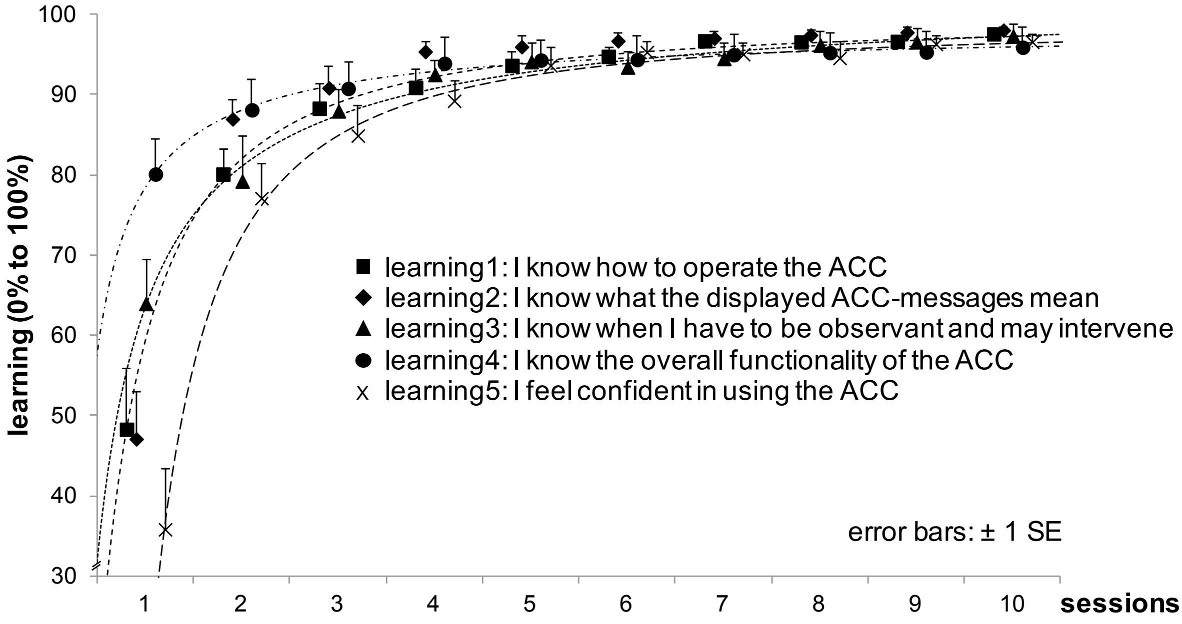


Figure 23. Development of self-reported learning and fitted power law.

Table 5 shows the fitted power functions and goodness-of-fit statistics for all dependent variables. Calculations were performed using the non-linear-regression-function (NLR) of IBM SPSS version 21. The goodness-of-fit statistics indicate how close the observed data points are to the model's predicted values. R-squared ranges from 0 to 1 and denotes the improvement in prediction from the regression model, relative to the mean model. The value can be interpreted as the proportion of total variance that is explained by the model. Higher R-squared values indicate better fit. The root mean squared error (RMSE) is the square root of the variance of the residuals and has the same units as the response variable. It indicates the absolute fit of the model to the data, whereas R-squared is a relative measure. Lower RMSE values indicate better fit.

Table 5. Power functions and goodness-of-fit.

		Goodness-of-fit	
Variable	Power function $P(N\|a, b, c) = a + bN^{-c}$	R-squared (R^2)	Root mean square error (RMSE)
Trust	$P = 6.27 – 1{,}78x^{-0.7}$	.443	0.474
Acceptance	$P = 1.19 – 0.68x^{-2.55}$	.145	0.491
Learning1	$P = 99.41 – 51.07x^{-1.37}$	.621	11.272
Learning2	$P = 97.99 – 50{,}83x^{-2.06}$	.731	9.046
Learning3	$P = 102.82 – 39.26x^{-0.85}$	.420	11.716
Learning4	$P = 98.17 – 18.2x^{-0.89}$	.133	11.988
Learning5	$P = 98.47 – 62.55x^{-1.48}$	.659	12.818

6.3.4 Mental model

The mental model questionnaire was applied five times at sessions 1, 2, 3, 5 and 10. The objective was to assess, 1) how users interpret the ACC limitations stated in the owner's manual, and 2) how the facets of the mental model change with time and increased system experience. Figure 24 shows the seven items corresponding to the limitations stated in the owner's manual (the full questionnaire with all 32 items can be found in Appendix 9.4). In order to assess changes over time, repeated measures ANOVAs were calculated using the Greenhouse-Geisser correction in case of violation of sphericity. Concerning the ACC's ability to detect motorcycles, a statistically significant increase in agreement was observed as experience increased ($F(4, 56) = 4.69$, $p = .002$, $\eta_p^2 = .251$). Thus, participants perceived this system limitation as less critical with increasing experience. The same trend was observed for the ACC's perceived ability to detect all types of vehicles ahead ($F(2.91, 40.79) = 4.14$, $p = .013$, $\eta_p^2 = .228$). A rise-and-fall-tendency was observed for the ACC's ability to regulate the distance in cut-in situations ($F(4, 56) = 7.77$, $p < .001$, $\eta_p^2 = .357$), handle every speed difference ($F(2.72, 38.13) = 6.98$, $p < .001$, $\eta_p^2 = .333$) and react to stationary objects ($F(4, 56) = 6.85$, $p < .001$, $\eta_p^2 = .329$). Thus, initially increased confidence in these ACC functions declined after gaining more system experience. No statistically significant changes were observed for perceived limitations on curvy roads ($F(4, 56) = 0.85$, $p = .499$, $\eta_p^2 = .057$) or system deactivation due to sensor obstruction ($F(2.69, 37.64) = 1.49$, $p = .235$, $\eta_p^2 = .096$).

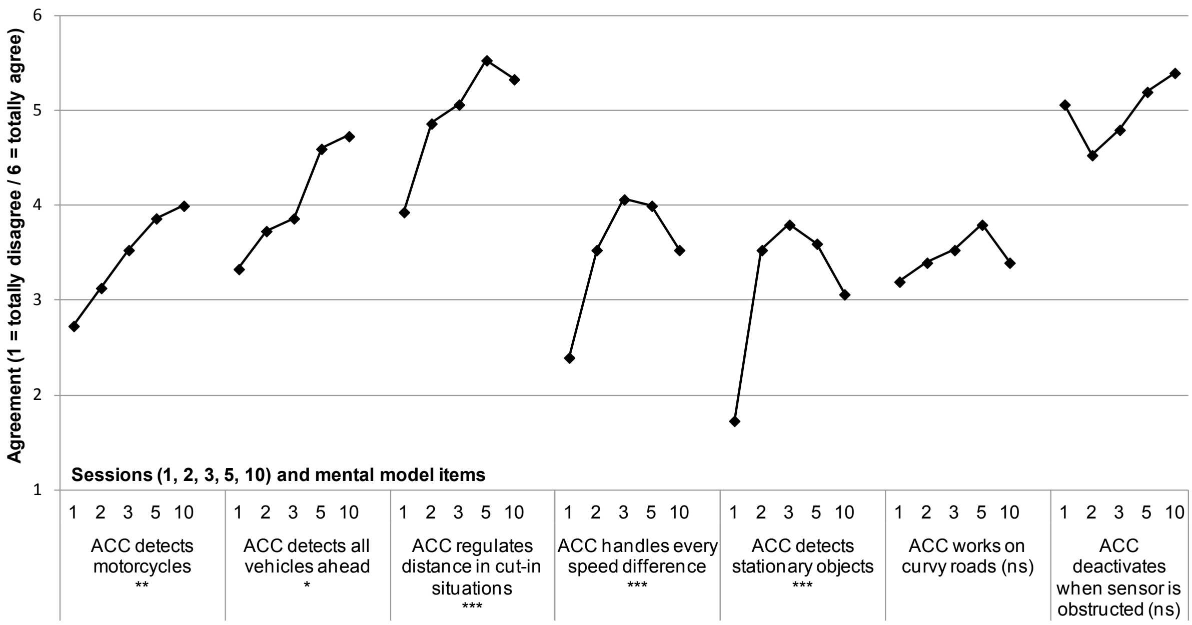


Figure 24. Development of mental model (*p < .05, ** p < .01, ***p < .001, ns p > .05).

6.4 Discussion

Overall, results on the development of trust, acceptance and learning show a non-linear trend over time. For all parameters, a steep growth was observed in the first sessions with a subsequent stabilization and no substantial declines. The curve observed here resembles typical learning curves, and consequently, when fitting the curve to the power law of learning, there is mostly a high goodness-of-fit. Thus, the overall development of trust, acceptance and learning appears to be similar to the process that occurs in other domains, such as perceptual-motor skills, memory, perception, decision, motor behaviour and problem solving (overview in Lacroix and Cousineau, 2006).

Specifically, acceptance of ACC climbs rapidly after the first session and remains stable at a rather high level after the first ACC experience. Trust stabilizes approximately after the fifth session, which corresponds to 185 km or 3.5 hours of driving. A similar pattern of stabilization was observed for aspects of self-reported learning. After the fifth session, participants reported high (96%) and stable learning values for overall ACC functionality, confidence in the system, meaning of display messages, operating the system, and handling manual override situations. Objective data on ACC usage showed a constantly high usage on motorways with some fluctuation in the first four trials and a subsequent stabilization. For the urban environment, the usage rate showed significant differences over time. Participants adopted a different behaviour in the beginning and end of the study. The lower ACC usage rate might indicate a more cautious behaviour in the first trials. In line with the subjective data, the fifth trial seemed to be the one where the behaviour changed in a significant and steadier way.

These results are consistent with previous findings from Simon (2005) as well as Ojeda and Nathan (2004), which also indicated a rather fast and steep learning curve. Self-reported knowledge and understanding of ACC functionality has been found to stabilize after two to three trips or 360 km of driving (Ojeda & Nathan, 2004) and users report familiarity with system functionality after two days of practice (Simon, 2005). The results of the present study are contrary to results found in Weinberger et al. (2001), where familiarity with ACC controls was reported after two weeks of driving or 2,800 km. However, these differences could result from the lower assessment rate (once per week), lack of controlled instructions for using the ACC, or less technologically advanced ACC systems available at the time. In contrast to the theoretical “satisfaction index” proposed by Winner et al. (2003), trust and acceptance data does not show an initial peak followed by subsequent decline due to experiencing an ACC that cannot automatically handle every situation. This discrepancy may result from differences in the initial information presented to participants about the system and the resulting initial mental model. Although participants in the present study were fully informed about ACC limitations before using the system, it is possible that users who are not aware of potential limitations will initially exhibit over-confidence in the abilities of the system, followed by subsequent disappointment as a result of experiencing unexpected problems. The critical impact of prior information on trust and acceptance has been shown in the driving simulator study by Beggiato and Krems (2013a). Trust and acceptance decrease dramatically in users who are not informed about potential limitations; whereas, informed users show a steady growth curve – despite experiencing the same system problems. Thus, it can be concluded that the power law of learning is applicable to trust, learning and acceptance if users have an appropriate initial mental model of the system, i.e. full information about the system's functionality and limitations prior to first use.

Results from the mental model questionnaire provide insight into how information from the ACC manual is understood and interpreted by users and how this interpretation changes due to experience with the system. Participants' rating of the ACC's ability to detect different vehicle types increased positively with experience. Thus, the system performed better in these situations than participants expected from reading the manual. The rise-and-fall effect observed in the evaluation of the system's ability to regulate distance in cut-in situations, handle speed differences, and react to stationary objects might have resulted from more extensive usage over time. With ongoing practice, users tried more ACC functions and realized system limitations in these functional areas. The rather optimistic evaluation after the first sessions decreased to a more realistic view by the last trips. The system's ability to function properly in bends was evaluated in the middle of the scale, showing no statistically significant changes over time. The mental model created by reading the owner's manual appears to be largely congruent with on-road experience. The same conclusion can be drawn for ACC deactivation due to sensor obstruction in adverse weather conditions, as no significant changes occurred over time. Regarding the detection of motorcycles by the ACC, participants were uncertain and sceptical in the beginning. Over time, this potential limitation was evaluated significantly less critically. However, the inspection of video data from the forward camera showed that none of the participants had ever encountered a motorbike. These results are consistent with findings from the driving simulator study (chapter 5.4). If a potential limitation is not experienced, it tends to drop from user's mental model. According to the explanation of the cognitive processes involved in constructing and updating a mental model (Durso et al., 2007; Krems & Baumann, 2009; Kintsch, 1998), bottom-up information which corresponds to the top-down memory structures accumulate activation on associated knowledge nodes whereas non-activated nodes may disappear from long-term memory.

7 General discussion and conclusions

7.1 Theoretical and practical considerations

The results of the studies show the enduring relevance of the initial mental model about ADAS for the learning process, SA, the development of trust, acceptance and the subsequent formation of a realistic mental model about automation possibilities and limitations. Preliminary information forms an initial mental model of the system, which is updated by real experience. Drivers with correct initial information on system limitations recognize such potentially critical situations already before they actually arise. The awareness is measurable by the reduction in secondary task engagement at the onset of such situations. Results show that also incorrect and incomplete initial mental models converge towards a realistic appreciation of system functionality and users adapt their behaviour in subsequent similar situations in terms of better SA. However, the more cognitive effort needed to update an incorrect or incomplete mental model, the lower trust and acceptance. This is in line with previous findings of Lee and See (2004), showing that effect of automation faults on trust depends mainly on its predictability than on its magnitude. Therefore, a discrepancy between the operator's expectations and the behaviour of the automated system can undermine trust even when the system performs well (Lee & See, 2004). Providing an idealised description, which omits potential problems, only leads to temporarily higher trust and acceptance in the beginning. The experience of unexpected failures results in a steady decrease in trust and acceptance over time. A trial-and-error strategy for ACC use, without accompanying information, is therefore considered insufficient for developing stable trust and acceptance. If mental model matches experience, trust and acceptance grow steadily – regardless of the experience of system failures. Provided that such events are known in advance, they will not cause a decrease in trust and acceptance over time. Even over-information about potential problems lowers trust and acceptance only in the beginning, and not in the long run. Potential problems should not be concealed in over-idealised system descriptions; the more information given, the better, in the long run. Given the importance of the initial mental model it is recommended that studies on system trust and acceptance should include, and attempt to control, users' initial mental model of system functionality.

The on-road study shows that learning, as well as the development of acceptance and trust in in-vehicle automation can be modelled as a non-linear power function, given the presence of an appropriate initial mental model of the system's functionality and limitations. With these preconditions, the power law of learning is applicable. Thus, the major part of the learning process occurs during the first interaction with the system and support in explaining the systems abilities (e.g. by tutoring systems) should primarily be given during this first stage. Stabilization occurs rather fast (after approximately five trips) and no decline is observable with ongoing system experience. The initial mental model formed by reading the owner's manual becomes a more realistic evaluation of system capabilities and limitations, as it is updated with ongoing practice.

However, results on the mental model development in both studies suggest that expected, but non-experienced system limitations over time may drop out the mental model if they are not activated by experience. Potential problems could be forgotten in the absence of periodic re-activation. The results of Jenness et al. (2008), showing that 7 of 10 ACC users are not aware of manufacturers' warnings about system limitations, could be interpreted from this point of view. It might explain why "Surprisingly, at higher levels of experience respondents are more likely to say that their system works 'fairly well' or 'perfectly' to help them avoid a collision in these situations [...] where ACC is not likely to work well and they are usually included as warnings in the vehicle owner's manual" (Jenness et al., 2008, p. 23). This phenomenon touches on the "ironies of automation" (Bainbridge, 1983), as an operator will not monitor automated processes efficiently if they have been working acceptably for a long period. Since efficient retrieval of knowledge from memory depends on the frequency of use, one potential solution suggested by Bainbridge (1983) is to periodically practice these critical situations using simulators. This may be an adequate measure in domains such as aviation, but it is obviously not feasible in road transportation. In the driving context, intelligent tutoring systems incorporated in ADAS (Simon, 2005) could provide a solution. As most modern cars are equipped with multifunction displays, periodic reminders about ACC limitations could be shown via this interface. In addition, tutoring systems could also be used to remind the driver of the presence of specific ADAS and reveal their benefits.

7.2 Methodological considerations

Mental model questionnaire: The developed and applied questionnaire is based on the definition of mental models as long-term knowledge structures, which represents a user's understanding of situation-specific system functioning (Durso & Gronlund, 1999). The standardized questionnaire approach offers some advantages: The assessment of profiles permits a quantification of mental model facets. This allows for statistical tests between different groups and as well within subjects over time. The latter is considered fruitful in the context of understanding processes of behavioural adaptation, as it provides relevant insights by tracking changes of the mental model. Due to the defined construction principle, the questionnaire can flexibly be adapted to various (technical) systems outside of the transportation domain, as well. The mental model questionnaire allows the transformation of statements as numbers, thereby making it useful for different purposes. That is, it allows for checking: how users perceive and interpret information about a system; how their mental model changes over time (e.g., due to experience); how mental models differ between groups (or persons) and descriptions provided by different manufacturers; which information is unclear; and so on. Due to standardization, statistics can be calculated, such as profile distances (see chapter 5.3.1) or differences in single items (see Chapter 6.3.4). The questionnaire can be easily administered and the analysis is straightforward.

The studies presented in this thesis show that the mental model questionnaire provides insights into the construction of a mental model and its development over time. However, there are some limitations of this approach. Designed as a standardized questionnaire, relevant items must be selected in the development phase. In contrast to qualitative methods, such as focus groups or in-depth interviews, users do not include their own topics but only rate existing statements. Moreover, items need to be pretested to make certain that all questions are correctly understood. Another limitation concerns unconscious/implicit aspects of mental models (Bellet et al., 2009). The questionnaire technique only captures conscious aspects stored in long-term memory. Automatic processes or implicit knowledge cannot be assessed. In sum, the mental model questionnaire is a useful tool for quantifying conscious aspects of participants' mental models, in a standardized and comparable way.

Online SA assessment: The measurement of SA developed in the PhD project is designed as an implicit performance-based approach, based on participants' continuous completion of a secondary task (SURT). It follows the principle of Rauch et al. (2009) that situationally aware drivers decide – according to the demands of a present or imminent situation – if the execution of a secondary task is possible without compromising driver safety. In contrast to prior studies, the secondary task is not only implemented in specific situations but is continuously present, whereby users are asked to solve as many secondary tasks as possible without neglecting the primary task of driving. A major advantage of this implicit measurement approach is the possibility to assess SA online without the need to interrupt a given situation. Artificial and intrusive freezing of a simulation is therefore not necessary. Moreover, the measure is not biased by human judgement or memory errors in retrospective SA evaluation. As task completion is a behavioural indicator, implicit knowledge also enters into the SA evaluation, and not only conscious and explicit facts mentioned by users. Therefore, the technique is applicable in the dynamic domain of driving, as many processes are automated, unconscious and integrated in a holistic assessment. Further, it is considered especially useful for assessing SA in connection with behavioural adaptation to ADAS, as it does not strongly interfere in the dynamic interaction of driver, system and environment.

Results of the driving simulator study show that the measure is sensitive to user's awareness of potentially critical situations. However, there are some limitations of the SA measurement technique. Firstly, it can only be applied in the context of a driving simulator and not on the road, as the continuous engagement in secondary task completion under real traffic conditions poses safety and ethical problems. Secondly, the total number of completed secondary tasks depends not only on SA, but on other factors, such as motivation to engage in a task, as well. This is shown by the rather wide range of completed tasks (from 115 to 1,082 per trip) in the driving simulator study. Differences in total number of solved secondary tasks will be subject to further research of, for example, personality factors. However, when trip duration is not too long it can be assumed that participants maintain a consistent level of motivation. To solve the problem of differences in SURT completions, the absolute rate can be transformed into relative values, such as percentages (see chapter 5.3.3), rendering the evolvement of completion rates comparable. Another limitation of the technique is the duration of a situation: While the technique is useful and appropriate for long-lasting situations, such as car following or approaching, it is not suitable for situations where unexpected events require an immediate reaction, for example, in the case of emergency braking. For these situations, other measures, such as brake reaction time, are better indicators.

Database analysis framework: The amount of data created by every one of us is constantly growing due to the increased use of technology in all parts of our lives. This process of "datafication" (Cukier & Mayer-Schoenberger, 2013) takes almost all aspects of life and turns them into data. This concerns for instance online and offline purchases, web browsing history, phone call data, position data from navigation devices or smartphones, financial transactions, biometric data as well as video and audio data. All this data represents human behaviour and is therefore an important objective source in psychological science. However, classical data analysis tools in social science such as SPSS or Excel are primarily centred on the statistical analysis of questionnaires. Data collected with a higher frequency from sensors, logfiles, video or audio is difficult to process. This topic touches the "Big Data"-discussion, as one elementary definition of Big Data includes all data that cannot be processed anymore with classical software tools and technologies (Heuer, 2013). Especially in human factors research there is a specific demand for combining objective sensor data from technical equipment and subjective evaluations. Relational databases are one way of dealing with this emerging data problem. Databases are designed for large, heterogeneous and related datasets, such as for instance sensor data with different frequency, questionnaires, video and interview data from a study. The use of a database is especially indicated when dealing with large datasets (i.e. more than 1 million records), with relational data, when data sharing or parallel access is required, for persistent storage and when complex retrieval procedures are needed. However, databases do not replace classical analysis tools but extend them. In the data analysis process, databases cover the storage and retrieval parts, whereas statistical analysis is still performed by common tools. The main operations inside the database concern structuring and aggregating data, which indeed is the main analysis step for large and heterogeneous datasets.

Alongside the benefits of using a database, new challenges arise for social scientists. Firstly, the complexity of the data structure increases due to several related data types. However, this fact is mainly related to the inherent complexity of the studies itself, e.g. when using different assessment methods such as video, interviews and multiple sensors. Databases help to deal with data complexity and do not create it. Secondly, researchers need to learn how to work with a database, i.e. using SQL for querying the database. Despite SQL is a new data-processing language for most of the social scientists, similarities to data analysis with standard tools are present, e.g. pivot-tables in Excel. Therefore trainings can build on existing knowledge. The experience with the database seminar carried out twice at the Professorship of Cognitive and Engineering Psychology at TU Chemnitz gives convincing evidence that the use of databases can be a feasible way for tackling Big Data issues in social science.

7.3 Limitations and directions for future research

A limitation of both studies is the fact that the participants were obviously interested in testing the system and therefore maybe more motivated than a usual user would be. However, some degree of interest in such a system must be present as well for real customer; otherwise the ADAS would probably not be bought. In addition, the sampling process ensured that potential confounding variables are equally distributed over the experimental groups, reducing selection bias as best as possible. Another concern is the limited number of trials. The driving simulator study was limited to three trials in a simulator environment, which provides a high level of experimental control but limited external validity. Due to the repeated measures design, familiarization effects regarding the simulator track and the measures of trust, acceptance and mental models cannot be ruled out completely. However, the rather long time intervals between the test sessions (13 days on average) should minimize familiarization, and potential effects can be considered equal for all experimental groups. Furthermore, the continuous engagement in the secondary task as well as the randomization of simulator track elements (position of trees, type and colour of the surrounding traffic) are supposed to minimize learning effects. The on-road study extended the number of trials up to ten, however, only for the condition of complete information about the ADAS. It would be very interesting to know how trust, acceptance and the mental model evolve over longer time in case of incomplete or incorrect preliminary information. Due to safety and ethical reasons it is hardly possible to experimentally test this development in real conditions. However, further research using data from naturalistic driving studies could explore this phenomenon.

The development of mental models, trust and acceptance will become an even more important issue in more complex combinations of vehicle automation. Identifying and linking cognitive processes to the vehicle is considered as a key factor on the roadmap from assisted driving towards autonomous driving (Heide & Henning, 2006). Human-machine interaction issues are considered the most important future research topic in the area of vehicle automation (Gasser, 2012). In the near future drivers might experience some of the same challenges that are described for pilots on the flight deck, such as e.g. mode awareness (Sarter & Woods, 1995). In the study of Larsson (2012) one third of ACC users already reported mode errors in terms of having forgotten if the system was active or inactive. Mental models are considered as an important factor for avoiding conflicts in complex combinations of automation. As Flemisch et al. (2012) put it: “A sufficient consistency of the mental models of human and machines, not only in the system use but also in the design and evaluation, can be a key enabler for a successful dynamic balance between humans and machines” (p. 3).

8 References

Abdi, H., & Williams, L. J. (2010). Contrast analysis. In N. J. Salkind (Ed.), *Encyclopedia of Research Design* (pp. 243–251). Thousand Oaks, CA, USA: Sage.

Adell, E. (2010). Acceptance of driver support systems. In J. Krems, T. Petzoldt, & M. Henning (Eds.), *Proceedings of the European conference on human centred design for intelligent transport systems* (pp. 475–486). Berlin, Germany: Humanist VCE.

Ausserer, K., & Risser, R. (2005). Intelligent Transport systems and services - chances and risks. *Proceedings of the 18th ICTCT-workshop*. Helsinki, Finland.

Bainbridge, L. (1983). Ironies of automation. *Automatica*, *19*(6), 775–779.

Baumann, M., & Krems, J. F. (2007). Situation awareness and driving. In P. C. Cacciabue (Ed.), *Modelling driver behaviour in automotive environments: Critical issues in driver interactions with intelligent transport systems* (pp. 253–265). London: Springer.

Beggiato, M., & Krems, J. F. (2012). The effects of preliminary information about adaptive cruise control on trust and the mental model of the system: a matched-sample longitudinal driving simulator study. In de Waard, D., Merat, N., Jamson, H., Barnard, Y., and Carsten, O.M.J. (Eds.), *Human Factors of Systems and Technology* (pp. 63-74). Maastricht, the Netherlands: Shaker Publishing.

Beggiato, M., & Krems, J. F. (2013a). The evolution of mental model, trust and acceptance of adaptive cruise control in relation to initial information. *Transportation Research Part F, 18,* 47-57. dx.doi.org/10.1016/j.trf.2012.12.006.

Beggiato, M., & Krems, J. F. (2013b). Auswirkungen erwarteter und unerwarteter Systemgrenzen von Adaptive Cruise Control auf das Situationsbewusstsein im Zeitverlauf. In VDI (Eds.). *Der Fahrer im 21. Jahrhundert. VDI-Berichte 2205* (pp.119-132). Düsseldorf: VDI-Verlag.

Beggiato, M., & Krems, J. F. (2013c). *Sequence analysis of glance patterns to predict lane changes on urban arterial roads.* Paper presented at 6. Tagung Fahrerassistenz - Der Weg zum automatischen Fahren, Munich, 28.-29.11.2013. Retrieved from http://mediatum.ub.tum.de/node?id=1187197.

Beggiato, M. (2014). Effect of ADAS use on drivers' information processing and Situation Awareness. In A. Stevens, C. Brusque & J. Krems (Eds.) *Driver adaptation to information and assistance systems* (pp. 57-80). London: The Institution of Engineering and Technology (IET).

Bellet, T., Bailly-Asuni, B., Banet, A., & Mayenobe, P. (2009). A theoretical and methodological framework for studying and modelling drivers' mental representations. Safety Science, 47(9), 1205–1221.

Breton, R., & Rousseau, R. (2001). *Situational Awareness. A review of the concept and its measurement* (Technical Report No. 2001–220). Valcartier: Defense Research and Development Canada.

Cacciabue, P. C., & Saad, F. (2008). Behavioural adaptations to driver support systems: a modelling and road safety perspective*. Cognition*, *Technology & Work*, *10*(1), 31–39.

Cahour, B., & Forzy, J. F. (2009). Does projection into use improve trust and exploration? An example with a cruise control system. *Safety Science*, *47,* 1260–1270.

Carroll, J. M., & Olson, J. R. (1987). *Mental models in human-computer interaction: Research issues about what the user of software knows.* Committee on Human Factors, Commission on Behavioral and Social Sciences and Education, National Research Council. Washington, D.C.: National Academy Press.

Cherri, C., Nodari, E., & Toffetti, A. (2004). *Review of existing tools and methods* (Del. 2.1.1 of AIDE IST-1-507674-IP). Retrieved November 28, 2012, from http://www.aide-eu.org/pdf/sp2_deliv_new/aide_d2_1_1.pdf.

Cocron, P., Bühler, F., Franke, T., Neumann, I., Dielmann, B., & Krems, J. F. (2013). Energy recapture through deceleration – regenerative braking in electric vehicles from a user perspective. *Ergonomics*, 1–13. doi:10.1080/00140139.2013.803160.

Cotter, S., & Mogilka, A. (2007). *Methodologies for the assessment of ITS in terms of driver appropriation processes over time.* HUMANIST Project Deliverable 6 of Task Force E. Retrieved November 28, 2012, from http://www.noehumanist.org/documents/Deliverables/TFE/E-6-HUMANIST_TRL_deliverable_VA1.pdf.

Cukier, K., & Mayer-Schönberger, V. (2013). The rise of big data: How it's changing the way we think about the world. *Foreign Affairs*, *May/June*.

Czaja, S. J., & Nair, S. N. (2012). Human Factors Engineering and Systems Design. In G. Salvendy (Ed.), *Handbook of human factors and ergonomics* (4th ed., pp. 38–56). Hoboken: John Wiley & Sons.

Dingus, T. A., Knipling, R. R., Jermeland, J., Doerzaph, Z. R., Bucher, C., Gupta, S., ⋯ (2006). *The 100-car naturalistic driving study. Phase II, results of the 100-car field experiment*. DOT HS 810 593. National Highway Traffic Safety Administration. Retrieved from http://www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/2006/100CarMain.pdf.

Dotzauer, M., Berthon-Donk, V., Beggiato, M., Haupt, J., & Piccinini, G. (2014). Methods to assess behavioural adaptation over time as a result of ADAS use. In A. Stevens, C. Brusque & J. Krems (Eds). *Driver adaptation to information and assistance systems* (pp. 35-55). London: The Institution of Engineering and Technology (IET).

Durso, F. T., Bleckley, M. K., & Dattel, A. R. (2006). Does SA add to the predictive validity of cognitive tests? *Human Factors*, *48,* 721–733.

Durso, F. T., & Gronlund, S. D. (1999). Situation awareness. In F.T. Durso, R. Nickerson, R. Schvaneveldt, S. Dumais, S. Lindsay, & M. Chi (Eds.), *Handbook of applied cognition* (pp. 284–314). New York, USA: John Wiley & Sons, Ltd.

Durso, F. T., Rawson, K. A., & Girotto, S. (2007). Comprehension and situation awareness. In F. T. Durso, R. S. Nickerson, S. T. Dumais, S. Lewandowsky, and T. J. Perfect (Eds.), *Handbook of applied cognition* (2nd ed., pp. 163–193). Chichester, UK: John Wiley & Sons, Ltd.

Durso, F. T., & Sethumadhavan, A. (2008). Situation awareness: Understanding dynamic environments. *Human Factors, 50*(3), 442–448.

Endsley, M. R. (1988). Situation Awareness Global Assessment Technique (SAGAT). *Proceedings of the National Aerospace and Electronics Conference* (NAECON) (pp. 789-795). New York: IEEE.

Endsley, M. R. (1990). Predictive utility of an objective measure of situation awareness. *Proceedings of the Human Factors Society 34th Annual Meeting,* (pp. 41-45). Santa Monica, CA: Human Factors & Ergonomics Society.

Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. *Human Factors*, *37*(1), 32–64.

Endsley, M. R. (2000). Situation models: An avenue to the modeling of mental models. *Proceedings of the Human Factors and Ergonomics Society 44th Annual Meeting*, (pp. 61–64). doi:10.1177/154193120004400117.

it-novum GmbH. (2011). Open *Source Datenbanken für analytische Systeme.* Retrieved from www.it-novum.com/download.

Flemisch, F., Heesen, M., Hesse, T., Kelsch, J., Schieben, A., & Beller, J. (2012). Towards a dynamic balance between humans and automation: authority, ability, responsibility and control in shared and cooperative control situations. *Cognition, Technology & Work, 14*(1), 3–18.

Gasser, T. M., Arzt, C., Ayoubi, M., Bartels, A., Eier, J., Flemisch, F., ⋯ (2012). *Rechtsfolgen zunehmender Fahrzeugautomatisierung*. *Berichte der Bundesanstalt für Strassenwesen - Fahrzeugtechnik (F): Vol. 83*. Bremerhaven: Wirtschaftsverl. NW Verl. für neue Wissenschaft.

Gasser, T. M. (2012). *Ergebnisse der Projektgruppe Automatisierung: Rechtsfolgen zunehmender Fahrzeugautomatisierung.: 5. Tagung Fahrerassistenz. 15.-16. Mai 2012 in München.* Retrieved from http://www.ftm.mw.tum.de/uploads/media/05_Gasser.pdf.

Ghazizadeh, M., Lee, J. D., & Boyle, L. N. (2012). Extending the Technology Acceptance Model to assess automation. *Cognition, Technology & Work, 14*(1), 39–49.

Göbel, P. (2012). *Der Einfluss von locus of control und sensation seeking auf das Fahrverhalten und die Nutzung des ACC.* (Bachelor's thesis). TU Chemnitz.

Grieger, S. (2013). *Akzeptanz eines ACC im Zeitverlauf. Eine Fahrsimulatorstudie mit parallelisierter Stichprobe.* (Bachelor's thesis). TU Chemnitz.

Gugerty, L. (1997). Situation awareness during driving: Explicit and implicit knowledge in dynamic spatial memory. *Journal of Experimental Psychology: Applied*, *3*, 42–66.

Gugerty, L. (2011). Situation awareness in driving. In Fisher, D. L., Rizzo, M., Caird, J. K., & Lee, J. D. (Eds). *Handbook of driving simulation for engineering, medicine, and psychology* (pp. 265–272). Boca Raton, FL: CRC Press.

Hauß, Y., & Timpe, K.-P. (2000). Automatisierung und Unterstützung im Mensch-Maschine-System. In K.-P. Timpe, T. Jürgensohn, & H. Kolrep (Eds.), *Mensch-Maschine-Systemtechnik. Konzepte, Modellierung, Gestaltung, Evaluation* (pp. 41–60). Düsseldorf: Symposion.

Heide, A., & Henning, K. (2006). The ‘‘cognitive car’’: A roadmap for research issues in the automotive sector. *Annual Reviews in Control, 30*(2), 197–203.

Heuer, S. (2013). *Kleine Daten, große Wirkung. Big Data einfach auf den Punkt gebracht.* Digitalkompakt, Nr. 6, Landesanstalt für Medien (LFM). Retrieved from www.lfm-nrw.de.

Hoyle, R. H., Stephenson, M. T., Palmgreen, P., Lorch, E. P., & Donohew, R. L. (2002). Reliability and validity of a brief measure of sensation seeking. *Personality and Individual Differences, 32*(3), 401–414.

Hummel, T., Kühn, M., Bende, J., & Lang, A. (2011). *Advanced Driver Assistance Systems: An investigation of their potential safety benefits based on an analysis of insurance claims in Germany.* Research report FS 03. Berlin: German Insurance Association - Insurers Accident Research.

ISO 15622 (2002). *Transport information and control systems – Adaptive Cruise Control systems – Performance requirements and test procedures.*

Itoh, M. (2012). Toward overtrust-free advanced driver assistance systems. *Cognition, Technology & Work*, *14*(1), 51–60. doi:10.1007/s10111-011-0195-2.

Jahn, G., Krems, J. F., & Gelau, C. (2009). Skill Acquisition While Operating In-Vehicle Information Systems: Interface Design Determines the Level of Safety-Relevant Distractions. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *51*(2), 136–151. doi:10.1177/0018720809336542.

Jenness, J. W., Lerner N. D., Mazor, S., Osberg J. S., & Tefft, B. C. (2008). *Use of Advanced In-vehicle Technology by Young and Older Early Adopters. Survey Results on Adaptive Cruise Control Systems.* Report No. DOT HS 810 917. Washington, D.C.: U.S. Department of Transportation, National Highway Traffic Safety Administration.

Jian, J. Y., Bisantz, A. M., & Drury, C. G. (2000). Foundations for an empirically determined scale of trust in automated systems. *International Journal of Cognitive Ergonomics, 4*(1), 53–71.

Jones, D. G. (2000). Subjective measures of situation awareness. In M. R. Endsley, & D. J. Garland (Eds.), *Situation awareness analysis and measurement* (pp. 101–114). Mahwah, NJ: Lawrence Erlbaum Associates.

Kazi T. A., Stanton N. A., Walker G. H., & Young M. S. (2007). Designer driving: drivers' conceptual models and level of trust in adaptive cruise control. *International Journal of Vehicle Design, 45*(3), 339–360.

Kazi, T. A., Stanton, N. A., Young, M. S., & Harrison, D. A. (2005). Assessing drivers' level of trust in Adaptive-Cruise-Control and their conceptual models of the system: Implications for system design. In L. Dorn (Ed.), *Driver Behaviour and Training - Volume 2* (pp. 132–142). Aldershot, UK: Ashgate.

Kintsch, W. (1998). *Comprehension: A paradigm for cognition*. New York, USA: Cambridge University Press.

Klamroth, A., & Winkler, J. (2013). *Einfluss von Fahrermerkmalen auf die Nutzung eines ACC und das Fahrverhalten im Fahrsimulator.* (Bachelor's thesis). TU Chemnitz.

Kompass, K., Huber, W., & Helmer, T. (2012). Safety and Comfort Systems: Introduction and Overview. In A. Eskandarian (Ed.), Handbook of intelligent vehicles (pp. 605–612). New York: Springer.

Krems, J. F., & Baumann, M. (2009). Driving and Situation Awareness: A Cognitive Model of Memory-Update Processes. In M. W. Greenlee (Ed.), *New Issues in Experimental and Applied Psychology* (pp. 56–75). Lengerich, Germany: Pabst.

Krems, J., Brusque, C., & Stevens, A. (2014). The ADAPTATION Project. In A. Stevens, C. Brusque, & J. Krems (Eds.), *Driver adaptation to information and assistance systems* (pp. 1–11). London: Institution of Engineering and Technology.

Lacroix, G. L., & Cousineau, D. (2006). The introduction to the special issue on "RT(N) = a + b N-c: The power law of learning 25 years later. *Tutorials in Quantitative Methods for Psychology*, *2*(2), 38–42.

Larsson, A. F. L. (2012). Driver usage and understanding of adaptive cruise control. *Applied Ergonomics, 43*(3), 501–506.

LeBlanc, D., Gordon, T., Goodsell, R., Bareket, Z., Hagan, M., Mefford, M., ⋯ (2006). *Road departure crash warning system field operational test: methodology and results. Volume 1: technical report*. UMTRI-2006-9-1. National Highway Traffic Safety Administration. Retrieved from http://www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/2006/RDCW-Final-Report-Vol-1_JUNE.pdf.

Lee, J. D., & See, K. A. (2004). Trust in automation: Designing for appropriate reliance. *Human Factors, 46*(1), 50–80.

Lietz, H., Petzoldt, T., Henning, M., Haupt, J., Wanielik, G., Krems, J., ... (2010). *Methodische und technische Aspekte einer Naturalistic Driving Study.* BASt FE 82.0351/2008. FAT-Schriftenreihe: Vol. 229. Berlin: VDA.

Mahrt, M. (2006). *OpenOffice.org 2.0 Base*. Köln: O'Reilly.

Martens, M. H., & Jenssen, G. D. (2012). Behavioural adaptation and acceptance. In A. Eskandarian (Ed.), *Springer Reference. Handbook of intelligent vehicles* (pp. 117–138). New York: Springer.

Mattes, S., & Hallén, A. (2009). Surrogate distraction measurement techniques: The Lane Change Test. In M. Regan, J. D. Lee, & K. L. Young (Eds.), *Driver distraction: Theory, effects and mitigation* (pp. 107–122). Boca Raton: CRC Press.

Mehlenbacher, B., Wogalter, M. S., & Laughery, K. R. (2002). On the reading of product owner's manuals: Perceptions and product complexity. *Proceedings of the Human Factors and Ergonomics Society 46th Annual Meeting* (pp. 730–734), Santa Monica, CA: Human Factors and Ergonomics Society.

Metz, B., Schömig, N., & Krüger, H.-P. (2011). Attention during visual secondary tasks in driving: Adaptation to the demands of the driving task. *Transportation Research Part F: Traffic Psychology and Behaviour*, *14*(5), 369–380.

Metzner, M. (2012). *Einfluss von Vorinformationen über ACC auf Situation Awareness.* (Master's thesis). TU Chemnitz.

Meyer, G., & Deix, S. (2014). Research and innovation for automated driving in Germany and Europe. In G. Meyer & S. Beiker (Eds.), *Lecture Notes in Mobility. Road Vehicle Automation* (pp. 71–84). Cham, s.l: Springer International Publishing.

Montag, I., & Comrey, A. L. (1987). Internality and externality as correlates of involvement in fatal driving accidents. *Journal of Applied Psychology, 72*(3), 339–343.

Muir, B. M. (1994). Trust in automation: part 1. Theoretical issues in the study of trust and human intervention in automated systems. *Ergonomics, 37*(11), 1905–1922.

Muir B. M., & Moray, N. (1996). Trust in automation: II. Experimental studies of trust and human intervention in a process control simulation. *Ergonomics, 39*(3), 429–460.

Najm, W. G., Stearns, M. D., Howarth, H., Koopmann, J., & Hitz, J. (2006). *Evaluation of an automotive rear-end collision avoidance system.* Report no. DOT HS-810-569. Washington, D.C.: U.S. Department of Transportation, National Highway Traffic Safety Administration.

Newell, A., & Rosenbloom, P. S. (1981). Mechanisms of Skill Acquisition and the Law of Practice. In J. R. Anderson (Ed.), *Cognitive Skills and their Acquisition* (pp. 1–55). Hillsdale, NJ: Erlbaum.

OECD. (1990). *Behavioural adaptations to changes in the road transport system*. Paris: Organization for Economic Co-operation and Development.

Ojeda, L., & Nathan, F. (2006). Studying learning phases of an ACC through verbal reports. In R.F.T. Brouwer & D.M. Hoedemaeker (Eds.), *Driver support and information systems: Experiments on learning, appropriation and effects of adaptiveness. Del. 1.2.3 of AIDE IST-1-507674-IP* (pp. 47–73). Retrieved from http://www.aide-eu.org/pdf/sp1_deliv_new/aide_d1_2_3.pdf.

Oswald, W. D., & Roth, E. (1986). *Der Zahlen-Verbindungs-Test.* Göttingen, Bern, Toronto, Seattle: Hogrefe Verlag für Psychologie.

Parasuraman, R., Sheridan, T., & Wickens, C. D. (2000). A model for types and levels of human interaction with automation. *Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on*, *30*(3), 286–297. doi:10.1109/3468.844354.

Pereira, M., Lietz, H., & Beggiato, M. (2014). Development of a database for storage and analysis of behavioural data. In A. Stevens, C. Brusque, & J. Krems (Eds.), *Driver adaptation to information and assistance systems* (pp. 301–317). London: Institution of Engineering and Technology.

Popken, A. (2009). *Drivers' reliance on lane keeping assistance systems as a function of the level of assistance.* (Doctoral dissertation). Retrieved November 28, 2012, from http://archiv.tu-chemnitz.de/pub/2010/0048/index.html.

Popken, A., & Krems, J. F. (2011). Automation and situation awareness. In G. Boy (Ed.). *The handbook of human-machine interaction. A human-centered design approach* (pp. 75–90). Farnham: Ashgate.

Pritchett, A. R., & Hansman, R. J. (2000). Use of testable responses for performance-based measurement of situation awareness. In M. R. Endsley, & D. J. Garland (Eds.), *Situation awareness analysis and measurement* (pp. 170–189). Mahwah, NJ: Lawrence Erlbaum Associates.

Rajaonah, B., Anceaux, F., & Vienne, F. (2006). Trust and the use of adaptive cruise control: A study of a cut-in situation. *Cognition, Technology and Work*, *8*(2), 146–155. doi:10.1007/s10111-006-0030-3.

Rajaonah, B., Tricot, N., Anceaux, F., & Millot, P. (2008). The role of intervening variables in driver–ACC cooperation. *International Journal of Human-Computer Studies, 66*(3)*,* 185–197.

Rammstedt, B., & John, O. P. (2007). Measuring personality in one minute or less: A 10-item short version of the Big Five Inventory in English and German. *Journal of Research in Personality, 41*(1)*,* 203–212.

Rauch, N. (2009). *Ein verhaltensbasiertes Messmodell zur Erfassung von Situationsbewusstsein im Fahrkontext.* (Doctoral dissertation). Retrieved from http://opus.bibliothek.uni-wuerzburg.de/volltexte/2009/3722/.

Rauch, N., Gradenegger, B., & Krüger, H.-P. (2009). Darf ich oder darf ich nicht?: Situationsbewusstsein im Umgang mit Nebenaufgaben während der Fahrt. *Zeitschrift für Arbeitswissenschaft, 63*(1), 3–15.

Rosenthal, R., Rosnow, R. L., & Rubin, D. B. (2000). *Contrasts and effect sizes in behavioral research: A correlational approach.* Cambridge, UK, Cambridge University Press.

Rousseau, R., Tremblay, S., & Breton, R. (2004). Defining and modeling situation awareness: A critical review. In S. Banbury, & S. Tremblay (Eds.), *A cognitive approach to situation awareness: Theory, measurement and application* (pp. 3–21). Aldershot, UK: Ashgate & Town.

Rudin-Brown, C. M., & Noy, Y. I. (2002). Investigation of behavioral adaptation to lane departure warnings. *Transportation Research Record,* no. *1803,* 30–37.

Rudin-Brown, C. M., & Parker, H. A. (2004). Behavioural adaptation to adaptive cruise control (ACC): implications for preventive strategies, *Transportation Research Part F: Traffic Psychology and Behaviour, 7*(2), 59–76.

Saad, F. (2007). Dealing with Behavioural Adaptations to Advanced Driver Support Systems. In P.C. Cacciabue (Ed.), *Modelling driver behaviour in automotive environments* (pp. 147–162). London: Springer.

Sarter, N. B., & Woods, D. D. (1995). How in the world did we ever get in that mode? Mode error and awareness in supervisory control. *Human Factors, 37*(1), 5–19.

Schade, J., & Baum, M. (2007). Reactance or acceptance? Reactions towards the introduction of road pricing. *Transportation Research Part A, 41*(1), S. 41-48.

Schmidt, K. (2012). *Analyse mehrdimensionaler Zeitreihen eines Fahrsimulators.* (Master's thesis). TU Chemnitz.

Schmidt, K., Beggiato, M., Hoffmann, K. H., & Krems, J. F. (2014). A mathematical model for predicting lane changes using the steering wheel angle. *Journal of Safety Research, 49*, 85–90. doi:10.1016/j.jsr.2014.02.014.

Schömig, N., Metz, B., & Krüger, H.-P. (2011). Anticipatory and control processes in the interaction with secondary tasks while driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, *14*(6), 525–538.

Schwarzwäller, M. (2013). *Transformationsprozesse des mentalen Modells eines ACC durch Erfahrung. Ein mixed methods Ansatz.* (Bachelor's thesis). TU Chemnitz.

Seppelt, B. D., & Lee, J. D. (2007). Making adaptive cruise control (ACC) limits visible. *International Journal of Human Computer Studies, 65*(3), 192–205. doi:10.1016/j.ijhcs.2006.10.001

Sheridan, T. B., & Verplank, W. L. (1978). *Human and computer control of undersea teleoperators*. Cambridge: Massachusetts Institute of Technology, Man-Machine Systems Laboratory.

Simon, J. (2005). *Learning to drive with Advanced Driver Assistance Systems. Empirical studies of an online tutor and a personalised warning display on the effects of learnability and the acquisition of skill.* (Doctoral dissertation). Retrieved from http://archiv.tu-chemnitz.de/pub/2006/0071/data/Dissertation_Simon.pdf.

Stanton, N., & Young, M. S. (2005). Driver behaviour with adaptive cruise control. *Ergonomics, 48*(10), 1294−1313.

Taylor, R. M. (1990). Situation awareness rating technique (SART): The development of a tool for aircrew systems design. *Situational awareness in aerospace operations* (AGARD-CP-478; pp. 3/1-3/17). Neuilly sur Seine, France: NATO Advisory Group for Aerospace Research and Development.

Tsang, P., & Vidulich, M. A. (2006). Mental workload and situation awareness. In G. Salvendy (Ed.), *Handbook of human factors & ergonomics* (pp. 243–268). Hoboken, NJ: Wiley.

Van der Laan, J. D., Heino, A., & De Waard, D. (1997). A simple procedure for the assessment of acceptance of advanced transport telematics. *Transportation Research Part C: Emerging Technologies*, *5*(1), 1–10. doi:10.1016/S0968-090X(96)00025-3.

Vidulich, M. A., & Hughes, E. R. (1991). Testing a subjective metric of situation awareness. *Proceedings of the Human Factors & Ergonomics Society 35th Annual Meeting*, (pp. 1307−1311). Santa Monica, CA: Human Factors & Ergonomics Society.

Vollrath, M., & Krems, J. (2011). *Verkehrspsychologie: Ein Lehrbuch für Psychologen, Ingenieure und Informatiker.* Stuttgart: Kohlhammer.

Waag, W. L., & Houck, M. R. (1994). Tools for assessing situational awareness in an operational fighter environment. *Aviation, Space, and Environmental Medicine, 65*(5, Suppl.), 13–19.

Ward, N. (2000). Automation of task processes: An example of intelligent transportation systems. *Human Factors and Ergonomics in Manufacturing*, *10*(4), 395–408.

Weinberger, M., Winner, H., & Bubb, H. (2001). Adaptive cruise control field operational test—the learning phase. *JSAE review*, *22*(4), 487–494. doi:10.1016/S0389-4304(01)00142-4.

Weller, G., & Schlag, B. (2004). Verhaltensadaptation nach Einführung von Fahrerassistenzsystemen. In B. Schlag (Ed.), *Verkehrspsychologie. Mobilität – Verkehrssicherheit – Fahrerassistenz* (pp. 351−370). Lengerich: Pabst Science Publishers.

Winner, H., Barthenheier, T., Fecher, N., & Luh, S. (2003). Fahrversuche mit Probanden zur Funktionsbewertung von aktuellen und zukünftigen Fahrerassistenzsystemen. In K. Landau (Ed.), *Fortschritt-Berichte VDI Reihe 12, Verkehrstechnik/Fahrzeugtechnik: Vol. 557. Fahrversuche mit Probanden - Nutzwert und Risiko.* Düsseldorf: VDI-Verlag.

Winner, H., Danner, B., & Steinle, J. (2012). Adaptive Cruise control. In H. Winner, S. Hakuli, & G. Wolf (Eds.), *Handbuch Fahrerassistenzsysteme* (2nd ed., pp. 478–521). Wiesbaden: Vieweg + Teubner.

Xiao, L., & Gao, F. (2010). A comprehensive review of the development of adaptive cruise control systems. *Vehicle System Dynamics*, *48*(10), 1167–1192. doi:10.1080/00423110903365910.

Xiong, H., Boyle, L., Moeckli, J., Dow, B., & Brown, T. (2012). Use patterns among early adopters of adaptive cruise control (ACC). *Human Factors, 54*(5), 722–733.

Zwaan, R.A., Magliano, J.P., & Graesser, A.C. (1995). Dimensions of situation model construction in narrative comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*, 386–397.

Zwaan, R. A., Radvansky, G. A., Hilliard, A. E., & Curiel, J. M. (1998). Constructing multidimensional situation models during reading. *Scientific Studies of Reading, 2*(3), 199–220.

9 Appendix

9.1 Questionnaires used in the driving simulator study

9.1.1 Original German version

Die folgenden Fragen beziehen sich auf die Funktionsweise und ihren Eindruck von *DriveFree*. Versuchen sie bitte auf jede Frage/Aussage eine Antwort zu geben auf Basis der Informationen und des Eindrucks, den sie bisher von *DriveFree* haben.

Geben sie dazu bitte bei jeder Aussage den Grad ihrer Zustimmung an durch Ankreuzen der entsprechenden Position zwischen „trifft überhaupt nicht zu“ und „trifft voll und ganz zu“.

DriveFree…	**Trifft überhaupt nicht zu**					**Trifft voll und ganz zu**
… hält eine eingestellte Geschwindigkeit bei freier Fahrspur	☐	☐	☐	☐	☐	☐
… lenkt automatisch	☐	☐	☐	☐	☐	☐
… funktioniert auf der Autobahn	☐	☐	☐	☐	☐	☐
… hält bei Stillstand einen Abstand von 5 Meter zum Vordermann ein	☐	☐	☐	☐	☐	☐
… reagiert auf Schlaglöcher in der gleichen Fahrspur	☐	☐	☐	☐	☐	☐
… wird durch Betätigen des Bremspedals außer Kraft gesetzt	☐	☐	☐	☐	☐	☐
… reagiert auf Fußgänger in der Fahrspur	☐	☐	☐	☐	☐	☐
… reagiert auf vorausfahrende LKW in der gleichen Fahrspur	☐	☐	☐	☐	☐	☐
… erkennt Vorfahrtsregelungen	☐	☐	☐	☐	☐	☐
… funktioniert bei Sonne	☐	☐	☐	☐	☐	☐
… reagiert auf Fahrzeuge, die sich von hinten nähern.	☐	☐	☐	☐	☐	☐
… reagiert auf vorausfahrende Busse in der gleichen Fahrspur	☐	☐	☐	☐	☐	☐
… funktioniert auf geraden Strecken	☐	☐	☐	☐	☐	☐
… funktioniert bei Nacht	☐	☐	☐	☐	☐	☐
… reagiert auf vorausfahrende PKW in der gleichen Fahrspur	☐	☐	☐	☐	☐	☐
… funktioniert auf kurvigen Strecken	☐	☐	☐	☐	☐	☐
… erlaubt bei Gaspedalbetätigung auch schneller zu fahren als die eingestellte Wunschgeschwindigkeit	☐	☐	☐	☐	☐	☐
… reagiert auf Ampeln	☐	☐	☐	☐	☐	☐
… funktioniert bei Regen	☐	☐	☐	☐	☐	☐
… reagiert auf vorausfahrende rote PKW in der gleichen Fahrspur	☐	☐	☐	☐	☐	☐
… reagiert auf vorausfahrende weiße PKW in der gleichen Fahrspur	☐	☐	☐	☐	☐	☐

DriveFree…	**Trifft überhaupt nicht zu**					**Trifft voll und ganz zu**
… kann auch bis zum kompletten Stillstand abbremsen	☐	☐	☐	☐	☐	☐
… reaktiviert sich automatisch nach Loslassen des Gas- oder Bremspedals	☐	☐	☐	☐	☐	☐
… reagiert auf alle vorausfahrenden Fahrzeuge in der gleichen Fahrspur	☐	☐	☐	☐	☐	☐
… reagiert auf Verkehrszeichen	☐	☐	☐	☐	☐	☐
… funktioniert bei Nebel	☐	☐	☐	☐	☐	☐
… hält einen eingestellten Abstand zum langsamer vorausfahrenden Fahrzeug in der gleichen Fahrspur	☐	☐	☐	☐	☐	☐
… reagiert auf Gegenverkehr	☐	☐	☐	☐	☐	☐
… wird durch Betätigen des Blinkers außer Kraft gesetzt	☐	☐	☐	☐	☐	☐
… reagiert auf vorausfahrende Motorräder in der gleichen Fahrspur	☐	☐	☐	☐	☐	☐
… funktioniert auf Landstraßen	☐	☐	☐	☐	☐	☐
… warnt beim Verlassen der Fahrspur	☐	☐	☐	☐	☐	☐
… reagiert auf vorausfahrende silberne Tankwagen in der gleichen Fahrspur	☐	☐	☐	☐	☐	☐
… reagiert auf Bodenwellen/Unebenheiten in der gleichen Fahrspur	☐	☐	☐	☐	☐	☐
… warnt beim Überschreiten der aktuell zulässigen Höchstgeschwindigkeit	☐	☐	☐	☐	☐	☐

Bitte beurteilen sie das *DriveFree*-System anhand der Informationen und des Eindrucks, den sie bisher haben. Setzen sie bitte jeweils ein Kreuz pro Zeile zwischen jedem der Eigenschaftspaare. Es geht hier um ihre persönliche Meinung, d.h. es gibt keine richtigen oder falschen Antworten.

Nützlich	☐	☐	☐	☐	☐	Nutzlos
Angenehm	☐	☐	☐	☐	☐	Unangenehm
Schlecht	☐	☐	☐	☐	☐	Gut
Nett	☐	☐	☐	☐	☐	Nervig
Effizient	☐	☐	☐	☐	☐	Unnötig
Ärgerlich	☐	☐	☐	☐	☐	Erfreulich
Hilfreich	☐	☐	☐	☐	☐	Wertlos
Nicht wünschenswert	☐	☐	☐	☐	☐	Wünschenswert
Aktivierend	☐	☐	☐	☐	☐	Einschläfernd

Nennen sie bitte wiederum den Grad ihrer Zustimmung zu jeder der folgenden Aussagen betreffend *DriveFree* durch Markieren einer Position zwischen „stimme überhaupt nicht zu“ und „stimme vollkommen zu“.

	Stimme überhaupt nicht zu						**Stimme voll-kommen zu**
Ich kann dem System vertrauen	☐	☐	☐	☐	☐	☐	☐
Das System ist irreführend	☐	☐	☐	☐	☐	☐	☐
Die Aktionen des Systems sind undurchsichtig	☐	☐	☐	☐	☐	☐	☐
Ich misstraue den Aktionen, Absichten oder Konsequenzen des Systems	☐	☐	☐	☐	☐	☐	☐
Ich bin dem System gegenüber wachsam	☐	☐	☐	☐	☐	☐	☐
Ich bin mit dem System vertraut	☐	☐	☐	☐	☐	☐	☐
Die Aktionen des Systems führen zu nachteiligen oder schädlichen Konsequenzen	☐	☐	☐	☐	☐	☐	☐
Ich traue mir zu, das System zu nutzen	☐	☐	☐	☐	☐	☐	☐
Das System ist glaubwürdig	☐	☐	☐	☐	☐	☐	☐
Ich kann mich auf das System verlassen	☐	☐	☐	☐	☐	☐	☐
Das System bietet Sicherheit	☐	☐	☐	☐	☐	☐	☐
Das System ist zuverlässig	☐	☐	☐	☐	☐	☐	☐

Vielen Dank für ihre Mitarbeit!

Melden sie sich bitte wieder beim Testleiter.

9.1.2 English translation

The following questions refer to the functions and your impression of *DriveFree*. Please try to answer each question/statement based on the information and the impression of *DriveFree* you have so far.

Please indicate your degree of approval for every statement by marking the appropriate position between “fully disagree” and “fully agree”.

DriveFree…	**disagree totally**					**agree totally**
… maintains a predetermined speed in an empty lane	☐	☐	☐	☐	☐	☐
… steers automatically	☐	☐	☐	☐	☐	☐
… works on highways	☐	☐	☐	☐	☐	☐
… keeps a distance of 5m to the car in front of you in case of complete standstill	☐	☐	☐	☐	☐	☐
… reacts to potholes in the same lane	☐	☐	☐	☐	☐	☐
… is overruled by pressing the brake pedal	☐	☐	☐	☐	☐	☐
… reacts to pedestrians in the traffic lane	☐	☐	☐	☐	☐	☐
… reacts to trucks driving ahead in the same lane	☐	☐	☐	☐	☐	☐
… detects right of way regulations	☐	☐	☐	☐	☐	☐
… works when the sun shines	☐	☐	☐	☐	☐	☐
… reacts when vehicles approach from behind	☐	☐	☐	☐	☐	☐
… reacts to busses driving ahead in the same lane	☐	☐	☐	☐	☐	☐
… works on straight roads	☐	☐	☐	☐	☐	☐
… works during night time	☐	☐	☐	☐	☐	☐
… reacts to passenger cars driving ahead in the same lane	☐	☐	☐	☐	☐	☐
… works on curvy roads	☐	☐	☐	☐	☐	☐
… allows to drive faster than the set speed by pressing the accelerator	☐	☐	☐	☐	☐	☐
… reacts to traffic lights	☐	☐	☐	☐	☐	☐
… works in case of rain	☐	☐	☐	☐	☐	☐
… reacts to red cars driving ahead in the same lane	☐	☐	☐	☐	☐	☐
… reacts to white cars driving ahead in the same lane	☐	☐	☐	☐	☐	☐

DriveFree…	**disagree totally**					**agree totally**
… can slow down to a complete stop	☐	☐	☐	☐	☐	☐
… reactivates automatically after a release of gas or brake pedal	☐	☐	☐	☐	☐	☐
… reacts to all vehicles driving ahead in the same lane	☐	☐	☐	☐	☐	☐
… reacts to traffic signs	☐	☐	☐	☐	☐	☐
… works in case of fog	☐	☐	☐	☐	☐	☐
… keeps a set distance to vehicles driving ahead in the same lane at a slower speed	☐	☐	☐	☐	☐	☐
… reacts to oncoming traffic	☐	☐	☐	☐	☐	☐
… is deactivated by activation of the blinker	☐	☐	☐	☐	☐	☐
… reacts to motorcycles driving ahead in the same lane	☐	☐	☐	☐	☐	☐
… works on rural roads	☐	☐	☐	☐	☐	☐
… warns when deviating from the traffic lane	☐	☐	☐	☐	☐	☐
… reacts to silver tank trucks driving ahead in the same lane	☐	☐	☐	☐	☐	☐
… reacts to bumps in the lane	☐	☐	☐	☐	☐	☐
… warns when exceeding the current speed limit	☐	☐	☐	☐	☐	☐

Please rate *DriveFree* on the basis of the information and the impression you gained so far. Please check one box per row in between the pairs of attributes. Your personal opinion is important, i.e. there are no wrong or right answers.

Useful	☐	☐	☐	☐	☐	Useless
Pleasant	☐	☐	☐	☐	☐	Unpleasant
Bad	☐	☐	☐	☐	☐	Good
Nice	☐	☐	☐	☐	☐	Annoying
Effective	☐	☐	☐	☐	☐	Superfluous
Irritating	☐	☐	☐	☐	☐	Likeable
Assisting	☐	☐	☐	☐	☐	Worthless
Undesirable	☐	☐	☐	☐	☐	Desirable
Raising Alertness	☐	☐	☐	☐	☐	Sleep-inducing

Please indicate your agreement concerning the following statements about *DriveFree* by checking a box in between “fully disagree“ and “fully agree“.

	fully disagree						**fully agree**
I can trust the system	☐	☐	☐	☐	☐	☐	☐
The system is deceptive	☐	☐	☐	☐	☐	☐	☐
The system behaves in an underhanded manner	☐	☐	☐	☐	☐	☐	☐
I am suspicious of the system’s intent, action, or outputs	☐	☐	☐	☐	☐	☐	☐
I am wary of the system	☐	☐	☐	☐	☐	☐	☐
I am familiar with the system	☐	☐	☐	☐	☐	☐	☐
The system’s actions will have a harmful or injurious outcome	☐	☐	☐	☐	☐	☐	☐
I am confident in the system	☐	☐	☐	☐	☐	☐	☐
The system has integrity	☐	☐	☐	☐	☐	☐	☐
The system is dependable	☐	☐	☐	☐	☐	☐	☐
The system provides security	☐	☐	☐	☐	☐	☐	☐
The system is reliable	☐	☐	☐	☐	☐	☐	☐

Thank you for your participation!

Please turn to the test administrator.

9.2 ACC descriptions used in the driving simulator study

9.2.1 Correct description

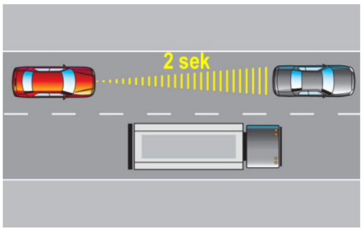
Test des Fahrerassistenzsystems „*DriveFree*“

Liebe/r Versuchsteilnehmer/in,

vorweg ein großes Dankeschön, dass du dich bereiterklärt hast an dieser Studie teilzunehmen!

Du wirst anschließend ca. eine halbe Stunde lang auf einer Autobahnstrecke im Fahrsimulator fahren und dort ein Fahrerassistenzsystem testen. Dieses System ist in Entwicklung und läuft unter dem Arbeitstitel „*DriveFree*“. Folgend findest du eine Beschreibung, wie das System funktioniert und was es macht. Lies dir diese Beschreibung bitte sorgfältig und in Ruhe durch:

DriveFree übernimmt die Steuerung der Geschwindigkeit des Autos, d.h. Gas geben und Bremsen werden automatisiert. Lenken muss allerdings immer noch der Fahrer. Das System erkennt bei allen Fahrbahnarten und Umgebungsbedingungen, ob sich ein Fahrzeug in der gleichen Fahrspur voraus befindet. Bei freier Bahn, d. h. wenn kein Fahrzeug voraus fährt, hält *DriveFree* automatisch eine eingestellte konstante Geschwindigkeit.



Befindet sich ein Fahrzeug in derselben Fahrspur voraus und fährt langsamer als die eingestellte Wunschgeschwindigkeit, passt *DriveFree* die Geschwindigkeit automatisch an die des Vorausfahrenden an. Und zwar so, dass bei jeder Geschwindigkeit ein konstanter Abstand von 2 Sekunden eingehalten wird: d.h. sobald der Vordermann eine Stelle passiert hat, dauert es 2 Sekunden bis du dieselbe Stelle passierst (siehe Bild).

Bremst das vorausfahrende Fahrzeug bis zum kompletten Stillstand (z.B. im Stau), bremst auch *DriveFree* bis zum kompletten Stillstand ab. Dann wird ein Abstand von 5 Meter eingehalten und dieser Abstand wird bei aktivem *DriveFree* nie unterschritten. Beschleunigt der Vordermann wieder oder verlässt die Spur, beschleunigt auch *DriveFree* wieder und regelt die Geschwindigkeit.

In der folgenden Simulatorfahrt sind eine Geschwindigkeit von 100 km/h sowie ein Abstand von 2 Sekunden fest eingestellt und können nicht verändert werden. Du kannst *DriveFree* aber jederzeit außer Kraft setzen, wenn du auf das Gas- oder Bremspedal trittst. Nach Loslassen des Pedals aktiviert sich das System wieder automatisch und regelt die Geschwindigkeit.

Einige wichtige Dinge gilt es bei *DriveFree* zu beachten:

- Ampeln und Verkehrszeichen werden von *DriveFree* nicht erkannt.
- Das System reagiert nicht auf Gegenverkehr.
- Fußgänger werden nicht erkannt und es erfolgt daher keine Reaktion.
- In engen Kurven kann es Probleme bei der Erkennung des vorausfahrenden Fahrzeugs geben.
- Bei schmalen Fahrzeugen wie Motorrädern oder Fahrrädern kann es Erkennungsprobleme geben.
- *DriveFree* kann bei starkem Regen, Nebel oder Schnee Probleme bei der Erkennung vorausfahrender Fahrzeuge haben.

Zusammenfassend erleichtert *DriveFree* also das Fahren, indem es die Geschwindigkeitsregelung automatisiert. Trotzdem muss der/die Fahrer/in immer noch selbst lenken, den Überblick über das Verkehrsgeschehen bewahren und bei Bedarf das System durch manuelles Bremsen oder Gas geben übersteuern.

9.2.2 Incomplete description

Test des Fahrerassistenzsystems „*DriveFree*“

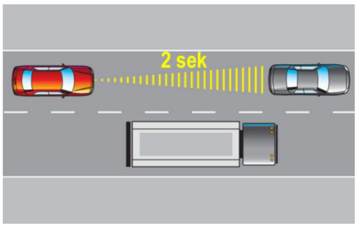
Liebe/r Versuchsteilnehmer/in,

vorweg ein großes Dankeschön, dass du dich bereiterklärt hast an dieser Studie teilzunehmen!

Du wirst anschließend ca. eine halbe Stunde lang auf einer Autobahnstrecke im Fahrsimulator fahren und dort ein Fahrerassistenzsystem testen. Dieses System ist in Entwicklung und läuft unter dem Arbeitstitel „*DriveFree*“. Folgend findest du eine Beschreibung, wie das System funktioniert und was es macht. Lies dir diese Beschreibung bitte sorgfältig und in Ruhe durch:

DriveFree übernimmt die Steuerung der Geschwindigkeit des Autos, d.h. Gas geben und Bremsen werden automatisiert. Lenken muss allerdings immer noch der Fahrer. Das System erkennt bei allen Fahrbahnarten und Umgebungsbedingungen, ob sich ein Fahrzeug in der gleichen Fahrspur voraus befindet. Bei freier Bahn, d. h. wenn kein Fahrzeug voraus fährt, hält *DriveFree* automatisch eine eingestellte konstante Geschwindigkeit.

Befindet sich ein Fahrzeug in derselben Fahrspur voraus und fährt langsamer als die eingestellte Wunschgeschwindigkeit, passt *DriveFree* die Geschwindigkeit automatisch an die des Vorausfahrenden an. Und zwar so, dass bei jeder Geschwindigkeit ein konstanter Abstand von 2 Sekunden eingehalten wird: d.h. sobald der Vordermann eine Stelle passiert hat, dauert es 2 Sekunden bis du dieselbe Stelle passierst (siehe Bild).



Bremst das vorausfahrende Fahrzeug bis zum kompletten Stillstand (z.B. im Stau), bremst auch *DriveFree* bis zum kompletten Stillstand ab. Dann wird ein Abstand von 5 Meter eingehalten und dieser Abstand wird bei aktivem *DriveFree* nie unterschritten. Beschleunigt der Vordermann wieder oder verlässt die Spur, beschleunigt auch *DriveFree* wieder und regelt die Geschwindigkeit.

In der folgenden Simulatorfahrt sind eine Geschwindigkeit von 100 km/h sowie ein Abstand von 2 Sekunden fest eingestellt und können nicht verändert werden. Du kannst *DriveFree* aber jederzeit außer Kraft setzen, wenn du auf das Gas- oder Bremspedal trittst. Nach Loslassen des Pedals aktiviert sich das System wieder automatisch und regelt die Geschwindigkeit.

Einige wichtige Dinge gilt es bei *DriveFree* zu beachten:

- <u>Ampeln und Verkehrszeichen</u> werden von *DriveFree* nicht erkannt.
- Das System reagiert nicht auf <u>Gegenverkehr</u>.
- <u>Fußgänger</u> werden nicht erkannt und es erfolgt daher keine Reaktion.

Zusammenfassend erleichtert *DriveFree* also das Fahren, indem es die Geschwindigkeitsregelung automatisiert. Trotzdem muss der/die Fahrer/in immer noch selbst lenken, den Überblick über das Verkehrsgeschehen bewahren und bei Bedarf das System durch manuelles Bremsen oder Gas geben übersteuern.

9.2.3 Incorrect description

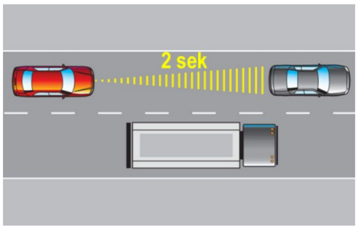
Test des Fahrerassistenzsystems „*DriveFree*“

Liebe/r Versuchsteilnehmer/in,

vorweg ein großes Dankeschön, dass du dich bereiterklärt hast an dieser Studie teilzunehmen!

Du wirst anschließend ca. eine halbe Stunde lang auf einer Autobahnstrecke im Fahrsimulator fahren und dort ein Fahrerassistenzsystem testen. Dieses System ist in Entwicklung und läuft unter dem Arbeitstitel „*DriveFree*“. Folgend findest du eine Beschreibung, wie das System funktioniert und was es macht. Lies dir diese Beschreibung bitte sorgfältig und in Ruhe durch:

DriveFree übernimmt die Steuerung der Geschwindigkeit des Autos, d.h. Gas geben und Bremsen werden automatisiert. Lenken muss allerdings immer noch der Fahrer. Das System erkennt bei allen Fahrbahnarten und Umgebungsbedingungen, ob sich ein Fahrzeug in der gleichen Fahrspur voraus befindet. Bei freier Bahn, d. h. wenn kein Fahrzeug voraus fährt, hält *DriveFree* automatisch eine eingestellte konstante Geschwindigkeit.



Befindet sich ein Fahrzeug in derselben Fahrspur voraus und fährt langsamer als die eingestellte Wunschgeschwindigkeit, passt *DriveFree* die Geschwindigkeit automatisch an die des Vorausfahrenden an. Und zwar so, dass bei jeder Geschwindigkeit ein konstanter Abstand von 2 Sekunden eingehalten wird: d.h. sobald der Vordermann eine Stelle passiert hat, dauert es 2 Sekunden bis du dieselbe Stelle passierst (siehe Bild).

Bremst das vorausfahrende Fahrzeug bis zum kompletten Stillstand (z.B. im Stau), bremst auch *DriveFree* bis zum kompletten Stillstand ab. Dann wird ein Abstand von 5 Meter eingehalten und dieser Abstand wird bei aktivem *DriveFree* nie unterschritten. Beschleunigt der Vordermann wieder oder verlässt die Spur, beschleunigt auch *DriveFree* wieder und regelt die Geschwindigkeit.

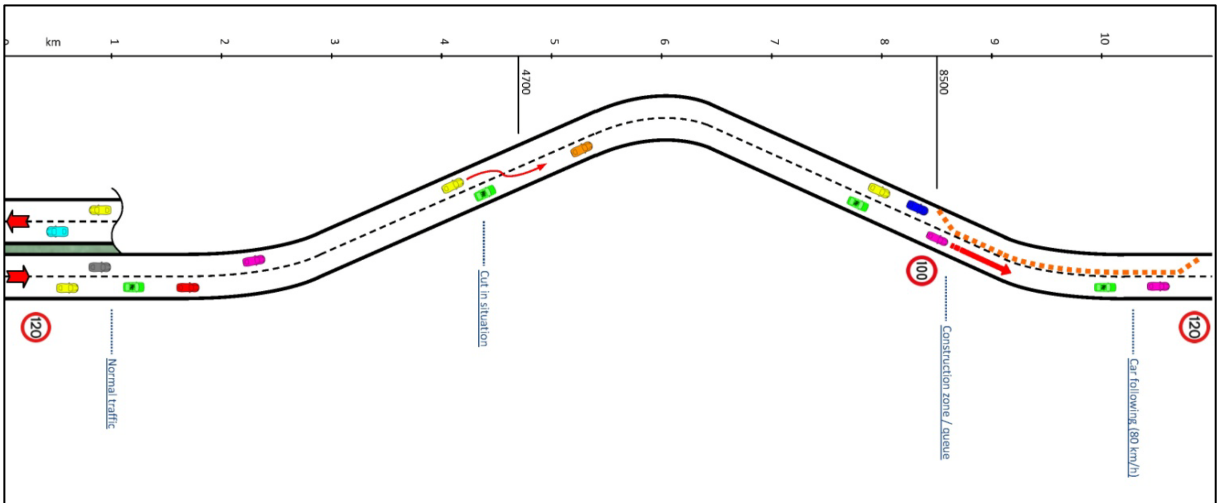
In der folgenden Simulatorfahrt sind eine Geschwindigkeit von 100 km/h sowie ein Abstand von 2 Sekunden fest eingestellt und können nicht verändert werden. Du kannst *DriveFree* aber jederzeit außer Kraft setzen, wenn du auf das Gas- oder Bremspedal trittst. Nach Loslassen des Pedals aktiviert sich das System wieder automatisch und regelt die Geschwindigkeit.

Einige wichtige Dinge gilt es bei *DriveFree* zu beachten:

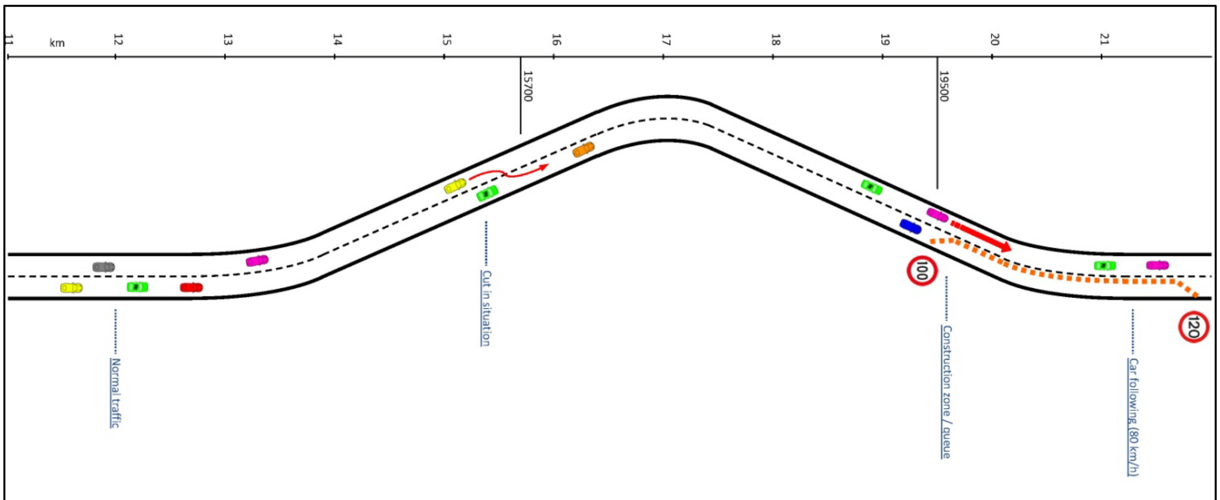
- Ampeln und Verkehrszeichen werden von *DriveFree* nicht erkannt.
- Das System reagiert nicht auf Gegenverkehr.
- Fußgänger werden nicht erkannt und es erfolgt daher keine Reaktion.
- In engen Kurven kann es Probleme bei der Erkennung des vorausfahrenden Fahrzeugs geben.
- Bei schmalen Fahrzeugen wie Motorrädern oder Fahrrädern kann es Erkennungsprobleme geben.
- *DriveFree* kann bei starkem Regen, Nebel oder Schnee Probleme bei der Erkennung vorausfahrender Fahrzeuge haben.
- Bei silbernen bzw. weißen Fahrzeugen können Erkennungsprobleme wegen Reflexionen auftreten.
- Bei großen Fahrzeugen wie LKW und Bussen kann es aufgrund der großen Fläche Probleme in der korrekten Erkennung geben.

Zusammenfassend erleichtert *DriveFree* also das Fahren, indem es die Geschwindigkeitsregelung automatisiert. Trotzdem muss der/die Fahrer/in immer noch selbst lenken, den Überblick über das Verkehrsgeschehen bewahren und bei Bedarf das System durch manuelles Bremsen oder Gas geben übersteuern.

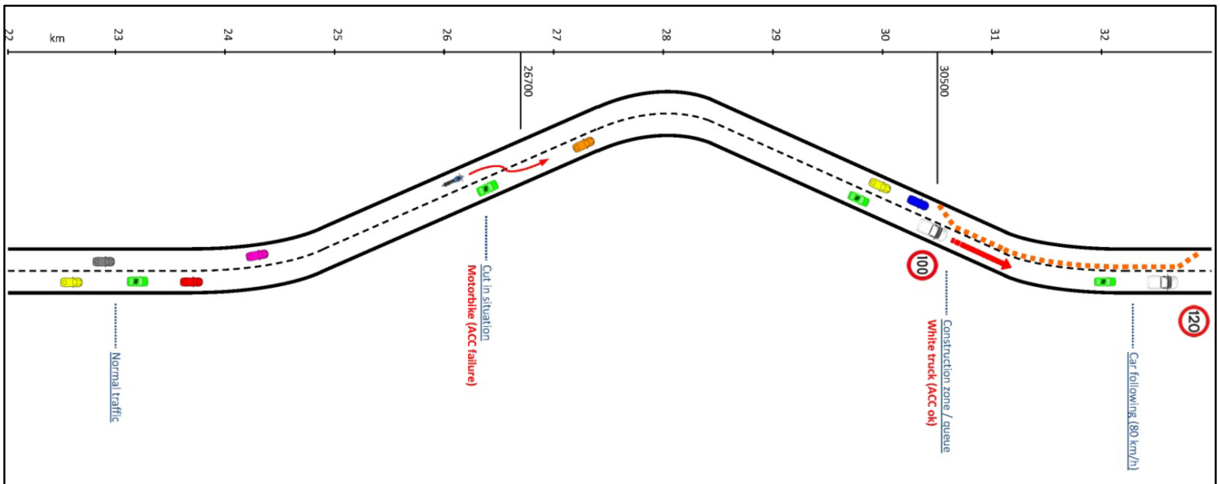
9.3 Schematic overview of the driving simulator track



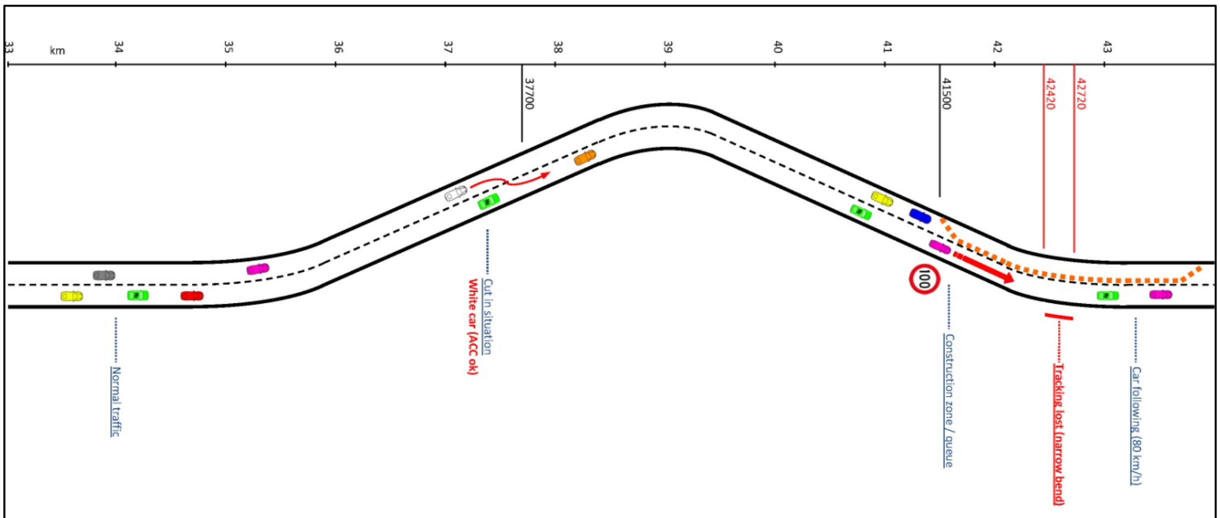
Part 1 (0-11 km): Base module, good weather



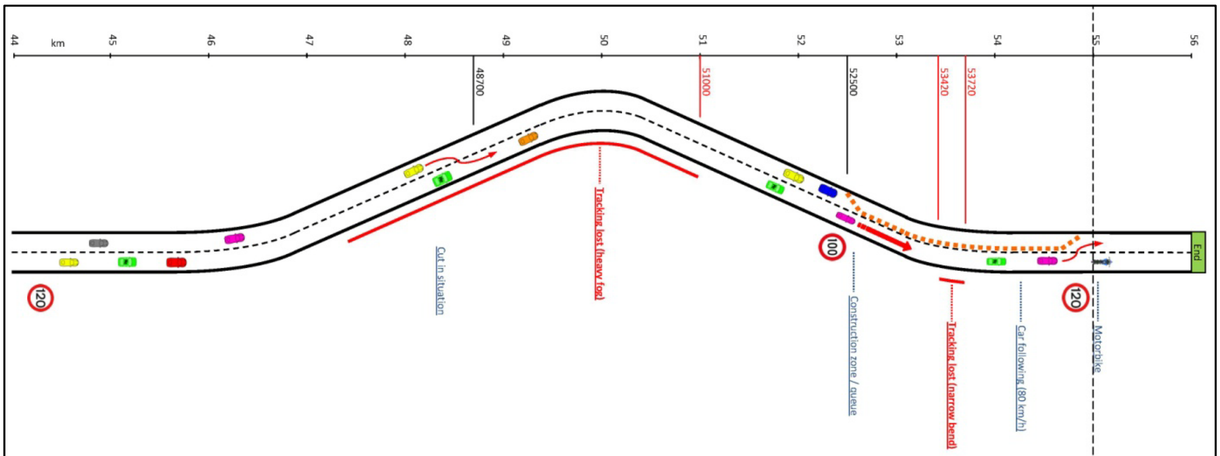
Part 2 (11-22 km): Light fog



Part 3 (22-33 km): Motorbike; white truck



Part 4 (33-44 km): White car; tracking lost (narrow bend)



Part 5 (44-56 km): Tracking lost (heavy fog); tracking lost (narrow bend); motorcycle

9.4 Questionnaires used in the on-road study

9.4.1 Original German version

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FAKULTÄT FÜR HUMAN- UND SOZIALWISSENSCHAFTEN
ALLGEMEINE UND ARBEITSPSYCHOLOGIE

Probanden ID: _______________ Fahrt Nr: ________ Datum:____________

Die folgenden Fragen beziehen sich auf die Funktionsweise des ACC. Versuchen Sie bitte auf jede Frage/Aussage eine Antwort zu geben auf Basis der bisherigen Informationen bzw. Erfahrungen mit dem System.

Geben Sie dazu bitte bei jeder Aussage den Grad Ihrer Zustimmung an, indem Sie die entsprechende Position zwischen „trifft überhaupt nicht zu" und „trifft voll und ganz zu" ankreuzen.

Das ACC…	**Trifft überhaupt nicht zu**					**Trifft voll und ganz zu**
… hält eine eingestellte Geschwindigkeit bei freier Fahrspur	○	○	○	○	○	○
… lenkt automatisch	○	○	○	○	○	○
… funktioniert auf der Autobahn	○	○	○	○	○	○
… reagiert auf stehende Objekte	○	○	○	○	○	○
… funktioniert auf kurvigen Strecken	○	○	○	○	○	○
… reagiert auf Querverkehr	○	○	○	○	○	○
… wird durch Betätigen des Bremspedals unterbrochen	○	○	○	○	○	○
… passt die Geschwindigkeit an langsamer vorausfahrende Fahrzeuge an	○	○	○	○	○	○
… reagiert auf Fußgänger in der Fahrspur	○	○	○	○	○	○
… warnt, wenn ein manuelles Eingreifen erforderlich ist	○	○	○	○	○	○
… reagiert auf vorausfahrende LKW in der gleichen Fahrspur	○	○	○	○	○	○
… erkennt Vorfahrtsregelungen	○	○	○	○	○	○
… beschleunigt nach Abbremsen bis zum Stillstand automatisch, wenn das Vorausfahrzeug wieder losfährt	○	○	○	○	○	○
… reagiert auf Fahrzeuge, die sich von hinten nähern.	○	○	○	○	○	○
… reagiert auf vorausfahrende PKW in der gleichen Fahrspur	○	○	○	○	○	○
… erlaubt bei Gaspedalbetätigung auch schneller zu fahren als die eingestellte Wunschgeschwindigkeit	○	○	○	○	○	○
… passt den Abstand an, wenn Vorausfahrer auf die eigene Spur ausscheren	○	○	○	○	○	○
… reagiert auf Ampeln	○	○	○	○	○	○

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Das ACC…	**Trifft überhaupt nicht zu**					**Trifft voll und ganz zu**
… kann auch bis zum kompletten Stillstand abbremsen	◯	◯	◯	◯	◯	◯
… reagiert auf alle vorausfahrenden Fahrzeuge in der gleichen Fahrspur	◯	◯	◯	◯	◯	◯
… reagiert auf Verkehrszeichen	◯	◯	◯	◯	◯	◯
… warnt bei Auffahren auf ein stehendes Hindernis	◯	◯	◯	◯	◯	◯
… hält einen einstellbaren Abstand zum langsamer vorausfahrenden Fahrzeug in der gleichen Fahrspur	◯	◯	◯	◯	◯	◯
… reagiert auf Gegenverkehr	◯	◯	◯	◯	◯	◯
… passt die Geschwindigkeit vorausschauend an Kurven an	◯	◯	◯	◯	◯	◯
… reagiert auf vorausfahrende Motorräder in der gleichen Fahrspur	◯	◯	◯	◯	◯	◯
… funktioniert auf Landstraßen	◯	◯	◯	◯	◯	◯
… kann jeden Geschwindigkeitsunterschied zum langsam vorausfahrenden Fahrzeug ausgleichen	◯	◯	◯	◯	◯	◯
… reagiert auf Bodenwellen/Unebenheiten in der gleichen Fahrspur	◯	◯	◯	◯	◯	◯
… warnt beim Überschreiten der aktuell zulässigen Höchstgeschwindigkeit	◯	◯	◯	◯	◯	◯
… unterbricht wenn der Radarsensor verschmutzt ist	◯	◯	◯	◯	◯	◯
… kann auch im Stand aktiviert werden	◯	◯	◯	◯	◯	◯

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Bitte beurteilen Sie das ACC-System anhand der Informationen und des Eindrucks, den Sie bisher haben. Setzen Sie bitte jeweils ein Kreuz pro Zeile zwischen jedem der Eigenschaftspaare. Es geht hier um Ihre persönliche Meinung, d.h. es gibt keine richtigen oder falschen Antworten.

Nützlich	○	○	○	○	○	Nutzlos
Angenehm	○	○	○	○	○	Unangenehm
Schlecht	○	○	○	○	○	Gut
Nett	○	○	○	○	○	Nervig
Effizient	○	○	○	○	○	Unnötig
Ärgerlich	○	○	○	○	○	Erfreulich
Hilfreich	○	○	○	○	○	Wertlos
Nicht wünschenswert	○	○	○	○	○	Wünschenswert
Aktivierend	○	○	○	○	○	Einschläfernd

Geben Sie bitte den Grad Ihrer Zustimmung zu jeder der folgenden Aussagen zum ACC an. Markieren Sie dazu eine Position zwischen „stimme überhaupt nicht zu“ und „stimme vollkommen zu“.

	Stimme überhaupt nicht zu						**Stimme vollkommen zu**
Ich kann dem System vertrauen	○	○	○	○	○	○	○
Das System ist irreführend	○	○	○	○	○	○	○
Die Aktionen des Systems sind undurchsichtig	○	○	○	○	○	○	○
Ich misstraue den Aktionen, Absichten oder Konsequenzen des Systems	○	○	○	○	○	○	○
Ich bin dem System gegenüber wachsam	○	○	○	○	○	○	○
Ich bin mit dem System vertraut	○	○	○	○	○	○	○
Die Aktionen des Systems führen zu nachteiligen oder schädlichen Konsequenzen	○	○	○	○	○	○	○
Ich traue mir zu, das System zu nutzen	○	○	○	○	○	○	○
Das System ist glaubwürdig	○	○	○	○	○	○	○
Ich kann mich auf das System verlassen	○	○	○	○	○	○	○
Das System bietet Sicherheit	○	○	○	○	○	○	○
Das System ist zuverlässig	○	○	○	○	○	○	○

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ALLGEMEINE UND ARBEITSPSYCHOLOGIE

Wie sicher fühlen Sie sich aktuell im Umgang mit dem ACC? Bitte beantworten Sie die folgenden Fragen durch Markieren eines Punkts auf der Linie zwischen 0% und 100%.
(zum Beispiel: |——+——+——+——+X——+——+——+——+——+——|)

	0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Ich weiß, wie ich das ACC bediene	
Ich weiß, was die Anzeigen bedeuten	
Ich weiß, wann ich achtsam sein muss, um eventuell selbst einzugreifen	
Ich weiß, wie das ACC grundsätzlich funktioniert	
Ich fühle mich sicher im Umgang mit dem System	

Vielen Dank für ihre Mitarbeit!

Melden sie sich bitte wieder beim Testleiter.

9.4.2 English translation

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Participant ID: _______________ trip no: ________ date:____________

The following questions refer to the functions of ACC. Please try to answer each question/statement based on the information and the impression you have so far.

Please indicate your degree of approval for every statement by marking the appropriate position between "totally disagree" and "totally agree".

ACC...	totally disagree					totally agree
... maintains a predetermined speed in an empty lane	○	○	○	○	○	○
... steers automatically	○	○	○	○	○	○
... works on highways	○	○	○	○	○	○
... reacts to stationary objects	○	○	○	○	○	○
... works on curvy roads	○	○	○	○	○	○
... reacts to cross traffic	○	○	○	○	○	○
... is overruled by pressing the brake pedal	○	○	○	○	○	○
... adjusts the speed to slower vehicles ahead	○	○	○	○	○	○
... reacts to pedestrians in the traffic lane	○	○	○	○	○	○
... warns in case manual intervention is necessary	○	○	○	○	○	○
... reacts to trucks driving ahead in the same lane	○	○	○	○	○	○
... detects right of way regulations	○	○	○	○	○	○
... accelerates automatically after complete standstill if the car in front restarts again	○	○	○	○	○	○
... reacts when vehicles approach from behind	○	○	○	○	○	○
... reacts to passenger cars driving ahead in the same lane	○	○	○	○	○	○
... allows to drive faster than the set speed by pressing the accelerator	○	○	○	○	○	○
... regulates the distance in case of cut-in situations	○	○	○	○	○	○
... reacts to traffic lights	○	○	○	○	○	○

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ACC…	**totally disagree**					**totally agree**
… can slow down to a complete stop	◯	◯	◯	◯	◯	◯
… reacts to all vehicles driving ahead in the same lane	◯	◯	◯	◯	◯	◯
… reacts to traffic signs	◯	◯	◯	◯	◯	◯
… warns when approaching a stationary object	◯	◯	◯	◯	◯	◯
… keeps a set distance to vehicles driving ahead in the same lane at a slower speed	◯	◯	◯	◯	◯	◯
… reacts to oncoming traffic	◯	◯	◯	◯	◯	◯
… adjusts speed anticipatory before bends	◯	◯	◯	◯	◯	◯
… reacts to motorcycles driving ahead in the same lane	◯	◯	◯	◯	◯	◯
… works on rural roads	◯	◯	◯	◯	◯	◯
… can handle every speed difference to the slower vehicle ahead	◯	◯	◯	◯	◯	◯
… reacts to potholes in the same lane	◯	◯	◯	◯	◯	◯
… warns when exceeding the current speed limit	◯	◯	◯	◯	◯	◯
… is deactivated in case the radar sensor is dirty	◯	◯	◯	◯	◯	◯
… can be activated in standstill	◯	◯	◯	◯	◯	◯

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Please rate the ACC-system on the basis of the information and the impression you gained so far. Please check one box per row in between the pairs of attributes. Your personal opinion is important, i.e. there are no wrong or right answers.

Useful	◯	◯	◯	◯	◯	Useless
Pleasant	◯	◯	◯	◯	◯	Unpleasant
Bad	◯	◯	◯	◯	◯	Good
Nice	◯	◯	◯	◯	◯	Annoying
Effective	◯	◯	◯	◯	◯	Superfluous
Irritating	◯	◯	◯	◯	◯	Likeable
Assisting	◯	◯	◯	◯	◯	Worthless
Undesirable	◯	◯	◯	◯	◯	Desirable
Raising Alertness	◯	◯	◯	◯	◯	Sleep-inducing

Please indicate your agreement concerning the following statements about ACC by checking a box in between “fully disagree“ and “fully agree“.

	fully disagree						**fully agree**
I can trust the system	◯	◯	◯	◯	◯	◯	◯
The system is deceptive	◯	◯	◯	◯	◯	◯	◯
The system behaves in an underhanded manner	◯	◯	◯	◯	◯	◯	◯
I am suspicious of the system’s intent, action, or outputs	◯	◯	◯	◯	◯	◯	◯
I am wary of the system	◯	◯	◯	◯	◯	◯	◯
I am familiar with the system	◯	◯	◯	◯	◯	◯	◯
The system’s actions will have a harmful or injurious outcome	◯	◯	◯	◯	◯	◯	◯
I am confident in the system	◯	◯	◯	◯	◯	◯	◯
The system has integrity	◯	◯	◯	◯	◯	◯	◯
The system is dependable	◯	◯	◯	◯	◯	◯	◯
The system provides security	◯	◯	◯	◯	◯	◯	◯
The system is reliable	◯	◯	◯	◯	◯	◯	◯

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ALLGEMEINE UND ARBEITSPSYCHOLOGIE

How confident do you feel in using ACC? Please indicate your degree of approval for every statement by marking the appropriate position between 0% and 100%.

(example: |—|—|—|—|—|—|—|—X—|—|—|)

	0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
I know how to operate the ACC	|—|—|—|—|—|—|—|—|—|—|
I know what the displayed ACC-messages mean	|—|—|—|—|—|—|—|—|—|—|
I know when I have to be observant and may intrevene	|—|—|—|—|—|—|—|—|—|—|
I know the overall functionality of the ACC	|—|—|—|—|—|—|—|—|—|—|
I feel confident in using the ACC	|—|—|—|—|—|—|—|—|—|—|

Thank you for your participation!

Please turn to the test administrator.

9.5 Seminar programme: Databases as analysis tool in social science

TECHNISCHE UNIVERSITÄT CHEMNITZ

Einsatz von Datenbanken zur Messdatenanalyse

Termine und Dauer:	Blockveranstaltung, 4 Einheiten: Fr 9.5., 9.30-16.00, Fr 23.5., 09.30-16.00, Fr 6.6., 9.30-16.00, Fr 13.6., 09.30-16.00
Ort:	PC-Raum 035, W.-Raabe-Str. 43
Dozent:	MMag. Matthias Beggiato
Max. Teilnehmer:	10-12
Didaktisches Konzept:	Theorieblöcke mit jeweils unmittelbar anschließender Übung am PC Folienskript wird bereitgestellt, inklusive Übungsaufgaben
Anmeldung:	Per Email bei matthias.beggiato@psychologie.tu-chemnitz.de

Beschreibung

In den Human- und Sozialwissenschaften werden neben klassischen Erhebungsmethoden wie Fragebogen, Tests und Interviews auch zunehmend Messdaten mittels Sensoren erfasst und analysiert. Beispiele dafür sind physiologische Daten (Herzschlag, Hautleitwert, Atmungsfrequenz…), Blickbewegungsdaten, Logfiles von Webseiten, Videoannotationen oder auch Messwerte aus genutzten Geräten wie z.B. Mobiltelefonen oder Fahrzeugen. All diesen Datentypen ist gemein, dass sie mit einer bestimmten Frequenz gemessen werden und damit kontinuierlich anfallen. Je nach Messfrequenz können dabei schnell umfangreiche Datenmengen von 1 Mio Datenzeilen und mehr entstehen, die mit herkömmlicher sozialwissenschaftlicher Auswertesoftware wie SPSS oder EXCEL nicht mehr direkt handhabbar sind. Eine Lösung für diese Probleme bieten Datenbanken. Aktuelle Datenbanksysteme wie PostgreSQL oder MySQL können im Prinzip unbegrenzte Datenmengen speichern und bearbeiten, sind kostenlos verfügbar und mittlerweile so anwenderfreundlich gestaltet, dass sie auch ohne technische Spezialkenntnisse verwendet werden können.

Diese Lehrveranstaltung vermittelt sowohl theoretische als auch unmittelbar praktische Kenntnisse zum Einsatz von Datenbanken in der sozialwissenschaftlichen Datenanalyse. Die Teilnehmer werden nach Abschluss des Kurses in der Lage sein, selbstständig alle Schritte durchzuführen von der Nutzenabwägung über Installation, Planung und Betrieb von Datenbanken im Verbund klassischer sozialwissenschaftlicher Analysetools bis hin zur komplexen Analyse verknüpfter Daten. Die Veranstaltungen bauen grundsätzlich aufeinander auf - ohne die Grundlagen aus Einheit 1 kann keine der weiteren Veranstaltungen besucht werden.

Grobübersicht Inhalte

Einheit 1:	Grundlagen, Anwendungsfälle, einfache Abfragen bestehender Daten, Weiterverarbeitung der Daten
Einheit 2:	Komplexere Abfragen, Gruppierung, Statistikfunktionen
Einheit 3:	Anlegen von Datenbanken, Planung der Struktur, Import/Export von Daten, Datenbankmanagement
Einheit 4:	Spezialthemen: Arbeiten mit Videoannotationen und Sequenzen, Erweiterte Programmierung mit eigenen Funktionen, Themen der Teilnehmer

Detailübersicht Inhalte

Einheit 1	• Was sind Datenbanken? Grundlegende Datenbankkonzepte: SQL, Tabellen, Views & Co • Wann brauche ich sowas? Anwendungsfälle in der human- und sozialwissenschaftlichen Forschung, Positionierung im Ablauf der Datenanalyse • Wie arbeite ich generell mit einer Datenbank? Einführung in die grafische Datenbankmanagement-Software NAVICAT anhand einer Beispieldatenbank • Wie komme ich an meine Daten? Anzeigemöglichkeiten und einfache SELECT-Anweisungen • Wie führe ich Daten zusammen? Verbindungen zwischen Tabellen • Wie reduziere ich meine Daten? Aggregatfunktionen Mittelwert, Summe, Anzahl, Min/Max
Einheit 2	• Wie aggregiere ich Ergebnisse nach Gruppen? Gruppierungsfunktionen • Was mache ich mit den abgefragten Daten? Zugriff und Weiterverarbeitung in Excel/SPSS • Wie baue ich komplexe Abfragen schrittweise auf? Verschachtelte Abfragen • Wie kombiniere ich Einzeldaten und Aggregate in derselben Tabelle? Window-Funktionen • Wie erzeuge ich Tabellen aus Abfragen? CREATE AS • Was kann ich mit verschiedenen Datentypen machen? Wichtige Funktionen für Zeichenketten, Datum/Zeit, mathematische Funktionen, Kontrollstrukturen case-when
Einheit 3	• Wie lege ich eine Datenbank an? Erstellen von Datenbanken, Datentypen, Tabellen • Wie kommen meine Daten in die Tabellen? Import, Update/Delete • Wie bringe ich Daten in eine andere Datenbank? Datentransfer zwischen Datenbanken • Datenbank auf dem eigenen PC? Installation, Management, Wartung, Sicherung • Wie arbeite ich mit mehreren Nutzern? Management von Usern und Rechten
Einheit 4	• Wie kann ich Abfragen automatisieren z.B. mit Schleifen? Die prozedurale Sprache PL/PGSQL • Spezialthemen: - Arbeiten mit Videoannotationen (ELAN + Datenbank) - Analyse von Sequenzen: Allgemeines Verfahren mit OLAP-Funktionen - User defined functions (z.B. median, range) • Eigene Themen der Teilnehmer

9.6 Curriculum vitae and publications

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MMag. BEGGIATO MATTHIAS

born on 11.03.1976 in Bruneck (South Tyrol, Italy), citizenship: Italian

EDUCATION

1982-1990	Primary school in Sand in Taufers
1990-1995	„Gewerbeoberschule Max Valier" secondary school for computer science, Bozen
1995 - 1996	EU vocational training course „technician for system-integration"
September 1998	Bilingualism exam for German and Italian, category „A"
October 1998 - November 2004	Master's degree in Psychology at the University of Vienna
March 2000 - March 2005	Master's degree in educational science at the University of Vienna
2005 – 2006	Postgraduate education as clinical and health psychologist
March 2006	ECDL-Advanced-Expert exam (expert knowledge in MS Office)

PROFESSIONAL EXPERIENCE

1990-1996	Different summer jobs as sales assistant, construction worker, forestry worker, postal clerk and programmer
October 1996 - December 1997	Freelancer (interviewer) at the market-research institute "Info Research International" in Vienna
January 1998 - October 1998	Civilian service at the organization for disabled people „Lebenshilfe" in Bozen
Summer 1999 + Summer 2000	Attendant at a social project for teenagers from difficult social conditions in Bruneck
2001-2002	Summer jobs in the hotel and restaurant industry (South Tyrol)
Summer 2003	Six-week traineeship in the Psychological Service of Bruneck
October 2003 - December 2004	Junior researcher at the Institute of Psychology, University of Vienna (Prof. DDr. Christian Klicpera, BeLiS-Study)
April 2005 – September 2006	Traineeships at Fonds Soziales Wien (dep. for disabled persons), WUK Domino (vocational guidance) and FACTUM/INFAR (traffic psychology)
May 2006 – April 2007	Conducting the study JOBFIT concerning the career history of young people with special needs
September 2006 – December 2009	Junior researcher and traffic psychologist at FACTUM OHG Vienna (traffic and Social analysis)
Since March 2007	Consulting activities concerning socio-scientific methods for various institutions in South Tyrol
Since February 2010	Junior researcher at TU Chemnitz, Cognitive and Engineering Psychology

LANGUAGES

German: Mother tongue

Italian: fluent

English: fluent (UNICERT Level III degree = European Level C1)

INTERESTS

Computers (Programming, Office-Applications, Graphic, Web-applications, Databases), Guitar, Billiards, Golf, Tennis and the mountains.

SCIENTIFIC ACTIVITIES

„BeLiS“ study

Study concerning occupational changes of apprentice on behalf of the department for vocational education of the province of Bozen. Planning, coordination, implementation and analysis of a quantitative survey of 3.000 apprentices, qualitative interviews with career advisers as well as teachers, focus groups with company owners.

Traffic psychology at FACTUM/INFAR

Cooperation on national and international research projects for child safety in the car (EUCHIRES), traffic behaviour observation (Viennese driving test), acceptance of intelligent transport systems (ISA - intelligent speed adaption), disability and mobility (Club mobil research project on the driving ability of persons after stroke), balanced diet and mobility of senior citizens (CHANGE), children and public transport (MOBI-KID), designing a video study on communication by cyclists, group discussions in the framework of Austrian multi-stage driver training as well as traffic-psychological diagnostics.

Freelance job as social scientist and consultant in socio-scientific methodology

JOBFIT study (2007): Planning and implementation of a study concerning the professional career of young people with special needs on behalf of the department for vocational education of the province of Bozen.

TIME-S study (2008): Cooperating in the data analysis at the Südtiroler Arbeitsförderungsinstitut (AFI) on an ESF-financed study concerning in-company continuing vocational training in Southern Tyrol. Realisation of focus groups and case studies in small South-Tyrolean companies, software-supported qualitative data-analysis and reporting.

Dropout study in apprenticeship training (2009, ongoing): Conception and realisation of a study on the dropout in South-Tyrolean apprenticeship training on behalf of the Provincial Statistics Institute (ASTAT) and apollis OHG Bozen.

Consulting and supervision in socio-scientific methodology at the Südtiroler Arbeitsförderungsinstitut (AFI). Execution of two AFI-internal trainings concerning the software supported analysis of qualitative data with MAXQDA and the use of Excel for data analysis in social science.

Junior researcher at TU Chemnitz

Research on Human-Machine-Interaction in transportation with focus on driver assistance systems (Project ADAPTATION), automation, intention recognition (Project UR:BAN). Lectures on the use of relational databases for data analysis, supervision of master’s and bachelor’s theses. Joint multidisciplinary projects within the Interdisciplinary center for driver assistance systems at TU Chemnitz (I-FAS, www.i-fas.de).

PUBLICATIONS (CHRONOLOGICAL)

Beggiato, M. (2014). Effect of ADAS use on drivers' information processing and Situation Awareness. In A. Stevens, C. Brusque & J. Krems (Eds.) *Driver adaptation to information and assistance systems* (pp. 57-80). London: The Institution of Engineering and Technology (IET).

Pereira, M., Lietz, H., & Beggiato, M. (2014). Development of a database for storage and analysis of behavioural data. In A. Stevens, C. Brusque, & J. Krems (Eds.), *Driver adaptation to information and assistance systems* (pp. 301–317). London: Institution of Engineering and Technology.

Dotzauer, M., Berthon-Donk, V., Beggiato, M., Haupt, J., & Piccinini, G. (2014). Methods to assess behavioural adaptation over time as a result of ADAS use. In A. Stevens, C. Brusque & J. Krems (Eds). *Driver adaptation to information and assistance systems* (pp. 35-55). London: The Institution of Engineering and Technology (IET).

Schmidt, K., Beggiato, M., Hoffmann, K. H., & Krems, J. F. (2014). A mathematical model for predicting lane changes using the steering wheel angle. *Journal of Safety Research, 49,* 85–90. doi:10.1016/j.jsr.2014.02.014.

Beggiato, M., & Krems, J. F. (2013). The evolution of mental model, trust and acceptance of adaptive cruise control in relation to initial information. *Transportation Research Part F, 18*, 47-57. dx.doi.org/10.1016/j.trf.2012.12.006.

Beggiato, M., & Krems, J. F. (2013). Auswirkungen erwarteter und unerwarteter Systemgrenzen von Adaptive Cruise Control auf das Situationsbewusstsein im Zeitverlauf. In VDI (Eds.). *Der Fahrer im 21. Jahrhundert. VDI-Berichte 2205* (pp.119-132). Düsseldorf: VDI-Verlag.

Beggiato, M., & Krems, J. F. (2013). *Sequence analysis of glance patterns to predict lane changes on urban arterial roads.* Paper presented at 6. Tagung Fahrerassistenz - Der Weg zum automatischen Fahren, Munich, 28.-29.11.2013. Retrieved from http://mediatum.ub.tum.de/node?id=1187197.

Beggiato, M., & Krems, J. F. (2012). The effects of preliminary information about adaptive cruise control on trust and the mental model of the system: a matched-sample longitudinal driving simulator study. In de Waard, D., Merat, N., Jamson, H., Barnard, Y., and Carsten, O.M.J. (Eds.), *Human Factors of Systems and Technology* (pp. 63-74). Maastricht, the Netherlands: Shaker Publishing.

Grünseis-Pacher, E., Beggiato, M., Reiter, D., Risser, R., Chroust, S., Häusler, J., & Sommer, M. (2009). *Sicher mobil mit Handicap. Vertrauliche Fahreignungsprüfung im Vorfeld der Behörde.* Schriftenreihe Forschungsarbeiten aus dem Verkehrswesen, Band 193, BMVIT: Wien.

Beggiato, M., & Risser, R. (Eds.) (2009). *State of the Art. Public Report of Workpackage 2 of the EU-Project CHANGE: Care of Health Advertising New Goals for Elderly people*, GRUNDTVIG Multilateral Projekt 2008-2010. (Online at http://www.changeonline.eu)

Beggiato, M., & Pramstrahler, W. (2008). Gründe, Barrieren und Effekte von Weiterbildung in Südtiroler Kleinbetrieben. In AFI-IPL (Ed.), *TimeS – Training in MicroEnterprises South Tyrol. Die berufliche Weiterbildung in Südtirol. Ein Beitrag zur Entwicklung des Systems* (S. 54-92). Bozen: Arbeitsförderungsinstitut. (Online at http://www.afi-ipl.org/ Arbeitsmarkt_und_berufliche_Weiterbildung_TimeS_deu.html)

Beggiato, M., Steinmair, J., & Gasser, G. (2007). *JOBFIT - Studie zum Ausbildungs- und Berufsverlauf von Jugendlichen mit besonderen Bedürfnissen im Südtiroler Berufsbildungssystem.* Bozen: Autonome Provinz Bozen – Südtirol, deutsche und ladinische Berufsbildung. (Online at http://www.provinz.bz.it/berufsbildung/publ/publikationen_d.asp)

Beggiato, M. (2004). *Berufswahl und Berufsverlauf Südtiroler LehrabsolventInnen.* Diplomarbeit, Institut für Psychologie Wien. (Online at http://www.diplomarbeiten24.de/vorschau/54450.html)

Klicpera, C., Gasteiger-Klicpera, B., & Beggiato, M. (2004): *BeLiS - Berufswechsel von LehrabsolventInnen in Südtirol.* Bozen: Autonome Provinz Bozen - Südtirol. (Online at http://www.provincia.bz.it/berufsbildung/belis/default_d.htm)

PRESENTATIONS AND POSTERS (CHRONOLOGICAL)

Beggiato, M., & Krems, J. F. (2014). Dynamische Aufmerksamkeitsverteilung im Straßenverkehr: Analyse von Blickmustern vor Fahrstreifenwechseln. In O. Güntürkün (Ed.). *49. Kongress der Deutschen Gesellschaft für Psychologie*, 21.-25. September 2014 (p. 526). Lengerich: Pabst Science Publishers.

Beggiato, M., Pereira, M., & Krems, J. F. (2014). Lernprozesse, Vertrauens- und Akzeptanzentwicklung im Umgang mit Automatisierung im Fahrzeug. In O. Güntürkün (Ed.). *49. Kongress der Deutschen Gesellschaft für Psychologie*, 21.-25. September 2014 (p. 603). Lengerich: Pabst Science Publishers.

Beggiato, M., Pech, T., & Krems, J. F. (2014). *The predictive potential of driver characteristics for lane changes on urban arterial roads.* Poster presented at the 5th conference on Applied Human Factors and Ergonomics (AHFE), 19.-23 July 2014, Krakow, Poland.

Beggiato, M., & Krems, J. F. (2014). *Vermeidung von Unfällen durch elektronische Steuerungs- und Beeinflussungssysteme im Verkehrsraum und im Kraftfahrzeug; Möglichkeiten der Stärkung der Aufmerksamkeit der Verkehrsteilnehmer durch das Zusammenspiel Mensch/Maschine.* Presentation at the Seminar der Vereinigung der Straßenbau- und Verkehrsingenieure in Niedersachsen, 3 April 2014, Osnabrück, Germany.

Beggiato, M., & Krems, J. F. (2013). Situation Awareness in relation to the initial information about adaptive cruise control. A matched sample longitudinal driving simulator study. In U. Ansorge, E. Kirchler, C. Lamm, & H. Leder (Eds.), *TeaP 2013 - Abstracts of the 55th Conference of Experimental Psychology* (p.28). Lengerich: Pabst Science Publishers.

Beggiato, M. (2012). *Databases as analysis tool for big and heterogeneous data in transportation research.* Presentation at the ADAPTATION final event, 21-22 November 2012, Vienna, Austria.

Beggiato, M. (2012). *The effect of preliminary information about ACC: a matched sample driving simulator study.* Presentation at the 5th International Conference on Traffic and Transport Psychology (ICTTP), 29-31 August 2012, Groningen, The Netherlands.

Beggiato, M. (2012). *Sharing methodological knowledge in qualitative data analysis.* Poster presented at the Marie-Curie-Workshop, ESOF conference, 1-2 July 2012, Torino, Italy.

Beggiato, M. (2012). *Can computer based trainings improve driver education?.* Presentation at the CIECA Congress, 13-16 June 2012, Istanbul, Turkey.

Beggiato, M. (2011). Der Einfluss des initialen mentalen Modells eines ACC auf Fahrverhalten, Situation Awareness, Systemvertrauen und Akzeptanz. In K. Bittrich, S. Blankenberger & J. Lukas (Hrsg.), *Beiträge zur 53. Tagung experimentell arbeitender Psychologen* (p. 16). Lengerich: Pabst Science Publishers.

Beggiato, M. (2010). *Kurz- und langfristige Veränderungen höherer kognitiver Prozesse beim Fahren mit Fahrerassistenzsystemen.* Presentation at the Doktorandenworkshop der Fachgruppe Verkehrspsychologie, 16-17 September 2010, Würzburg, Germany.

SUPERVISION OF MASTER'S, BACHELOR'S AND DIPLOMA THESES (CHRONOLOGICAL)

Mennig, I. M. (2014). *Eignung eines Fahrsimulators mit Bewegungsplattform für die Erlebbarkeit von Fahrdynamik.* (Master's thesis). TU Chemnitz.

Springer, S. (2014). *Akzeptanzbedingungen des Fahrerassistenzsystems Economic Cruise Control.* (Bachelor's thesis). TU Chemnitz.

Zschoche, E. (2014). *Der Einfluss von Fahrercharakteristika auf Fahrstreifenwechsel.* (Bachelor's thesis). TU Chemnitz.

Endler, C. (2013). *Untersuchung eines Fahrerassistenzsystems zur Darstellung einer Umgebungsansicht.* (Bachelor's thesis). TU Chemnitz.

Grieger, S. (2013). *Akzeptanz eines ACC im Zeitverlauf. Eine Fahrsimulatorstudie mit parallelisierter Stichprobe.* (Bachelor's thesis). TU Chemnitz.

Klamroth, A., & Winkler, J. (2013). *Einfluss von Fahrermerkmalen auf die Nutzung eines ACC und das Fahrverhalten im Fahrsimulator.* (Bachelor's thesis). TU Chemnitz.

Schwarzwäller, M. (2013). *Transformationsprozesse des mentalen Modells eines ACC durch Erfahrung. Ein mixed methods Ansatz.* (Bachelor's thesis). TU Chemnitz.

Thon, I. (2013). *Evaluierung räumlicher Darstellungsarten von Rasterkraftmikroskopie – Volumendaten hinsichtlich der Vermittlung fachrelevanter Inhalte.* (Bachelor's thesis). TU Chemnitz.

Göbel, P. (2012). *Der Einfluss von locus of control und sensation seeking auf das Fahrverhalten und die Nutzung des ACC.* (Bachelor's thesis). TU Chemnitz.

Metzner, M. (2012). *Einfluss von Vorinformationen über ACC auf Situation Awareness.* (Master's thesis). TU Chemnitz.

Schmidt, K. (2012). *Analyse mehrdimensionaler Zeitreihen eines Fahrsimulators.* (Master's thesis). TU Chemnitz.

Steinmair, J. M. (2008). *Berufliche Entwicklung und Arbeitszufriedenheit von Jugendlichen mit besonderen Bedürfnissen in Südtirol.* (Diploma thesis). University of Vienna.

Eidesstattliche Erklärung

Hiermit erkläre ich, dass ich die vorliegende Arbeit selbstständig verfasst habe und keine anderen als die angegebenen Hilfsmittel verwendet habe.

Chemnitz, 27.10.2014

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Matthias Beggiato