Cooperative Automation in Automobiles

Dissertation
zur Erlangung des akademischen Grades Dr. rer. nat.
im Fach Psychologie

eingereicht an der

Mathematisch-Naturwissenschaftlichen Fakultät II
der Humboldt-Universität zu Berlin

von
Dipl.-Psych. Lars Biester
geb. am 23.05.1974 in Hamburg

Präsident der Humboldt-Universität zu Berlin
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Dekan der Mathematisch-Naturwissenschaftlichen Fakultät II
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Tag der mündlichen Prüfung: 12.12.2008

Zusammenfassung

Das Ziel dieser Dissertation ist die systematische Entwicklung eines weiterführenden Konzeptes zur Fahrer-Fahrzeug Kooperation, dessen Tauglichkeit anhand empirischer Daten evaluiert und im Hinblick auf sein belegbares Potential in Bezug auf bestehende Ansätze bewertet werden soll.

Da Annahmen und Prämissen der Mensch-Maschine-Interaktion den Ausgangspunkt bilden, beginnt die dezidierte Auseinandersetzung und begriffliche Differenzierung von *Kooperation* in eben diesem Kontext und führt folgerichtig zu einer definitorischen Abgrenzung gegenüber existierenden Ansätzen, der Forderung eines spezifischen Rollenverständnisses zur Interaktion sowie der Ableitung konzeptueller Grundbedingungen. Anschließend werden die strukturellen und prozeduralen Merkmale dieser spezifischen Interaktion herausgearbeitet und dazu benutzt, die generellen Attribute von *Kooperation* zwischen Fahrer und Fahrzeug zu identifizieren. Dafür wurden nachfolgend solche Indikatoren abgeleitet, vermittels derer der unterstellte Gewinn infolge der Kooperation von Fahrer und Fahrzeug kontrolliert und bewertet werden kann.

Im Rahmen mehrerer Voruntersuchungen wurden Fahrsituationen identifiziert, die am meisten von einer kooperativen Interaktion zwischen Fahrer und Fahrzeug profitieren würden. Im Ergebnis wurden für die zwei Hauptuntersuchungen das „Überholen auf der Autobahn“ und das „Linksabbiegen auf innerstädtischen Straßen und Landstraßen mit Gegenverkehr“ als Fahrszenarien ausgewählt, die in jeweils einem eigenständigen Experiment mit alternativen Systemvarianten verglichen worden sind. Die Prüfung spezifischer Hypothesen wurde dabei in die prototypische Umgebung eines Fahrsimulators eingebettet.

Die Befunde zeigten, dass ein kooperatives Plattformsystem gebildet aus mehreren Fahrerassistenzsystemen im PKW - technologisch betrachtet - prinzipiell realisierbar ist und dass das diesem hinterlegte Konzept empirisch zugänglich ist bzw. ein System erfolgreich als ein Interaktionspartner etabliert werden konnte. Psychologisch besonders interessant sind die Ergebnisse, weil kooperative Systeme in den geprüften Fällen gewinnbringend sind, z. B. durch signifikant weniger Fahrfehler und weniger benötigte Spiegelblicke. In beiden Experimenten war der kooperative Prototyp zudem hoch akzeptiert und wurde als vertrauenserweckend erlebt; ferner wurde das Verhalten des Systems von den Probanden gut verstanden und geschätzt.

Auch wenn dies mit den Daten der psychophysiologischen Parameter nicht so eindeutig gelingt, weisen diese Parameter zumindest auf eine Optimierung hin, was im Umkehrschluss auf stressfreieres und entspannteres Fahren unter dieser Bedingung schließen läßt.

Berücksichtigt man alle Ergebnisse, so kann dem entwickelten Konzept der kooperativen Interaktion im Fahrzeug ein Potential unterstellt werden, weil der hier untersuchte Prototyp nicht nur akzeptiert wurde, sondern seine Nutzung auch zu messbaren Vorteilen führte.

Abschließend werden in dieser Arbeit die Möglichkeiten zur Etablierung und Einbettung dieses Interaktionskonzeptes in den übergreifenden sozio-technischen Kontext aufgezeigt und zukünftige Perspektiven diskutiert.

Abstract

The aim of this dissertation is to systematically develop a continuative concept of driver-automobile cooperation, to evaluate its suitability on the basis of empirical data, and to value its provable potential in relation to existing approaches.

Assumptions and premises regarding the human-machine interaction constitute the starting point of this work. The decisive altercation and notional differentiation of cooperation are explained in just this context, leading logically to a definitional demarcation of existing approaches, the demand of a specific role understanding of the interaction as well as the derivation of conceptual basic conditions. The structural and procedural characteristics of this specific interaction are then elaborated upon and used to identify the general attributes of cooperation between driver and automobile. In the following, such indicators are derived by which the implied profit as a result of cooperation between driver and automobile can be controlled and valued.

Within the framework of several preliminary investigations, those driving situations were identified that would profit most from a cooperative interaction between driver and automobile. As a result, the two driving scenarios "Overtaking on Highways" and "Turning Left on Urban and Country Roads with Oncoming Traffic" were utilized in the experiments. Both single scenarios have been compared in independent experiments with regard to alternative system variants. The prove of specific hypotheses was embedded in the prototypical surroundings of a driving simulator.

The findings showed that, in principle, a cooperative platform system built from several driver assistance systems is practical in the automobile - from a technological point of view - and that the system's underlying concept is empirically accessible. Consequently, it is possible to successfully establish a system as an interaction partner. Particularly interesting from a psychological point of view are the results indicating that cooperative systems were profitable in the examined cases, e.g., there was significantly less driving error and fewer required mirror looks. Moreover, in both experiments the cooperative prototype was highly accepted and was experienced as trust-arousing; the behavior of the system was well understood by the test persons and was appreciated.

Even if this does not hold so unambiguously for the data corresponding to the physiological parameters, at least these parameters demonstrate an optimization, which suggests the presence of more stress-free and relaxing driving in this experimental condition.

Taking all the results into consideration, the potential for the developed concept of cooperative interaction in automobiles can be assumed, because the prototype evaluated here was not only well accepted, but its use also led to measurable advantages.

Finally, the possibility of establishing and embedding this interaction concept into the overall socio-technical context will be presented, and future perspectives will be discussed.

Dicta of the dissertation

A theory is the more impressive the greater is the simplicity of its premises, the more different are the kinds of things it relates and the more extended the range of its applicability.

Albert Einstein (Schilpp, 1955)

Machines have less problems. I'd like to be a machine, wouldn't you?

Andy Warhol (Moderna Museet, Stockholm, Sweden 1968)

Acknowledgements

I would like to take this opportunity of the completion of my doctoral thesis to thank the persons who have supported my previous career path as well as the genesis of this work.

First of all, I would like to deeply thank the supervisor of this work, Prof. Hartmut Wandke, who has supported the writing of this thesis with much engagement in every phase and who was accessible to me at any time. Without his ideas, indications, and advice this work would not have been possible.

Further, I thank him for the access to the topic of the human-machine interaction. By doing so he provided me with my “professional home.”

Prof. John D. Lee I would like to thank for agreeing to serve as my second supervisor and judge, as well as for his attention to my work itself from across the pond. Additionally, I thank his wife Mireille Raby for her encouraging support at our meeting in Maine in 2005.

In terms of the realization of the experiments, I especially thank my colleagues Tobias Altmüller, Michael Dambier, Michael Dorna, Wolfgang Krautter, and Bilge Manga, with whom I have cooperated within the framework of a Bosch internal project. All have cared - under immense expenditure of time and in spite of innumerable change requests on my behalf - for the fact that the examinations could take place the way they were scheduled.

Dr. Ulrich Ladstätter I notably thank for his warm admittance into the driving simulator environment in Stuttgart, the evenings of discussions with him sitting on the “Strümpfelbacher bench,” and for his help in analyzing the psychophysiological data.

Each of the examinations has taken place in collaboration with interns. I would like to thank particularly Florian Aue, Uwe Bernard, Torsten Lange, Juliane Sauer, and Jessica Schwarz for supporting the production of materials, for managing the plentiful participants, and for the preparation of the data. The teamwork made the work fun. More special thanks to Tobias Keil, who also put in many extra hours in my first driving simulator experiment and who contributed to it with some tips to ensure the success of the experiment.

Other colleagues have also given me consistently valuable advice and indications during many conversations. Therefore, I would like to thank particularly Dr. Dietrich Manstetten, Dr. Andreas Engelsberg, and Dipl.-Ing. Andreas Kynast, as well as Dipl.-Inf. Jens Fänger.

Tim Loßnitzer, Tobias Keil, Kim Van Meter, and Jessica Schwarz I thank for the proofreading and for their loving support in all circumstances.

Andreas Dubrowsky I would like to thank for his encouragement of my career path and his support of me over the years, being available both day and night as a partner in discussion, informant, adviser, and friend.

I thank my brother for leading the way into science. And finally, I would like to thank my parents, Margrit and Hans-Dieter Biester, for their emotional and financial support during my studies. I very much appreciate the opportunities I have had to pursue this education.

Declaration in lieu of oath

Herewith I express in oath that I have written the present thesis independently and have applied only the auxiliary equipment and sources indicated in the text. In addition to the utilities specified in the text, I have applied the data evaluation programs SPSS 12 and 13 as well as Matlab.

Eidesstattliche Erklärung

Ich versichere, dass ich die von mir vorgelegte Dissertation selbstständig und ohne unerlaubte Hilfe angefertigt, die benutzten Quellen und Hilfsmittel vollständig angegeben und die Stellen der Arbeit (einschließlich Abbildungen), die anderen Ursprungs sind in jedem Einzelfall mit Angabe des Urhebers als solche kenntlich gemacht habe. Zusätzlich zu den im Text spezifizierten Hilfsmitteln habe ich für die Datenauswertung die Programme SPSS 12 und 13 sowie Matlab verwendet.

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Introduction

The human-machine interaction will face several major challenges during the next two decades, particularly in the automotive sector. These challenges will result from newly introduced features that will fundamentally change the interaction between drivers and driver-assistance systems. Independent systems such as semiautonomous, surround-sensing, or car-to-car communication systems are technically developed to such a degree that a market launch is foreseeable. However, instead of putting too much focus on technological developments, it is crucial to develop an efficient and effective human-automobile interaction so that the innovative technologies will be accepted by the user, e.g. the driver.

Several approaches to the lay out of this type of interaction are being discussed in contemporary research and development. One of these approaches, which has until now received little attention, is that of cooperation between driver and automobile. Therefore, a concept of driver-automobile cooperation will be developed and analyzed in the theoretical part of this thesis in order to evaluate its provable potential as well as to show qualitative differences between it and already existing approaches of human-machine interaction.

Furthermore, the concept of a cooperation-based functional distribution between driver and automobile is described herein so as to provide a basis for evaluation of this concept. Firstly the idea of cooperation is discussed. Then the conceptual determination of this idea based on the introduction of an integrative model on the foundation of existing approaches to the cooperative interaction is deliberated. Second, the characteristics of the structures and processes of the cooperative interaction are explained. These proposed fundamental characteristics serve to identify general description characteristics, which in turn allow the derivation of indicators that visualize the profit that can be realized by cooperation between driver and automobile.

In the empirical part of the work, an initial online survey, two preliminary investigations, and two experiments are presented that serve as a partial examination of the theoretical concept. In the online survey, information regarding the wishes and requirements of individual users concerning the potential functional distribution between driver and automobile with regard to driving functions was obtained. Two scenario-based interviews were completed as preliminary investigations to identify the respective specifications of the experiment. Here it was a matter of identifying which functions related to the specific driving scenario, which was also to be completed in the relating experiment, were best suited to evaluation of a cooperative prototype compared to other system variants.

The first experiment was the driving simulator experiment called "Overtaking on Highways.” In this experiment, 12 slow trucks were presented to the candidate and had to be overtaken in a high- or low-traffic density environment on an interstate according to the specific test group conditions (system variants) such as manual, cooperative, half automatic, automatic.

The second experiment represented the driving simulator experiment "Turning Left on Urban and Country Roads with Oncoming Traffic.” In this scenario participants had to turn left at specific marked and standardized crossing types in and out of cities facing oncoming traffic. One test group drove completely manually, and the other had a cooperative prototype as an interaction partner.

The results of the two respective driving simulator tests are presented, discussed, and evaluated with regard to the formulated questions and hypotheses. Furthermore, the results of the preliminary investigations and the experiments are integrated, analyzed, and discussed with regard to the primary postulated comprehensive concept. Affiliating this result integration, a possible establishment and embedding of the cooperative driver-automobile interaction into the overall context is considered.

Finally, a discussion of future perspectives and the assumed potential of driver-automobile interaction based on the newly acquired knowledge concludes the thesis.

1 Problem definition and intention of the thesis

The intent of the present thesis is to develop and begin to evaluate the psychological concept of and framework for the future design of human-machine interaction and its optimization – particularly in the research field of automobiles on the basis of an extension of existing approaches.

The concept's starting point derives from the necessity of "cooperation," which becomes necessary when several diverse automobile systems are merged and integrated into one hardware and software platform: the resulting excessive workload for the driver and the rising complexity demands cooperation (Onken, Otto, & von Garrel, 2001). Furthermore, it must be taken into consideration that drivers – as a rule - perform holistic evaluations of the interaction processes, while the classic engineer's approach to R&D focuses on single, individual, and independent functions.

Empirical evidence related to this problem can be obtained in the analysis of incidents and accidents. Due to the comprehensive research that has already been carried out in this field, the present thesis will limit itself to verifying, confirming, and proving only the major influencing factors and to sufficiently illustrating them by some examples in the following.

In recent years, the number of problems related to the system components of automobiles has dramatically increased, and it is not uncommon for systems to suddenly break down. According to Peters (2004), the number of overall automobile breakdowns that can be tracked back to the car's electronic system will increase to almost 63% of all reliability-related problems of automobiles in the year 2013. One of the major reasons for this increase is the rapid development of soft- and hardware components, with up to 80 different primarily manufacturer-specific systems being linked and expected to communicate and interact. Obviously, further automation can not be the exclusive solution for these types of reliability problems (Billings, 1997; Parasuraman & Riley, 1997).

In regard to the driver's performance, it was found that automatic systems can have a significant negative impact on the individual's subjective status (Scerbo & Mouloua, 1998). For example, Endsley and Kiris (1995) have shown that persons who have to perform manually because of the breakdown of automation have performance losses compared to persons who have done these tasks manually from the beginning. Being aware that users will not be able to perform all tasks manually due to the number of subsystems implemented, the proper mix of systems must be determined.

In addition, the social context involved with the introduction of a new technology is highly important, especially when formulating a psychological concept of interaction: a system may function perfectly from a technical perspective, but it still will not be used by the target group if it is not accepted. In particular, intervening systems, which are systems that take over control in certain situations or limit the user's freedom of choice to a large degree, are often refused (Van der Laan, Heino, & De Waard, 1997). Consequently, an increase in automation does not go hand in hand with a linear increase in user acceptance.

Several studies have been able to show that the psychological construct of "trust" provides a consistent, measurable, and reliable parameter for the attitude towards automation and the trust in technology itself, serving well to describe the human-machine interaction (Lee & Moray, 1992b;

Lewandowsky, Mundy, & Tan, 2000; Muir & Moray, 1996). Kantowitz et al. (1997) have shown in a navigation experiment related to route information that drivers tolerate an individual degree of uncertain information without a loss in trust. However, beyond this limit, the interaction with the system is disturbed lastingly.

The stated examples show that neither the quantity nor the quality of previous assistance is entirely sufficient to eliminate the monocausal problem or even their reciprocal effects. Consequently, the following concept of cooperation in the driver-automobile interaction is potentially beneficial and indicates at the same time an existing deficit in the scientific theoretical research.

On this account, a more extensive integration of different approaches must be carried out to achieve optimal cooperation of human-technology interaction. It is therefore important to foster more interdisciplinary research alongside the field of engineering psychology investigated here in fields such as mechanical engineering, informatics, and robotics.

State-of-the-art navigation systems, for example, do not utilize car-to-car communication. Integration in the sense described herein, for example in the enablement of self-organizing traffic[1], would require a combination of motor-electronical data with the navigation device and communication of the resulting information with other road users. This type of integration would allow the individual human-automobile interaction to make better decisions regarding driving maneuvers such as overtaking on highways and turning left with oncoming traffic.

Due to the complexity of the named research fields and so as to not digress from the goal of this thesis, a filter must be set. As such, only psychological approaches, and especially those involving engineering psychology, sociology, and particularly socionics, as well as linguistics approaches shall be considered in the present work.

Keeping in mind what has just been stated, it is essential to determine what kind of hardware and software platform, integrating all driver-assistance systems into one counterpart for the driver, must be created in order to provide a range of action alternatives respective to the particular function distribution, that is neither predefined nor based on dynamically fixed criteria, but results from a continuous and cooperative process of exchange. This process of exchange is supposed to serve the formation of a common knowledge base that ensures a transferability of experiences by means of educability.

In the following, the aims of this thesis shall be outlined in their chronological order of achievement.

[1] Self-organization is a process in which the internal organization of a system, normally an open system, increases in complexity without being guided or managed by an outside source. Hereby, car-to-car communication is an important research and future application topic which is gaining increased attention from all major car manufacturers. Direct communication between individual vehicles can significantly increase passenger safety and comfort. An example for an exchange of traffic information is the novel Self-Organizing Traffic Information System (SOTIS).

The first aim represents the discussion and elaboration of relevant influencing factors on the driver-automobile interaction by introducing an integrative model from which a definition for this specific context shall be derived.

The second aim of this thesis is the integration of these approaches according to the above-mentioned filter. Therefore, the experiences of the research field of linguistics, particularly regarding dialogue design and the embedding of this design into a multimodal interaction concept, should be discussed here as well and should at least be applied to the linguistic dialogue in the experiments. Knowledge from the field of psychology regarding the procedure of action processes and their characteristics should also be included in this context. From the interdisciplinary research field of teamwork, one can deduce from another perspective the psychological basic conditions and characteristics for cooperation between humans.

The third aim is the conceptual design of test scenarios based on the assumed presumptions and several preliminary investigations in order to verify parts of the concept and the associated influencing factors.

The fourth aim is the discussion of the concept's provable potential based on the acquired test results and gathered information and data in regard to selected influencing factors for the individual participants.

And finally, the intent of the paper is to offer decisive help and inspiration regarding the future design of driver-automobile interaction as well as its affiliated exchange processes.

1.1 Selected approaches of human-machine interaction

Although former approaches considering the functional distribution between humans and machines cannot offer complementary and exhausting solutions, as stated above, they nonetheless must be outlined and discussed briefly because they provide valuable insight into and indispensable advice for a greater understanding the concept of cooperation. However, for a more detailed discussion of these approaches the reader is advised to turn to the relevant literature (Bailey, 1996; Helander, 1988; Preece, 1995; Salvendy, 1997; Sheridan, 2002). In the following, current approaches to the functional allocation between humans and machines and their use in present systems will be discussed.

The "Men are better at-Machines are better at"-approach (MABA-MABA) (Fitts, 1951) which is more than 50 years old and still quite popular throughout industrial production, determines who of the interparticipants is best suitable for what task and is therefore always fulfilling it. Later, another very popular and well-respected approach in both industrial practice and scientific research was developed by Sheridan (1978). Sheridan's approach illustrates the potential allocation of functions between humans and machines on a 10-fold scale of automation levels, which he later changed to a 8-fold scale: functions of a system can be realized on several of these levels simultaneously or just on a single level (Kraiss, 1989). For a more in depth discussion of the interaction between humans and automation if implemented on the logical basis of levels, read Sheridan (2002).

However, in the last twenty years the distribution of tasks or functional allocation was organized less statically and more and more dynamically. Hereunto specific criteria have to be applied to fine-tune the adaptation of certain conditions during the operating and action processes. Accordingly, two extreme states are possible: with flexible automation this can be intended, for example, exclusively by the user, while he determines existing possibilities; however, with adaptive automation the system chooses independently on the basis of certain system characteristics from a range of potential alternatives. In most cases, one of these two extreme possibilities is implemented. Accordingly, these scenarios are referred to as either human- or technology-centered designs (Billings, 1991).

Nevertheless, for the newer approaches to which the cooperation in human-machine interaction belongs, the common classification patterns must be extended, because both entities - human as well as machine – are considered to be valuable resources whose common goal as a closed unit must be emphasized. This change has already been implemented in theoretical minted approaches like those of Inagaki et al. (1997); the main focus here is the so-called situation-adaptive autonomy with which the automation levels change dynamically as well as in dependence of the surrounding situation. An example of this would be the trading of authority in a case where the workload of a pilot has become too high and a critical situation emerges. Depending on the reaction of the pilot to system warnings, some of the necessary actions, e.g. the avoidance of a collision, would then be taken over by the aircraft itself.

However, cooperative interaction as an advanced and extended approach as well as a new integration, is the outcome of the interaction of driver and automobile defined form of automation and, therefore, can be flexible and adaptive alike. Yet, in cooperative interaction, it is explicitly considered that the concept refers to two adaptive systems (human and system), assuming that the hardware and software subsystems of the automobile are linked with each other and can be perceived as one system by the driver. This definition excludes on one hand in the first step, the perception of the body of the automobile as part of the system, thus postponing a discussion of whether the body of the automobile is seen, due to the mentioned holistic approach of the driver, as part of the system. On the other hand, it does include repetitive negotiation of the degree of automation by starting the “interaction” as proposed in the approach of contextual design (Beyer & Holtzblatt, 1998) (i.e. driver and developers design the system together) and continuing it in the particular driving situation, which is then influenced by the driver's state and environmental situation.

1.2 Premises for a justification to extend the existing concepts and approaches

The following four premises should be taken as the target of all efforts for an optimal functional allocation between drivers and automobile, in the case that this allocation is provided by cooperation. In addition, developers should consider the following four aspects in regard to the design of systems having the future driver participating in this process or not:

1. Gaining and maintaining an acceptance of automation is a very complex matter, as many factors influence this process. For example, trust as one condition for acceptance can easily lead to overreliance on the system (Weinberger, Winner, & Bubb, 2001). In contrast, a low degree of acceptance, for example due to bad experiences with similar technical devices, can lead to disuse of automation (Parasuraman & Riley, 1997).

Additionally, studies of the human use of automation typically find large individual differences in these factors (Riley, 1994). Therefore, the concept and its implemented prototypes should be developed with the ongoing goal of gaining and maintaining acceptance and trust (see section 2.4.1.3).

2. To design a prototypical system in such a way that it leads to a reduction and optimization of workload and strain is the second premise. Research regarding the parameters of influence on and the connection between strain and workload continues to be an important task, as does being able to measure whether a user is experiencing overload or underload (de Waard, 1996). This research provides a mandatory basis for design manifestations (see section 2.4.1.1.4).

3. As cockpits of future automobiles will have more and more speech-based applications, continuative concept systems must be considered as a whole and be integrated into a multimodal interaction concept (Salmen, 2002) (see section 2.4.1.1) to prevent and to intercept communicative misunderstandings between human and technology. Badly designed interaction concepts can, for example, lead to phenomena like mode confusion (Sarter, 2002; Sarter & Woods, 1995). Additionally, this multimodality can easily represent the complexity described in premise 1 that will then lead to overload and non-acceptance.

4. In the aviation and astronautics sectors there are various examples of inadequate conflict management (Billings, 1997; Martensson, 1995) between the single components of the system itself as well as in the system interaction with humans. Despite the difference in applications between automobiles and aviation and the different basic conditions, it is to be assumed that a plurality of the psychological effects traded off in premises one through three that are to be observed with the operation of airplanes could also occur in the driver of an automobile and therefore have to be prevented. Accordingly, systems must be able to guarantee successful conflict management (see section 2.4.1.1).

The design of the experiments to prove the hypotheses in chapter 3 will focus primarily on these four premises.

2 A concept for cooperative interaction in automobiles

In 1992 Sheridan already described the possibility of what he called “cooperative control”: while one of the participants (human or machine) initiates a specific action or process, the other adapts himself to it or refines and fine tunes it. Unfortunately, the subsequent discussion of this approach was insufficiently intense and of rather a theoretical nature. Furthermore, a different understanding of the range of cooperation developed. For example, Hoc describes human-automobile cooperation as taking place between a human and a single application with an interactive scope that does not surpass common, commercially available driver assistance systems (Hoc & Blosseville, 2005).

For the purposes of problem definition and to further the aims of this thesis, the ideas of Sheridan will be picked up again and will be developed with regard to the just mentioned premises into a broader concept of driver-automobile interaction.

Furthermore, the theoretical part of this paper will refer iteratively to the premises for the design of a technical system to make the approach to cooperative interaction easier to comprehend and to better illustrate its inherent terms and conditions. However, it is logical to start with a conceptual containment of the cooperation to be conceived here.

2.1 Conceptual disposition of cooperation in automobiles

To generate the conceptual disposition of cooperation in automobiles and to explore its span and attached understanding, this proposed form of interaction shall be elucidated in the following by examples from today’s human-machine interactions in the context of automobiles. This is necessary to be able to compare the state-of-the-art in current vehicles with the integrative model of cooperation and its related working definition that are introduced in this chapter so as to ultimately integrate the two in a human-machine cooperation in the next section.”

To better illustrate the following examples, research results shall be described in this thesis in relation to the two driving situations of the test scenarios from experiments 1 and 2 (for the selection process see chapter 4; for the detailed illustration see chapters 5 and 6), namely “Overtaking on Highways” and “Turning Left on Urban and Country Roads with Oncoming Traffic.”

The state-of-the-art Lane Departure Warning system (LDW) warns the driver when the vehicle begins to move out of its lane, unless the indicator is active in that direction. Herewith many different optical or infrared systems are in control. The warning usually takes places via acoustics with a characteristic sound of a washboard or a wobbling seat.

Curry et. al (Curry, Artz, Blommer, & Cathey, 2006) tested drowsy participants driving on highways with one or a combination of four lane departure warning systems. In the study, if a driver departed out of a lane, the system activated (e.g. steering wheel torque that showed the driver the appropriate steering wheel angle needed to return to the lane, a rumble strip sound recording, steering wheel vibration, or a row of flashing red LEDs on the top of the instrument panel). All four warning systems cut drivers' reaction time almost in half, though the steering wheel vibration warning in combination with steering wheel torque proved to be the most effective (Curry et al., 2006).

Adaptive Cruise Control (ACC) has been established in automobiles since 1998. State-of-the-art ACC function due to sensors that calculate the position and speed of the advancing vehicle and therewith adaptively regulate the distance between it and the user’s vehicle via motor and brake interference.

Koziol et. al (Koziol, 1999) tested 108 participants in a 5-week field test on highways using an adaptive, a conventional, or a manual cruise control. The data showed that under certain conditions of short time-headway settings (e.g., 1.0 seconds) and high velocities, ACC systems can improve roadway capacity, e.g. through traffic flow improvement. Furthermore the number of critical incidents was almost half (3.4 on 100 kilometer) then with purely manual driving (6.2. on 100 kilometers), making possible an improvement in the driving parameters. Additionally, the ACC generally had a very high level of acceptance by the participants. In the end, participants ranked the ACC over the manual and conventional equipped vehicles for convenience, comfort, and enjoyment (Koziol, 1999).

As one can see, much research is focused on the above briefly introduced single systems. These systems can be extended, however, such as by a connection between a Lane Keeping Support (LKS) (i.e. a driver assistance system that in addition to the LDW functions actively provides a slight torque to the steering wheel in order to maintain the car inside a lane on a straight road) and ACC. With the simultaneous operation of these two systems, almost all of the driver’s driving operations are accounted for, and therefore a drop in driver´s motivation is expected.

Honda has developed a Lane Keeping Assistance System (LKAS) where there is not only a connection between the LKS and ACC, but also the capacity for both systems to operate jointly with the driver (Ishida, 2003; Waibel & Ishida, 2007). The center of this system is the LKAS continuation judgement, which determines whether the driver is still performing operations, and if not, the assistance is temporarily stopped. In an evaluation of this system, the test participants were given only two tasks as driving conditions on a highway route – driving while maintaining a fixed headway with the vehicle in front, and driving while keeping in the same line without fail. The data showed a reduction in steering torque of 50 percent, a reduction in the number of steering operations by the driver, and a wider driver´s field of view (Ishida, 2003). In the end, the evaluators asked four questions regarding the benefits and influence experienced by the drivers when using the LKAS.

The results showed that 92% of respondents reported that the LKAS was easy to become accustomed to. As for the amount of assistance, 96% replied either that it was just the right amount, or just slightly insufficient. Concerning the stimulation state, only 2% said that they became sleepy, and 13% replied that they felt refreshed, which is a larger proportion. As for the effect in reducing workload, 8% replied that there was no reduction, while 88% of respondents felt there was a workload reduction (Ishida, 2003; Waibel & Ishida, 2007).

This short discussion of current research results indicates that the present human-automation interaction and related function allocation concepts can already lead to significant improvement in driving comfort and with it a drop in traffic accidents. On the other hand, it appears evident that this research has been carried out exclusively on single or twofold solution systems.

According to the first goal of this thesis, it is essential for a description and therewith conceptual disposition of cooperation in the driver-automobile context to transfer the current forms of the “human-machine interaction" by means of a platform (i.e. a combination of these single systems) into a new understanding of "human-machine cooperation."

To do this it is initially necessary to briefly explain the terms of cooperation.

Most fields of research that are dealing explicitly with the term of cooperation do this exclusively with regard to the human-human-interaction, based on a classic approach by Deutsch. This approach refers to cooperation as a social relationship that exists between the objectives of the participants in a specific social situation (Deutsch, 1949, 1960).

The encyclopedia of psychology (Kazdin, 2000) defines cooperation as the tendency to maximize the outcome of an interaction, not only for oneself but also for others (e.g. "doing well together"). However, Dix, researching in the area of CSCW, defines cooperation as "... *communication with a purpose*" (Dix, 1994).

In addition, the terms cooperation and collaboration are frequently used together or even synonymously. Due to the difficulties of an accurate division as well as the transition between the two, the higher-valued term of cooperation[2] is generally applied in the present work.

The term cooperation, which is referred to throughout several domains, has not yet been established as a terminus technicus in the automobile environment. In many sciences, the term cooperation is often closely associated with certain other termini (see Borghoff & Schlichter, 2000; Piepenburg, 1991; Spiess, 2003). For the human-automation context discussed herein, an integrative model shall be derived from the literature mentioned above to set an initial framework of cooperation (see figure 1).

This integrative model of cooperation in human-automobile interaction shall be introduced by a working definition and then explained in its factors with a first attempt to allegorize and describe their coherences.

[2] While in English the terms of co-operation, namely collaboration and cooperation are commonly synonymously applied (Simpson & Weiner, 1989), the conceptual division of Borghoff and Schlichter should be joined here. This division refers to the more sporadic interaction with the term collaboration concerning the degree of communication rather than with cooperation (Borghoff & Schlichter, 2000). In addition, it must be noted that the connotations of collaboration and cooperation have underlying cultural differences, such as in the meaning of the word collaboration, which can also mean co-operation with the enemy.

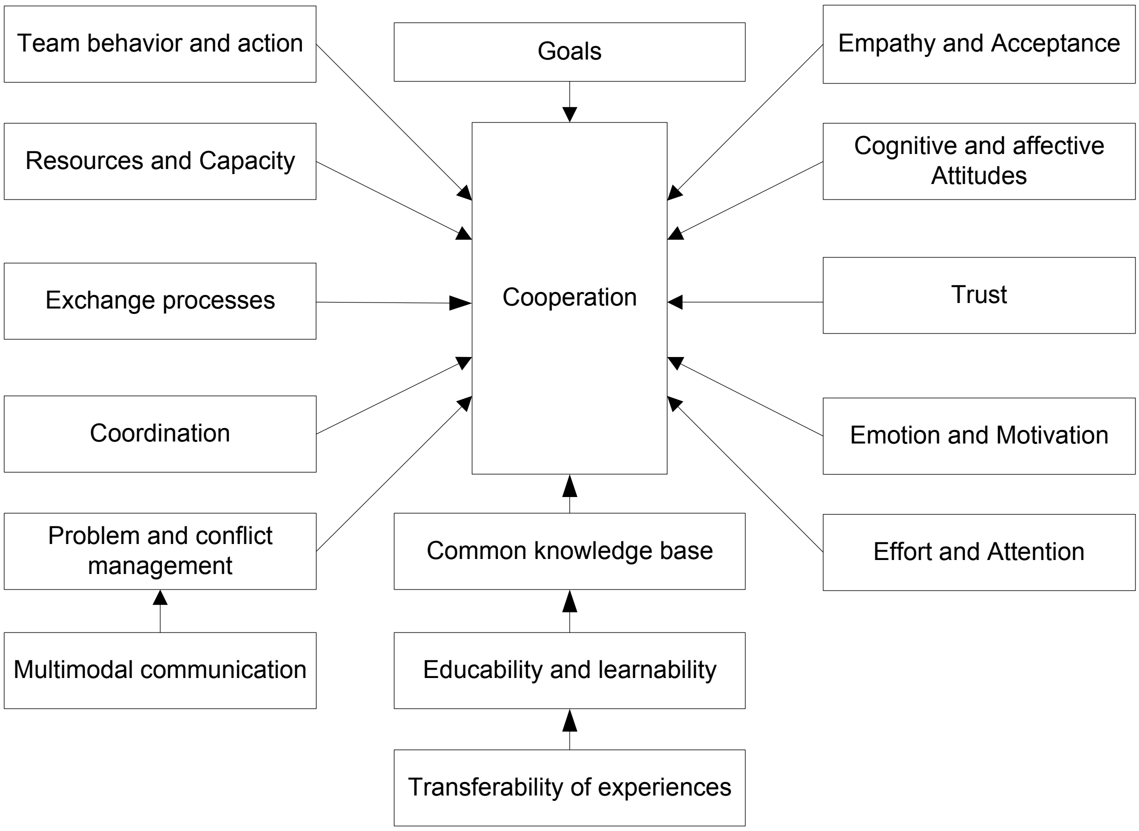

Figure 1: An integrative model for the most important characteristics of cooperation in human-automobile interaction in relation to Spiess (Spieß, 1998, 2003).

In the following, a suggestion for a working definition of cooperation in the human-machine context will be formulated: Cooperation is defined as a continuous exchange process between driver and automobile, with the exchange process creating a common knowledge base and goals, which in turn ensure a transferability of experiences by means of educability. Keeping in mind the goal of an optimal realization of driving tasks, both participants are responsible for certain parts of the commonly defined whole task, which is the result of a continuous coordination process. As a result, the current interaction of human and automobile is a continuously negotiated form of automation which in its degree can range between adaptive and flexible; parameters inducing this process of negotiation are the driving situation, the driver's condition, and the environmental situation. In principle, it can be assumed that in each case the realized interaction produces an identifiable profit for both sides (Biester, 2004) to create a solution, a positive result for the respective task, or to fulfill a social need (e.g. outcome and costs efficiency as well as security).

This definition is to be specified in detail as follows:

First, the definition implies a process of exchange (e.g. for information acquisition, information analysis, action selection, and action execution) and a bringing in of resources[3], defined as the inferred underlying commodity, of limited availability, that enables performance of a task (Wickens, 1984). In this concept, resources such as emotions and motivation are included in the context to make the terms capacity, effort, and attention of the driver more visible in the concept of resources.

Second, it implies a quasi-social interaction, in which humans accept systems as social actors, so that the goals of both actors can be positively related to each other (Nass, Steuer, & Tauber, 1994). Already today it is known from the media equation hypotheses that people treat and respond to computers in many quasi-social aspects (Reeves & Nass, 1996). As such, from the developer's perspective, it should be of relatively little importance that he is the one who implements the goals of the system, if not working according to the contextual design guidelines, mentioned in the previous paragraph. Rather, the developer should pay close attention to the basis of the cognitive and mental models of the user, the properties of which the driver subordinates to the system, as an example of goal deployment (Brave & Nass, 2003; Nass, Moon, Fogg, Reeves, & Dryer, 1995; Nass et al., 1994). For the realization of shared goals it is important not only to keep in mind one's own goals but also to engage in a negotiation process with the interaction partner. The earlier this process is initialized and the more openly it is realized by both sides, the better the resulting cooperation. A primary goal agreement is especially important because long-term teamwork is to be expected (excluding rental cars) in the automotive sector.

Third, cooperation means a distinction from pure coordination, which is here seen as one key component due to the conscious and planned approach to teamwork with regard to behavior and action as well as processes of mutual voting and agreeing.

Fourth, with regard to a potential hierarchy in the cooperative interaction, it should be identifiable in each interaction or specific situation whether a partner is subordinated to the other, and in which way that relation manifests. Such a requirement is supported by results showing that users perceive systems not as a medium for the social interaction with the designer but as the direct and intermediate interaction partner (Nass et al., 1994). Accordingly, the asymmetry seen currently where the driver stands hierarchically higher than the system will change (see also the sections dealing with role distribution and basic conditions), and social interactions between humans and automobiles must always be based on an individual dyadic arrangement that can only be prepared by the system designers.[4]

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[3] Whereas the automation is to be seen first as a technical resource in the respective working process for the cooperation (Onken et al., 2001).

[4] The,in this context, known and already existing resentments in regard to anthropomorphic systems such as Avatars are still a matter for examination (Kraemer & Bente, 2002).

Fifth, cooperation, especially between humans and machines, must incorporate certain aspects of outcome and cost efficiency. This is not only in a material sense, but even more so in regard to psychological effects. A driver who has until now "communicated" with his automobile only to a slight degree will neither be able to nor want to engage in a fully cooperative dialogue or multimodal interaction from one day to the next. It must be noted that a driver's costs with regard to the degree to which he engages himself in an initial interaction process should not be too excessive.

Sixth, the cooperation partners must provide each other with security (e.g. shared actions will not lead to accidents, information has a high degree of correctness), in that the cooperation is reliable. In the case that the interaction results in situations that are more dangerous than if only one of the participants had acted, evaluation of the dyad will quickly turn negative.

Seventh, the personal cognitive and affective attitudes as well as the attitudes of the cooperation partner prime the expectations of the relationship. Consequently, it is important that both sides check their attitudes (i.e. with the system's parameters and settings) independently from each other, because it might be that both actors agree upon their goals while their attitudes in regard to crucial aspects of the cooperation do not match. Communication and the exchange of information must be considered as fundamental. Effective communication is the basis for a constructive problem discussion process, even on a meta-level and with regard to a long-term perspective. By means of these indicators it is possible to evaluate the type of driver-automobile cooperation and to analyze whether trust has developed or can be generated, and whether empathy can be communicated (Lee & See, 2003b), from which acceptance arises. This gains even more importance, as It must be understood that a tendency toward either cooperative or competitive behavior often is inspired by the beliefs regarding or actual observations of the behavior of the other (Piepenburg, 1991).

Eighth, in order to establish a lasting cooperative interaction between human and system, the interaction should generate an obvious benefit for both sides.

According to the logical principle Occam's razor (Maurer, 1996), it should be asked how many of the just established assumptions can be left out to still be able to speak of cooperation in this context. Due to the supposed complexity of the research, however, this approach will not be dealt with directly in this thesis, but will be implicitly discussed due to the aims of this thesis and the respective experiments.

Coming back to the examples of current systems like the LDW, LKS, and ACC, the question arises as to what distinguishes cooperation from these forms of interaction. First, there is no negotiation regarding function allocation taking place, as these systems have a fixed adaptive behavior. Therefore, the type of exchange described herein does not occur; action takes place independently, and the driver is always able to override the recommendation or action of the system. Resources and capacity are exchanged to a certain degree, but only in a small number of driving tasks. Furthermore, due to the communication concept of actual systems, drivers confusing modes would have to find their way out on their own, as no multimodal communication concept with an approach to problem solving and conflict management is attached, that would learn by means of an evaluation phase after a respective dialogue. Bringing forward the results of relating studies, the psychological effects of the integrative model other than acceptance were not evaluated, so that a comparison of these factors is not possible.

On the other hand, the LKAS already combines two driver assistance systems, but with only four fixed system states (Waibel & Ishida, 2007) and at a fixed level of driver operation of more than 20 percent. In relation to the integrative model, Waibel and Ishida have only evaluated the motivation, which was found to improve during use. The communication always takes place via acoustics and a display, and no mode changes are intended.

Coverage of the model components in current systems is heading in the right direction. However, the essential superiority of cooperation is due to the synergistic effects that are manifested when the shared interaction of both agents, here human and overall system, produce a net benefit over all components that is bigger than the benefit that one of the actors could have generated individually without cooperation (Biester, 2004). This “shared” interaction will be interpreted herein more philosophically. In the real interaction, this commonality produces three types of action, serial, parallel, and alternating. Endsley et al. (Endsley, Bolte, & Jones, 2003) have shown in a literature review that the reliability of human and machine components is higher when operating in parallel rather than in series. This result is primarily due to system components where the driver and system must act as in direct-manipulative tasks (i.e. accelerating, braking, lane keeping), for interaction parts in relation to, for example, information acquisition or action selection both parallel and serial operation can be necessary. This brings up the assumption that function clusters can be built in which certain functions can be undertaken serially, while others take place in parallel. On the other hand, if there is no parallel action, redundant automation should be buffering the emerging difference in reliability.

For example, an overtaking maneuver can be accomplished faster when driver and system can cooperatively communicate with each other regarding information they need at what time for what purpose, and then operate simultaneously. As a result, the system and driver could conduct diagnoses of the situation more effectively and more efficiently without bothering the driver with counterproductive dialogue loops leading to the phenomena of “mode confusion“ (Sarter & Woods, 1995).

Technically, the basis for cooperation on the systems side is a hardware and software platform on which all current driver assistance systems, including future systems located outside the vehicle (e.g. home or office devices), are interconnected so that data i.e. information from the various sensors and cameras, will be homogeneously utilized by all devices that then interact with the driver via one single multimodal communication concept so that this platform can be perceived by the driver as one single interaction partner. Furthermore this platform is programmed in the way of the described concept of cooperation.

In conclusion, the above issues shall be illustrated by an example. After an exhausting day at the office, a driver is on his way home and approaches a high traffic density section on the highway. Naturally, the driver reflects upon available alternate routes since he does not enjoy driving slowly. However, the systems navigation component recommends staying on this particular jammed highway because the alternate routes are also highly frequented and it would actually take longer to get home by choosing an alternative route (i.e. data-link via car-to-car communication and navigation devices).

On the basis of these data the platform system is in the position to offer the driver information about appropriate driving behavior to be able to “go with the flow.” During telephone calls by the driver, the system is primarily executing tasks like overtaking in the previously negotiated manner, as long as the situation does not change, but changes to visual communication so as to not disturb the telephone conversation, while the trusting driver is supervising the overall situation.

Finally, during the last section of driving before arriving home, both the driver and system component evaluate their decision criteria on the basis of the data provided by the system in relation to the other routes and agree that, with regard to each single decision as well as to the sum of all decisions, the most appropriate solution was chosen.

Accordingly, the duration of the driver-automobile interaction is primarily dependent on the development between the requirements of driver and system, since the needs, as described in the definition, can be heterogeneous or - based on the constellation - they always are.[5] The first requirement is effectiveness; the second one is efficiency. While effectiveness is associated with satisfying the social needs of the driver and - figuratively - the system’s development team, efficiency is strongly associated with the satisfaction of the individual motives of the driver.

These examples and the theoretical concept must be additionally reflected upon with regard to a changing understanding of the role distribution in the driver-automobile interaction in the future, an issue dealt with in the next section.

2.2 Role understanding and distribution

In order to establish a concept of cooperative interaction in the automotive-sector, as outlined in the previous chapter, it is essential to point out the already mentioned changing role distribution of driver and automobile. In general, a role can be described as an expected or prototypical behavior of a person who takes a certain position within a frame of reference (e.g. social system). The prototypical action pattern of a participant is specified by the appropriate goal orientation of the parallel or sequential actions (see also section 2.3.2) and the participant-specific competence for the assumptions regarding that exact role (Grimm, 1994).

As a rule, the role itself encloses a differentiated set of adequate action alternatives, while it is simultaneously provided with degrees of freedom for a situation-specific choice. Therefore, it is now important to transfer this definition to the context of driving automobiles. How can the role of the driver be described? What are the prototypical action patterns? And how is the frame of reference defined?

The latter question can be answered rather simply because instead of a social system, a socio-technical system can be assumed (Rammert, 2002a) within which the driver as well as the front seat

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[5] For example, for the driver it could be the wish to get from A to B (e.g. to the office, to friends) or to ride for pure pleasure and amusement, e.g. from A to A. The system, however, does not currently define itself by its own measures, but is defined by the research efforts of the system designer who aims to earn money or who is driven by the desire to create a better system than the competitor.

passenger take over well-defined roles. In addition, it can be affirmed that in a narrower sense the technical system takes over a role just as the driver does. Not least because it has been observed in recent years as a result of several developments in the automobile sector, particularly with regard to navigation systems, the role of the technical system is more often assigned as a front seat passenger, e.g. in the context of the adaptive automation attributed with terms like "virtual front seat passenger" or "quite/silent assistants" (Meyer & Vasek, 2004).

Prototypes of this kind are, for example, the cross-traffic and traffic light assistants, which exchange information regarding the actual traffic environment via car-to-car communication data about the position and actual vehicle states and provide them to the driver as a recommended course of action. The cross-traffic assistant, for example, recognizes a vehicle having the right of way that approaches the crossing, even though the driver cannot due to visual obstructions such as buildings. This feature gives the driver time to make decisions he would otherwise not have if using his own senses alone.

Another prototype of driver assistance is the "curve information as personal copilot" by BMW. This assistance system informs the driver via a navigation system or head-up display about his individual speed duly in regards to the curve progression so that he can adjust his speed accordingly (BMW-Media-Information, 22.3.2007).

However, thus far there are no approaches that go beyond the concept of communication between driver and virtual front seat passenger designed as a form of cooperation in which both participants interact. It can therefore be expected that implementing an interaction based on the idea of cooperation does result in a change of role understanding but not of role distribution, because role distribution comes with completely new qualities for human and machine with regard to the cooperative aspects of this concept (e.g. common goal definition, trading, agreeing, delegating[6]). In addition, the avoidance of role ambiguity and competence conflicts requires special attention; should these conflicts occur despite attempts to avoid them, the need for intelligent conflict management is further emphasized.

Thus, it is helpful for further notional determination of cooperation in the driver-automobile interaction to go beyond the definition and theoretical discussion of roles of the previous paragraphs by describing teamwork based on real and hypothetical cases from other contexts as well. This is important because the concept of cooperation in automobiles brings up the general question of whether there are other or better defined roles for the interaction between human and automobile besides "assistance" and "full automation." Again, examples of the interaction constellations are described briefly in order to illustrate the inherent transfer performance.

The interaction between pilot and air traffic controller, as an example of the human-human interaction, can provide helpful suggestions for the design of role distribution in the driver-automobile interaction.

[6] In this connection the question arises as to whether cooperation can be seen as a delegation or vice versa (Hoc & Blosseville, 2005). If one defines delegation as a transmission of a competence, this is contained in the concept described here, which goes however much further.

When crossing a certain air corridor, the pilot depends on one or even more air traffic controllers who give him the necessary clearance to pass in correspondence to all the other airplanes in that airspace. They must also master role ambiguities and communicative challenges. A tragic example is the collision of the Tupulev flight BTC 2937 of Bashkirian Airlines and a Boeing B757-200 Aero-Lloyd flight DHX 611 above the Bodensee in Germany in July 2002. The automatic Traffic Alert and Collision Avoidance System (TCAS) of both aircraft reacted correctly (i.e. commanding the Tupulev to ascend and the Aero-Lloyd aircraft to sink), but there was no data-link to either the air traffic controller, who commanded the Tupulev to sink (which the crew followed), or an autopilot connected to TCAS, which would have allowed the systems themselves to mitigate the situation.

As far as roles are concerned, emergency vehicle operations by the police can be drawn upon as a special example of human-human cooperation in a traffic situation between a professional driver and a co-pilot, because such rides stand out due to the increased risk potential and the high requirements for both participants. In this dyad, the emotional component is an important factor since the front seat passenger in particular (and only in few cases has the opposite case been mentioned) has the task of reducing stress and endangerment, e.g. by comforting or admonishing behavior (Neukum & Krüger, 2003). Keeping in mind that in this dyad in particular it is conventional that the participants alternate positions and therefore roles.

A less complex example, but significant for the development of role understanding in human-automation interaction, is the Collision Mitigation Brake System (CMS), which carries out all necessary actions for emergency braking without prior negotiation with or prior communication to the driver.

The prior examples show how cooperation can be converted by the experiences of the participants over time and how it is linked with different roles that can be taken over or handed over.

A completely different role understanding can be reached on the basis of metaphors such as the interaction H(aptic)-metaphor by Flemisch et al. (2003; Flemisch, Schomerus, Kelsch, & Schmuntzsch, 2005), which has been discussed in the last couple of years. This metaphor draws a comparison to the rider-horse interaction under special consideration of the haptic mode. Particularly positive characteristics beneficial to the *Co*-operation in this interaction are the emotional bonding as well as the temporally direct feedback and reaction. As a disadvantage of this metaphor, horses are also known for their stubbornness, as well as individualism and moodiness, which require affection and patience to be overcome.

All mentioned aspects of cooperation from the last two chapters will be explicitly and implicitly considered in the respective context of the following work to extract the provable potential of the extension of existing approaches by adding the term of cooperation.

2.3 Description of the cooperative interaction

As the next step after the conceptual determination of the cooperation, it is important to describe the driver-automobile cooperation according to its single components. This description will be carried out on the foundation of basic conditions that are derived from literature as well as from practical experiences, which are then further divided into process and structure characteristics.

2.3.1 Basic conditions

Based on the conceptual disposition and the general characteristics of cooperation, it is possible to derive specific conditions regarding the driver-automobile interaction. However, it must be considered that driver and system are fueled by different resources and that they are subject to time-critical restrictions: finally, they adopt a certain state, form opinions or goals, which in turn are based on specific intentions (Rammert, 2002b; Rammert & Schulz-Schaeffer, 2002).

Within this complex interplay and in accordance with the concept of Intention-Based-Supervisory-Control by Herczeg and keeping in mind Wilde's Risk-Homeostasis-Theory (Timpe, Jürgensohn, & Kolrep, 2000; Wilde, 2001), it is possible to define the following basic conditions for interaction (Herczeg, 2002). This definition is still based on the background of the question as to what in particular distinguishes cooperation in automobiles positively from other forms of interaction or concepts of function allocation.

The aim of establishing these basic conditions is to generate a common understanding of the quality and quantity of the interaction as well as to constitute rules for the invented integrative model of this interaction. Among other things, the concept defines the premises for the mutual and cooperative supervision and support of driver and system by postulating a shared basis of comprehension of the other's intention[7]:

1. Locus of control should reside with the driver for an appropriate amount of time.
2. Driver and system must be informed sufficiently to be able to act adequately.
3. The driver must be in a position to supervise the system, just as the system must be able to supervise the driver.
4. The system's "behavior", e.g. the actions and measures it takes, must be predictable.
5. Driver and system must know their mutual intentions.
6. The potential benefit of a successful interaction must be provable, significant, and perceivable.

Especially in the first condition, the difference in the control responsibility distinguishes from human-centered concepts of automation (see for example Billings, 1991).

It must be kept in mind that a violation of these conditions rules out the possibility of cooperation while the definition of this violation is realized within the dyad potentially starting at the design process and the already mentioned role understanding and cannot be effected ex ante.

[7] The system requires some kind of artificial intelligence which is able to conduct to the six levels of the human action model from the intentional level to the sensomotorical level (Herczeg, 2002) as also refered to in section 2.3.2.

Moreover, for reasons of error tolerance and proneness with regard to the basic conditions as well as so that users need not miss out on any system feedback or function supervision, it is necessary to implement redundant systems (Boy, 2005). By doing so, it is possible for the dyad to compensate for situations of higher workload and to provide the driver with an opportunity to recover. In addition, due to backups of user profiles, redundant systems allow safer operation and the realization of driver-automobile cooperation with several different drivers.

Due to their key role, the characteristics described below will be categorized according to their a) structural and b) process-related characteristics, especially with regard to their potential for implementation. This categorization is also carried out for the purpose of continuing the definition of the design frame of driver-automobile cooperation.

2.3.2 Structure characteristics

Even such a flexible and dynamic entity as the cooperation between human and automobile requires a form of structuring in its parallel and sequential actions. The structure of a cooperative interaction can be generally described by superordinated and subordinated characteristics.

The following starts with the superordinated structure, which has thus far been defined only in the human-human cooperation context. The definition will therefore be transferred into the present context by one example each and in order to additionally substantiate the selection criteria for the driving scenarios and test execution in chapter 4.

Superordinated characteristics according to Spiess (2003; 1998):

- The independence and autonomy of the participants. In this particular context, independence and autonomy are not easy to accomplish but are also not fully necessary, because as mentioned in the definition, the roles of both parties must first develop in the respective dyad. On the other hand, this criterion means that the driver could take a different transportation system or even walk, and that a vehicle with a state-of-the-art in research system would be able to drive alone (see DARPA Grand challenge 2004 for off-highway desert routes and 2007 Urban challenge for inner-city crossings).
- A relation based on voluntariness. The cooperation must rely on a certain degree of voluntariness in order to plausibly develop the characteristics mentioned in the previous section. Psychologically, this signifies the existence of alternatives from which at least the driver could choose either in selection of the means of transportation or in the selection of a particular action to execute.
- A creation of a commitment. In this context it means the connection of a statement made by the partner with its fulfillment in the interaction. Meaning that if either vehicle or driver commits themselves to an action (e.g. braking or blind spot detection), the other partner shall be able to “evaluate” that this is finally executed the way stated and agreed upon.
- The mutual trust between the cooperation partners. For a cooperative interaction, it is necessary that the respective cooperation partner can trust his counterpart to truly take over the tasks agreed upon. This is connected to the previous characteristic. If the vehicle

commits to preserve the driver from coming too close to a vehicle in front, the failure rate should not go above a certain threshold for this task.

- The increased achievement of individual and common goals as a purpose of cooperation. This corresponds to the real benefit, which can be both objective and subjective. This includes also the principle of success coupling, i.e. the achievement of goals only if the other one also achieves his goals (Grimm, 1994). The cooperation goal constitutes the aggregated quantity of all goals of both participants. In this context this could be achieved, for example, when vehicle and driver can turn left on a crossing significantly earlier due to cooperation in pedestrian and traffic detection, drive assistance, etc..
- The significant relation structure between the cooperation partners. This ensures that a certain basis already exists from the beginning or in conflict situations to prevent the cooperation from failure. This structure starts to build when the driver can perceive the overall system as one interaction partner and continues due to the seating of the driver in the vehicle while situations occur in which trust can build and reciprocal benefits arise.

With regard to mutual trust, the actual circumstances are of less importance than the system's features assumed by the driver, similar to the situation of goal development for the system.

During an actual cooperation, the following subordinated structures can be identified as carrying out action regulation.

Subordinated characteristics according to (Hacker, 1998; Nielsen, 1986; Norman, 1984; Rasmussen, 1986; Wandke, 2003):

Rasmussen (Rasmussen, 1986) hypothesizes a decision and action pyramid (i.e. the so-called decision-ladder), with which observations of the process are assimilated to cumulatively higher-valued and cumulatively semantically loaded information and cognition, which then leads to relatively fast actions (see appendix 1 figure A I - 1).

In a continuative model, Norman (Norman, 1986) outlined an action structure on six levels that included regulation of the deciding action. Herczeg (Herczeg, 2002; Herczeg, 2004) then refined these models of six typical action levels as a mental model of the user (i.e. in this context the driver) as well as a system model of an interactive system (i.e., in this context the cooperative system) (see appendix 1 figure A I – 2 and 3). On each of the six levels, actions and action regulations can take place that can be generated and controlled within each of the six levels either on the basis of skills, rules, or explicit knowledge, depending on the available time, training, and awareness state of the driver.

The quality of the equivalence of process, cooperative system model, and mental model of the driver determines to a high degree how well and directly the driver is able to understand and judge the state of the process, i.e. to reach an appropriate amount of situation awareness (Endsley et al., 2003; Herczeg, 2004).

As in these approaches, a stage model of human action with machines is assumed that can be assisted by its technical components. Unlike in these approaches for the structuring of the interaction, seven single or clustered action levels will be defined as coordinating, due to its important role as the frame of the relationship between the two interaction partners.

Additionally, it must be kept in mind that the term action level in this context shall be regarded only as a structured character. In an effective interaction, the levels described herein do not necessarily take place one after the other but instead play a continuous role (e.g. motivation).

Due to the complexity of the interaction, each stage will first be described by itself, and in the later chapters these descriptions will be used in a discussion of a potential third dimension of the spectrum of cooperative automation and also as a structure for the dialog concept, which is then applied in the investigations and experiments.

- Motivation, activation and goal setting: the essential part of this level is that the cooperation partners acquire a certain degree of motivation and activation in order to initiate an action (Bubb-Lewis & Scerbo, 1998). Knowing that motivation and activation are different factors and that their regulation identifies a different process than goal setting, they shall herein be mentioned on the same level for pragmatic reasons.
- Perception: On the one hand, the behavior within cooperation always derives from the interplay of motives and goals; on the other hand, it depends on the options offered by the interaction partner at a certain point in time. A requirement for this is that both sides are capable of receiving information about each other. However, this information in the form of signals is sometimes communicated very weakly or only briefly in the automobile environment.
- Information integration, generating situation awareness: The realization and perception of a current situation requires more than just perceiving one or more bits of information or signals. Both cooperation partners must construe what they have seen, heard, or possibly felt. An interpretation in this context refers to the allocation of perceived signals to the contents of the memory. The cooperation partners can provide each other with explanations of the information and signals by means of a) the lexical and syntactical, b) the semantical, and c) the pragmatical level.
- Decision-making, choice of action: This level of interaction between the cooperation partners ranges from information gathering and integration through interpretation and evaluation and then to behavior. Driver and overall system must decide collectively whether to wait for further external information or to act. Consequently, in the second case they should also - in the closer sense of cooperation – decide cooperatively what needs to be done. In the wider sense, one of the partners takes over the decision on behalf of the team, e.g. because of time criticality.
- Action execution is the result of the previous decision and the choice of action steps: Here, it depends on the mutual support between driver and automobile on the basis of the respective abilities and skills.
- Tracking the feedback of the action results, which in a closer sense implies monitoring and controlling: This is the final level in this process, which can also be seen as a loop. Thus, for both sides, the results of the attained cooperated action must become clear in order to verify congruency with regard to the expectations of the interaction partner. However, in the

driver-automobile context, it is not always possible to directly perceive the result of an action. Therefore cooperative interaction partners again require support to realize the effects of their action in order to evaluate these actions as successes or failures.

- Mutual and obligatory coordination (regarding goals, strategies, procedures) of the partners (in a closer sense coordination through communication) as an overall frame of this relationship: The so-called goal identity demands a conscious and methodical coordinated action of the participants in all processes relating to the action levels.

A current example of use for a potential formulation of one part of the above mentioned action levels, Flemisch's research example of arbitration[8] (Flemisch et al., 2005) derived from the H-metaphor introduced in section 2.2, shall be briefly described here.

Figure 2 shows that here, in contrast to completely manual driving, an additional entity has been developed[9]: the automation. Potential perception conflicts shall be avoided and respectively solved herein by a corporate decision-making process, the so-called arbitration, which is the novelty in relation to common approaches.

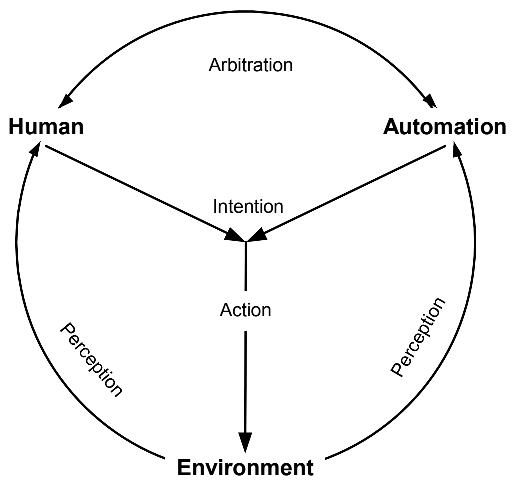

Figure 2: Arbitration model between human and automation (Flemisch et al., 2005).

[8] The term arbitration derives from the latin word arbitratus (to umpire, to mediate). In either case this approach requires a third instance which regulates, like a referee, the intentions of two potentially conflicting instances. Negotiation therefore takes place over an additional instance. With "arbitrariness," a second possible translation of the term, the application becomes even more complicated because it implicates that each of the participants regards himself as the more important one, which in turn makes it harder or even impossible to umpire.

[9] In the system theory, the entity defines either the initial or final state of a system within a string of closed operations or partly closed operations (Luhmann, 2002).

Comparing the arbitration model with the integrative model introduced in section 2.1 is not simple due to the early stage of implementation, especially of the arbitration model (Flemisch et al., 2005). The idea of arbitration matches the action level of negotiation, which also includes conflict management. The tested system is thus far unimodal but expandable. Psychological factors were not integrated into the model and their effects have not been evaluated, so assumptions regarding these factors shall not be made. Taking into account the initial user-expectations in Flemisch´s experiment for such an H-system, one can assume that Flemisch´s team will try to eliminate the problems that occurred with the H-Metaphor and expand its functionality as well as expand the model so that it can be assumed that both models are heading in the same direction.

To profit from the concept presented in this thesis it is necessary to relate the approaches explained thus far to the problem of cooperative action in the automobile and the cooperative interaction between driver and automobile, respectively. These structural approaches of human acting a) of the individual (Nielsen, 1993; Norman, 2000; Rasmussen, 1986; Wandke, 2003), b) of humans in groups (Spiess, 1998, 2003), and c) of humans and machines (Flemisch et al., 2005; Herczeg, 2002) can first be theoretically transferred to the cooperation between human and automobile and then examined empirically.

Moreover, the above-mentioned structural characteristics are at all times to be referred to in order to analyze and design relevant procedures during each phase of research and product development, and to solve interaction problems occurring in the driver-automobile interaction.

2.3.3 Process characteristics

The process of an interaction based on cooperation can be structured by means of the following characteristics:

- The **place** of cooperation (either the cooperation partners are located in the same place or in two different places). The concept discussed in this thesis refers first to the driver and the automobile being in the same place, that is to say the automobile itself, e.g. during a drive on a highway or a drive through a left turn at crossings scenario. In fact, because of the growing WLAN communication possibilities, it is also conceivable that the driver and automobile are cooperating from different places, e.g. when the system and driver exchange and compile information regarding the upcoming automobiles inspections via the home computer to transmit them to the garage;
- The **point in time** when the cooperation takes place (this can be either asynchronous by e-mail or synchronous while driving). This means that in the above-mentioned examples the cooperation partners do not simultaneously work on the compilation of information for the garage but that the system starts this task by reading out the data, which the driver later comments on and sends to the garage;
- The **type of utilization** of work equipment (parallel, serial or alternately). This aspect is closely connected to the two previously mentioned points and refers to the possibility that the cooperation partners can deal with several tasks where, for instance, in different

constellations one partner is more involved than the other one. Here, as an example from section 2.2, the brake in relation to the discussion of the findings by Endsley (Endsley et al., 2003) shall be mentioned. When simultaneously utilized, one of the participants could first activate the brake and the other would then provide residual force to reach the actual reasonable braking force needed for the situation;

- The **degree of transparency** (ranges from completely non-transparency to precise information about the partner's activities, whereas the degree can be optimized by coordination and communication). The system, continuing the ACC example, could be sensoring the situation in relation to an upcoming road block behind a curve and not communicating this to the driver so that he cannot prepare for an emergency brake to 0 km/h by e.g. buckling up. On the other hand, the car could inform the driver due to its information gathered via car-to-car communication about the situation and where the data comes from so that both together can decide to slow down well ahead. A rule of thumb for the design of cooperative systems should be that the less control for the driver, the greater the system's transparency needs to be, and vice versa.

These characteristics at a structural and procedural level are not only beneficial for upcoming system developments, but could also be referred to in terms of error analysis.

Error analysis should also take the dyad and its interactivities towards congeneric fields into consideration. An operating error could, for example, be caused by signals with a different meaning in the home computer environment than in the on-board computer of the automobile. In this case, an adaptation would be appropriate.

2.4 Supposed potential of the cooperative interaction concept

The first attempt at outlining the concept seems to be promising. To justify this continuative concept, then it must be asked how beneficial it is in comparison to existing approaches or concepts. For this purpose, the difference between the actual concept of assistance, as it has been described in the above examples of driver assistance systems, and the integrative concept introduced herein will be explained below.

As one could see from the comparison with the integrative model, both concepts have many elements in common but are by no means identical or analogical. In the case of cooperative interactions, the focus is mainly on the corporate and simultaneous performance of the task or on the utilization of existing functionalities by human and machine, which in a narrow sense is characterized by quasi-social exchange and interaction processes concerning the course of goal formation, planning, and coordination of driving-related activities.

Most of the current assistance systems are of autonomous character, as functional actions cannot be influenced by the driver in chronological order. This is exactly where cooperation sets in: initiated functions in the concept of cooperation in the human-machine interaction must always be understood as the final result of an interaction sequence; the cooperative adaptation modifies the way, the extent and the structure of individual assistance functions together with the required interaction sequences by both partners, whereas this varies in each case depending on situation and person.

The possible flexibility[10] arising from this concept is certainly not unlimited, but ranges within a defined sector, herein referred to as a design tunnel, since this sector alone can be used for creative measures. The boundaries of the defined sector result from the combination of potential ranges of two dimensions:

The level of automation

In accordance with existing approaches towards the level of automation (Billings, 1997; Herczeg, 2002; Parasuraman, Sheridan, & Wickens, 2000), the degree of automation is defined by the respective function allocation between human and machine, i.e. who does what. The popular level illustration is transferred here into a two-dimensional spectrum with a suggestion for a third dimension. The first dimension (y-axis) reaches from the exclusively manual performance of certain functions by humans to the complete automation of certain tasks.

Driver involvement

The second dimension (x-axis) describes the so-called driver's involvement and is defined by its cognitive-motorical attendance during the performance of individual tasks. Involvement in this context is to be understood more comprehensively than the social psychological term of involvement, as this only describes the stimulus-related sensory activation on the basis of situational and personal interests (Kapferer & Laurent, 1985). However, regarding the concept of cooperation in the human-machine interaction, it is to be emphasized explicitly that involvement in addition to the sensory activities (monitoring, showing interest) also comprises active integration into the interaction and operation sequences.

This active integration happens as described in section 2.1 as parallel, serial or alternating (Endsley et al., 2003) processes by driver and system, whereas parallel execution is the preferred option, due to its reliability. Due to the possible different outcomes when executing the same task (e.g. braking), an exchange process must take place.

Figure 3 depicts both dimensions and shall be referred to in the following as the spectrum of cooperative automation of assistance systems, whereas the relevant design tunnel is grey underlayed.

[10] This includes the adaptability of the cooperative interaction concept towards the specific dyad as well as the scope of design and action for the dyad itself resulting from the nature of this concept.

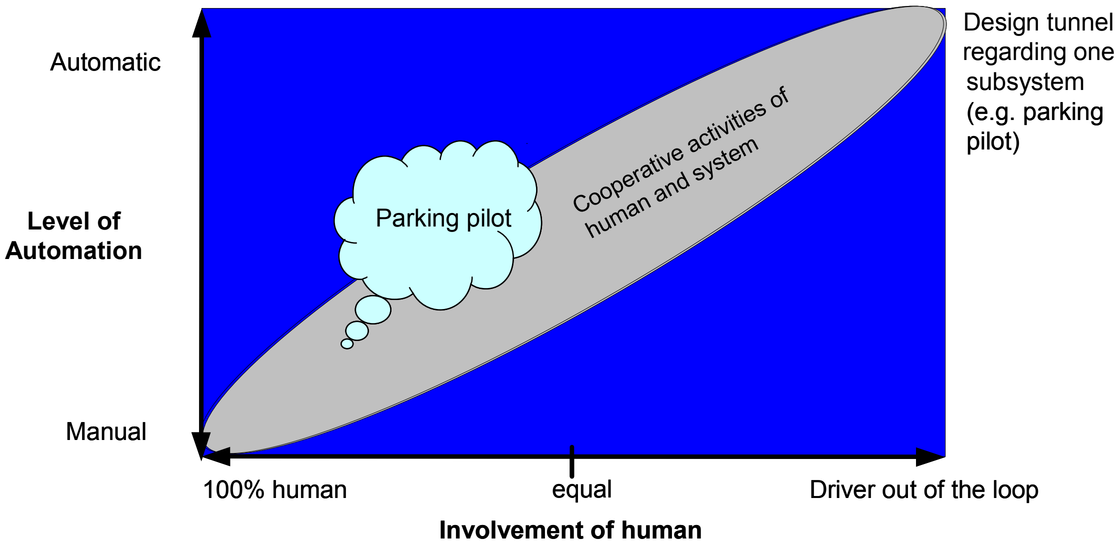

Figure 3: Spectrum of the cooperative automation of assistance systems (Biester, 2004).

To successfully lay out a cooperative system, the intersections of both dimensions must lie in the light grey area, as all solutions outside this area are inappropriate.[11] An exemplary solution is such a parking aid system in which the driver is relatively strongly involved (e.g. braking and acceleration), while the system offers partly automated support (e.g. parking-space measurement). This kind of distribution in today's systems is static and in terms of cooperation would have to be designed dynamically.

As a potential third dimension (z-axis) the subordinated characteristics described in section 2.3.2 can be taken into consideration in a further elaboration of this concept.

So the crucial question regarding the four aims of this thesis stays the same: What is the provable potential of the extension of existing approaches by adding the term of cooperation? It is herein postulated that cooperative interactions are a benefit because of their exchange and interaction processes in three contexts. These three contexts are the driver, the automobile, and the traffic environment. These will be described and discussed with the focus on the exchange and interaction processes in regard to their consequence, their utility, and their potential compared to classical assistance.

[11] Thus, for example, it is to assume that with increasing automation the driver's involvement decreases; but then a manual control without his involvement, at least beyond routine actions, is hard to imagine.

2.4.1 Supposed potential of a cooperative interaction for the driver

The first of these three contexts refers to the potential of a cooperative interaction for the driver derived from the integrative model. In detail, it signifies that,

- The exchange processes between human and automobile can be optimized by:
  - Increasing the quality of interaction
  - Supporting and improving communication (e.g. by natural spoken dialog)
  - Promotion of situation awareness
  - Optimization of workload, as well as
- Improved preservation of competence and support of the learning processes and by building up know-how, respectively
- A measurable increase in acceptance and trust
- An increased satisfaction in oneself and the overall system

In the following these fields of potential are further discussed in terms of their verifiability.

2.4.1.1 Optimization of the exchange processes between human and automobile

The optimization of exchange processes, as a medium to reach cooperation, can first of all be achieved by properly setting up and negotiating the process characteristics in the respective dyad, thus enabling the interaction partners to reach a common knowledge base. How these processes can be established and how they can be enhanced shall be discussed in the following.

2.4.1.1.1 Increasing the quality of interaction

The modality spanning improvement of the interaction quality is regarded as one of the cornerstones of the cooperation between driver and automobile. This starts with trading the communication styles for the scope of the linguistic interaction (e.g. the introduction of the possibility of asking questions), and, moreover, it also implies the existence of an option by which the system calls the driver's attention to unused functions that are similar to his choice of functions (e.g. in the logical advancement of the idea of today's known 'tip of the day,' as applied in some software programs).

Therefore, established basic conditions for the interpersonal interaction quality (Allwood, 2001; Stauss, 2002) shall be transferred to the relevant context stated herein (Miller, 2000; Miller & Funk, 2001; Wagner, 2002). These are, in detail, friendliness and politeness, empathy and understanding, endeavor and helpfulness, as well as activity, initiative, and reliability.

Attainment and compliance with those indicators requires a clear and binding communication. Its basic conditions are described in the following by means of a cooperative dialog concept and the cooperative maxims.

2.4.1.1.2 Support and improvement of communication

To be able to make a proposal regarding the support and improvement of communication in this concept, first the communication itself and some of its psychological influencing variables shall be elaborated upon.

According to its Latin roots, communication means "to make something common" (Simpson & Weiner, 1989), to make known, and this at least in a dyad. The driver and the system, if they want to cooperate, must closely coordinate their actions as a differentiation criterion towards other forms of interaction in order to communicate information known within their dyad (i.e. to add this information to the other one's basic knowledge and thus to the dyad).

The rising interaction complexity between driver, automobile, and environment and the presumed increased trade-off resulting from this, therefore demands an efficient communication, which in turn must be prepared by the team of developers.

As the exchange of information is the primary means of reducing uncertainty, the demands of communication between the interaction partners, human and machine, must be analyzed. This analysis includes consideration of the human psyche as well as the social structures of the interaction. Only with the aid of an interdisciplinary perspective such as outlined in the problem definition is an overall analysis and method of arrangement of the communication processes made possible.

Communication without cooperation at first does not seem possible: however, without the will to understand what the interaction partner has meant, communication must fail. The essential part of communication is the transfer of intentions by the sender (e.g. the transmission of a message, question, or request).

In the situation of a conflict, this dependency relationship will be the most obvious. As a result, reflection upon conflicts within an interaction concept becomes primary, as psychological factors become apparent when analyzing the conflict, for instance, by an analysis of different types of errors that occur (see therefor Reason, 1994).[12] A 'lack of knowledge' or 'ignorance' of the other's goals and expectations in general leads to conflicts, whereas the expectations can be influenced by the interaction partner's feedback.

Unfortunately, until now there has been no generally accepted concept that encompasses the management of conflicts (Easterbrook, 1993). This is why the biggest potential of cooperative

[12] Reasons for this may be that, for example, the actions as well as the measures of a system could not be perceived because of the semantics, the pragmatics, or only because of the visibility, a distraction, or avoidance, or because of a lack of adequate mapping (Norman, 1990, 2000). Furthermore, the psychological background of the human interaction partner can be favorable, for instance, if he attributes rather internally or externally (Rotter, 1971, 1980) or which strategies of behavior adaptation, risk compensation, and risk motivation, respectively, he pursues. However, as these psychological influencing variables cannot be explicitly referred to in the empirical part of the thesis, they will not herein be discussed in detail.

interaction lies in preventing conflicts between driver and system, or, in cases where they do appear, to identify, manage, and optimally solve these conflicts.

The maxims of a cooperative conversation by Grice (Grice, 1975) present a proper starting point for the topic of cooperative dialog in the herein explained dyad, as they offer the possibility of both avoiding conflicts and of solving them by returning to the maxims.[13]

Grices's theory, which is also the theoretical basis of the Halden human-automation-cooperation questionnaire by Skjerve et al. (Skjerve & Skraaning, 2004) applied in the experiments, proclaims a cooperative principle on the basis of four conversation maxims (see table 1). The main assumption is that the one who listens can expect that the speaker optimally tailors his contribution to the concerns of the conversation but also to a specified, agreed upon goal (Clark, 1996). The maxims are given in detail in table 1.

Table 1: The four maxims for the cooperative principle according to Grice (1975).

Maxim of Quantity	• Make your contribution as informative as required. • Do not make your contribution more informative than is required.
Maxim of Quality	• Do not say what you believe to be false. • Do not say that for which you lack adequate evidence.
Maxim of Relation	• Be relevant.
Maxim of Manner	• Avoid obscurity of expression. • Avoid ambiguity. • Be brief. • Be orderly.

The haptic sense, for example, should in the future play a far more significant role within this interaction (Flemisch et al., 2003), as haptic input and output underlie the smallest ambiguity of all

[13] A more recent approach by Miller (Miller, 2000; Miller & Funk, 2001) that has been developed more concretely from the experiences with adaptive assistance systems and which contains a 12-point rules of etiquettes list can be seen here as a summary for an interaction concept allowing more natural, more productive, and also more polite design of the driver-automobile interaction. Because of the design character of this approach, the better known theory by Grice has been chosen here as the platform.

senses and resolution possibilities, and the speed of processing haptic information is evidently better and faster than that allowed by optical or acoustical feedback (Salmen, 2002; Sarter, 2002).

However, since in the experiments a multimodal interaction could not be put into practice due to technical difficulties as well as the need for complexity reduction at this early stage of the conception of the cooperative driver-automobile interaction, the main focus shall be in the following directed toward a suggestion for a natural spoken dialog. This necessary limitation was suggested by the results of the scenario-based interviews, as speech was found to be the preferred interaction modus for the tasks discussed (see chapter 4).

Therefore, figure 4 shows a conceivable dialog concept for the support and improvement of communication in the driver-automobile interaction. The figure depicts the main network for the whole cooperative dialog, whereas the first parameter in brackets always signifies the sender and the second one the recipient. The states 1 to 4 are to be considered as inside the core dialog, and states 5 to 8 as terminal. The cooperation goal is to achieve state 5, preferably directly or within only a few cycles, after inquired or offered information is provided and judged to be sufficient. Usually this goal is not reached that easily. For information-seeking dialogs, common characteristics are corrections, embedded clarification sequences, and iterations (e.g. the cycle 1-2-3-4-1).

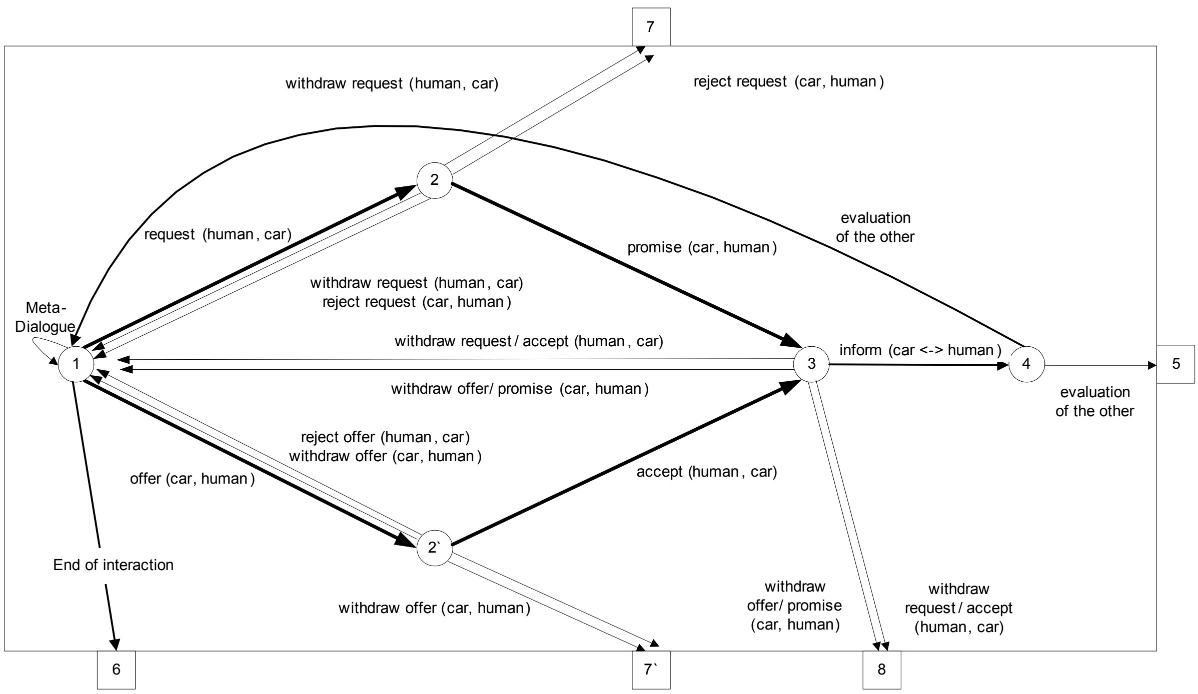

Figure 4: Cooperative dialog concept in automobiles as based on Stein (1995).

Transitions that lead back to state 1 or a terminal state are defined as “alternative,” so as to differentiate them from the expected transitions. Regarding the model of Stein (Bateman, Hagen, & Stein, 1995), these transitions shall not be interpreted as uncooperative deviations, interruptions, or even breakdowns. For example, the system still acts cooperatively with a reject request and termination of the specific dialog part, when a request by the driver cannot be answered and when no further action possibilities are available (Winograd & Flores, 1986). Certainly, a justification would be appropriate in this case. This cooperative dialog concept contains further subnetworks that explain the so-called “dialog moves” in this overall structure, which shall not be discussed herein due to space, but which are addressed in the description of the cooperative prototype (see section 5.2.1.1.2 and 6.2.1.1.2).

Additionally, based on the concepts of communication science, here in particular the intentional aspects of dialog contributions of sender and recipient, their conversational tactics, and their mutual role allocations (see also section 2.1) will be included (Stein, 1995). These factors serve, in connection with the before-mentioned maxims, to aid in the prevention of conflicts and misunderstandings.

Thus figure 4 illustrates a possible cooperative dialog concept for the herein discussed driver-automobile interaction that is also able to describe complex interaction patterns and dialog strategies. Referring to this dialog structure, the action levels of section 2.3.2 are reflected in the main experiments, at first exclusively for a linguistic interaction.

Connolly et al. have searched for a language of cooperation in a CSCW setting (Connolly & Pemberton, 1996). They have analyzed the frequency of used words and found 20 words that are most commonly used in human-human cooperation (e.g. with “you” being the most used word). These results can be taken as a base vocabulary for a cooperative system, thought they must be adapted to this specific context. One means of achieving this adaptation would be to search the language of drivers for conventional words and phrases that are used in specific situations, with regard to their confidence that the system shares their knowledge (Weinschenk & Barker, 2000). This endeavor, however, will be not be a part of this thesis.

A cooperative driver assistance system must be able to actively mediate between the driver and all corresponding components of the overall system by offering multimodally flexible interaction possibilities and reasonable user guidance strategies.[14] The dialog concept presented herein conceives of the interaction as a "cooperative negotiation,” within which the user and system develop corporate plans, goals, and solution strategies. It combines a comprehensive formalism to describe local conversation patterns and tactics with the modeling of global dialog strategies and plans.

On the other hand, it is critical to remember that the dialog concept of Stein is not exclusively reserved for the cooperative layout. It must also be extended by requirements such as the basic conditions of the interpersonal interaction quality and maxims postulated earlier in this thesis, to show more explicitly how, for example, a common knowledge basis can be established by this concept.

[14] As a preparation for an extension and improvement on this dialog concept, it would be of interest to analyze in diverse iterations what kind of questions (style), what numbers of questions and which length of questions arise in specific situations based on the interaction of this concept. Keeping also the avatar research in the automobile sector in mind, visual recognition studies focused on the driver's gesture and mimic would be of use for enriching prospective dialog concepts. The approach chosen herein provides the structuring basis for such research questions.

Furthermore, for an interactive and cooperative dialog, design of the systemic network shown in figure 4 must be based on a temporal organization and must allow recursive partial cycles to clarify or correct contents. Possible combinations and sequences of such dialogs could then be described as recursive state-transfer networks.

Therefore, considering the possibilities of automation use, misuse, disuse, and abuse (Beck, Dzindolet, & Pierce, 2002; Parasuraman & Riley, 1997; Pilke, 2004), a discussion of the related psychological effects of a cooperative dialog in the driver-automation context will be undertaken in the following.

2.4.1.1.3 Promotion of situation awareness

For specific technical systems based on present approaches to human-machine function allocation, critical problems in relation to automatic interferences have been observed and documented (Billings, 1997; Moray, 2003; Sarter & Woods, 1995; Wiener, 1989). In the literature, these problems are linked in relation to the user with diverse deficiencies like high workload (de Waard, 1996), complacency (Bahner & Manzey, 2004), decline in vigilance (Molloy & Parasuraman, 1996), and situation awareness (Endsley et al., 2003), whereas one of the main factors in these performance problems of users in complex systems is the so-called phenomenon of "Human out of the loop" (Endsley & Kaber, 1999; Kaber & Endsley, 2004).

In Endsley's (Endsley, 1995a) concept, situation awareness can be defined within the spectrum between recognition and understanding of the actual process modes and coverage of the overall situation (i.e. the integration of a state in a specific process of actions and the series of states resulting from this integration).

This spectrum is to be achieved by cooperation, which provides optimized information exchange between human and automobile, according to the principle of "two heads are better than one."

By implementing an interaction based on the fulfilled basic conditions of cooperation, as described in section 2.3.1, the above-mentioned performance problems can be overcome because the driver is thereby involved in the processes and a common intention and knowledge basis is developed that enables both the driver and the system to gain better information about each others' tasks.

2.4.1.1.4 Optimization of workload

In the concept presented herein, it is necessary to understand a cooperatively designed interaction between driver and automobile as an optimization factor for known situations in the traffic psychological environment. This cooperative interaction must be the counterbalance to any high or low workload, respectively.

The strain and workload model by Oesterreich (2001) refers to mental workload as all external influences that impinge upon a human and that are mentally stressful. In the traffic context, the form and extent of the workload depends on: the exact driving task and action, the organization of the collaboration (see also the process characteristics in section 2.3.3), the available auxiliaries (see section 2.3.3 again), the physical environment (e.g. visual range, construction, course of the route, surrounding traffic), and the social situation of the driving environment (e.g. role distribution or role understanding, interaction climate) (Nachreiner, 1998).

However, it is based only on individual psychological requirements like abilities, experience, motivation, attitude, constitution, etc. whether strain becomes positive workload, as to say a stimulation, or a negative workload and, thus, an impairment. Stimulation leads to activation and can contribute, in the long run, to personal development. Impairments, however, lead to fatigue, monotony, satiation, and stress for the driver, which can cause a break in the cooperative interaction.[15]

To exemplify such an effect, when the balance between strain and workload is not reached, the complacency-effect researched in aviation is discussed, and can be assumed to apply in the automobile sector as well (Farrell & Lewandowsky, 2000; Moray, 2003; Parasuraman, Duley, & Smoker, 1998; Parasuraman, Molloy, & Singh, 1993).[16] In German-speaking areas, this effect is also established under the terminus of learned carelessness (Frey & Schulz-Hardt, 1997).[17]

In the empirical part of the thesis, it is important to verify whether this or other effects will be promoted by one of the system variants.

This testing is conducted by utilizing the concept of modifying the form of the interaction and thus for the most part by designing the interface. For this purpose, this dissertation as a first step analyzes the interaction as the main manipulation variable by systematically varying external influencing factors. In doing so, the cooperative concept satisfies the complexity of interactional-related and individual particularities and paves the way for various approaches to intervention or prevention for the driver and the system by its inherent degrees of freedom, but above all by the system in order to optimize strain and workload. It is herein hypothesized that this approach can lead to an increase in the interaction quality.

[15] This can be measured, among others means, by evaluating the latencies of the driver's reactions on tasks, and by attention and fatigue based on the measurement of steering movements or by pupil movement and pupil opening, respectively.

[16] It must be mentioned here that there is still discordance about whether this effect truly exists or not.

[17] The phenomenon of learned carelessness in traffic is regarded as the cause, for example, of massive freeway pile-ups (Frey & Schulz-Hardt, 1997). It is characterized by four symptoms: reduced motivation in risk detection, reduced ability with regard to risk detection, noncritical cheerfulness, and a shortened time perspective. For the driver, this phenomenon results in delayed learning behavior or a missing willingness for behavior modification and a too hasty revision of these with the slightest signs of improvement, as well as too inappropriate and risky actions (e.g. a driver neglects to maintain his position in a lane because he assumes that the LDW will warn him if his behavior is dangerous).

2.4.1.2 Competence preservation and promotion of learning processes when establishing practical knowledge

To promote an understanding of and intuition regarding this continuative concept, as well as to promote learning, system and driver require the potential for developing complex and flexible perspectives (Burleson, 2005). The development of practical knowledge and the preservation of the competencies involved are two of the most important goals in relation to the cooperative concept.

The transparency of communication exchanges and information, in particular in a cooperatively designed interaction, as described in section 2.4.1.1.2, will enable various learning processes and above all will make them necessary. Proven effects from empirical research regarding cooperative learning methods such as Team-Learning (e.g. brainstorming) and cooperative computer supported learning (CSCL) between humans (Straub, 2001) have shown that some of these methods can also be considered as very efficient in the driver-automobile context. However, these assumptions are based on the requirement that the methods are applied correctly and, if necessary, are customized. Satisfying this requirement, however, is not an easy task and demands profound knowledge of the existing or potential problems that can arise from each individual method (Sharan, 1994).

To discuss these cooperative learning methods in detail would go too far at this point, but several relevant aspects shall be described herein because the idea of the integration of learning methods goes beyond actual interaction concepts of driver assistance systems. In the driver-automobile interaction, learning in terms of the cooperative concept must always be considered as an active and constitutive process in which, besides the affective components, most importantly the driver's experiences must be taken into account. To do so requires factors such as the driver’s willingness and individual competence as well as a structuring of interaction that is, as already mentioned, based to a certain extent on intentions.

One example taken from today's human-human cooperation is that a young driver learns from an advanced driver how to deal with the overall system, i.e. the automobile. Projects like "accompanied driving" in Germany, in which 17-year-old beginners receive a driving license only when they drive the car within the first year accompanied by experienced drivers aged over 30 years, provide an idea of what kind of potential results from a cooperative driver-automobile interaction: hence tutored driver training systems (Onken et al., 2001) or observational learning using an avatar as a pre-level for full cooperation are only two examples. This potential is emphasized by the first results of the "accompanied driving" field trial, for example, in leading to 22.7% fewer traffic violations and 28.5% fewer accidents (Feltz & Kögel, 2004). Some of the effective learning methods involved in the human-human interaction could likely be transferred to the human-automobile interaction.

In this example, again the close connection between driver-automobile and human-human cooperation can be illustrated by the conceptual disposition of the roles previously argued in section 2.2. As a further differentiation criterion compared to other interaction concepts, this correspondence can enable the driver to interact with the various interaction partners (technical or human) using the same action strategies.[18]

The learning effectiveness of an interaction situation is thereby defined by the design of the driving task. But if an effective learning situation promotes learning, it clearly depends on the learning culture of the dyad. Thus for the driving itself and for special driving tasks in the driver-automobile interaction, learning and competence-promoting characteristics must be defined.

Developing this process to enable functioning driver-automobile cooperation also includes the making of mistakes and the ability to detect and understand these mistakes as well as the motivation to learn from such mistakes. To effectively identify and learn from mistakes requires an error culture in which mistakes are managed mutually in terms of continuation of the cooperation.

2.4.1.3 Satisfaction gain through increased acceptance

Moreover, it is hypothesized that for the driver a cooperation-based interaction leads to a gain in satisfaction with technical innovations and thus leads to an increase in acceptance. For this purpose, the relevant influencing variables must be clarified with regard to acceptance of this concept. As the terminus acceptance is used inflationary, it shall be first of all specified for the herein discussed context.

In accordance with Lucke (1995) the term acceptance is defined by Stern & Schlag (1999) in the scope of their studies on the acceptance of traffic safety promoting measures as "the agreeing attitude of a person towards a certain traffic safety promoting measure, whereas the willingness exists to act and deal with it in a constructive manner." Attitudes and behavior intention are embodied in this definition. However, acceptance on the level of behavior intention does not meet the needs of a definition in the context of a cooperative interaction system, as the intention towards a certain behavior also cannot provide a reliable prediction of actual behavior (Ajzen, 1991).

Therefore, it is necessary to provide a short overview of the influencing factors on the acceptance of products that have been reported in the literature.

The adopted integration model by Dethloff (2004), which deals with the acceptance and nonacceptance of product innovations, is currently the most comprehensive. By means of this model, the predictability of the behavior of the product utilization presented in this case shall be verified and established.

[18] In relation to the dialog and interaction concept, respectively, presented in section 2.4.1.1.2, however, it must be considered that the driver must be aware that he opens himself to criticism and management (e.g. through the cooperate system or a front seat passenger) when disclosing his actions.[19] In this connection, it is imaginable to use the development of the "Autostädte" of several car manufacturers in order to give the car owner or user, respectively, the opportunity to experience mediation by the car dealer in the case of difficulties in the interaction, analog to the idea of arbitration, (see section 2.3.2) for gaining new trust in the cooperative dyad.

Dethloff's model has the access point origin to the subject matter at the triggers of acceptance or rejection of a product, respectively. Furthermore it correlates these triggers and therefore makes them measurable. Some of these relation patterns have been intensively discussed in the literature (Mackie & Wylie, 1988; Miller, 2000; Rouse & Morris, 1986; Van der Laan et al., 1997). Figure 5 therefore shows a possible model that additionally includes the aspects that have thus far been neglected.

The model also includes, based on personality characteristics, the learning processes demanded in the previous section, which in turn influence not only these characteristics and other diverse variables, but also the overall acceptance.

The most significant influencing factor spanning all technical product categories in this model is the perceived risk with both of its components: benefit and cost risk (Dethloff, 2004). Within the integrated adoption model, the perceived risk with a standardized overall effect of .61 and a single correlation coefficient of r = .44 shows the highest values, which means that almost 20% of the variance of the innovation disposition can be clarified by the perceived risk. In contrast, these values show, because of the coherence within the model, the difficulty of this research field and encourage further investigation; in addition, they represent the reason of its affiliation in the working definition in section 2.1.

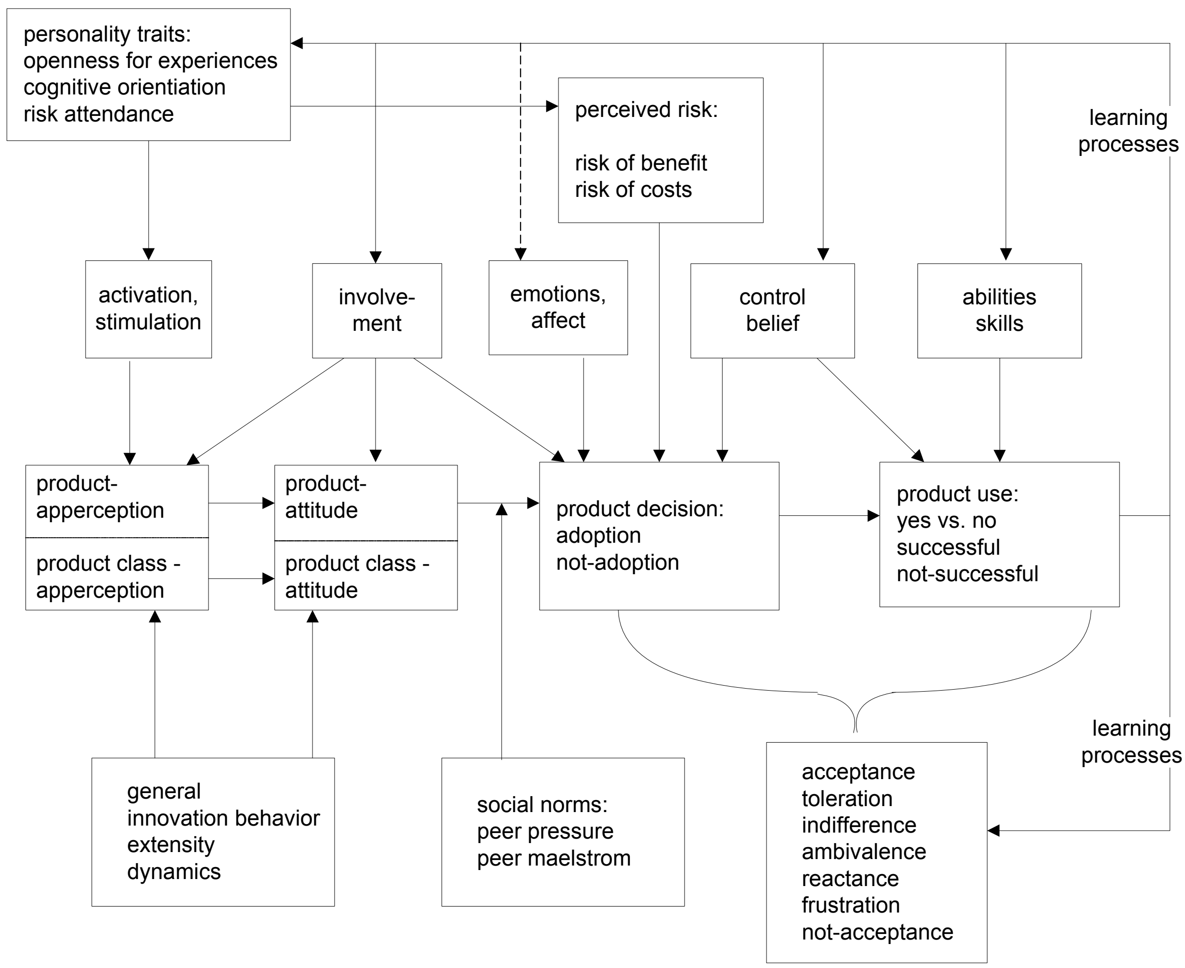

Figure 5: An integrative model of adoption of innovations according to Dethloff (2004).

Due to the complexity of the interplay of influencing factors of Dethloff's adoption model and their scope, however, a simplified model shall be applied for further discussion and evaluation (see figure 6).

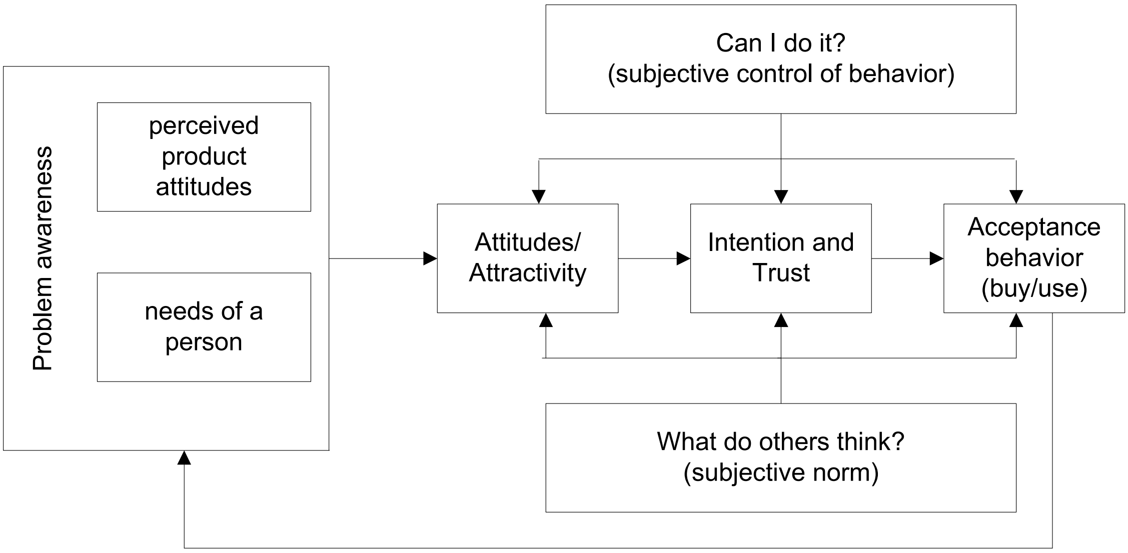

Figure 6: Simplified presentation of the model of acceptance in its components in regard to Arndt (2004).

The simplified model of acceptance by Arndt (for a comprehensive illustration see Arndt, 2004) is built on Ajzen's theory of planned behavior (Ajzen, 1991; Elliott, 2004) and represents the causal relations between attitude, behavioral intentions, and behavior itself. Ajzen's theory, therefore, has in many cases been taken into account as a model for the explanation of acceptance and for the design of acceptance models, respectively. In the concept presented herein, it constitutes the theoretical basis for the acceptance questionnaires in the empirical part of this thesis, mainly in the second experiment, and is extended by selected aspects from Dethloff's model.

Both acceptance models serve as a means of critical examination when implementing the testing environment.

2.4.1.4 ncreasing trust

As stated earlier, the development of cooperation in a particular situation requires a certain amount of time, for example, to build up trust; but the longer this period of evolution takes, the lower are the chances for a successful outcome for the cooperative behavior and the more likely it is that an individual approach will be taken by the driver in that situation (Lichtenberg, 1956). It seems that complex cognitive and communicative processes must take place before a partner is seen as trustworthy. The assumed mutual trustworthiness (e.g. the driver supposes that the system intends cooperative system behavior and expects - because the system presumes the user is aware of this intention - that in this situation the success of the two is based on collaboration) leads to cooperation, as Loomis (1959) has shown in human-human relationships.

Discordance, however, exists in whether trust can be considered as an expectation or attitude (Barber, 1983; Muir, 1994; Rempel, Holmes, & Zanna, 1985; Rotter, 1967), or intention or behavior (Deutsch, 1960). In the herein discussed context of the driver-automobile interaction, however, Lee & See's proposal (Lee & See, 2003a) appears to be the most practicable, as it also integrates the construct of reliance. Having recourse to the framework model by Fishbein & Ajzen (Ajzen & Fishbein, 1980) Lee & See (2003) understand trust in automation as attitude, and reliance as the corresponding behavior. As a result, trust exerts influence on behavior only indirectly through intentions (see also figure 6), whereas different external factors (e.g. time pressure) can influence the intention development and its realization into concrete behavior. Consequently, higher trust must not necessarily reflect actual behavior (for a graphical illustration of the overall coherences regarding Lee & See, 2003, see appendix I). Trust is hereby furthermore understood as a differentiating criterion between cooperation and conflict (see also integrative model 2.1).

For conceptual contexts it is important to understand that there are many ways to influence the trust-building process. Muir, for example, suggests recalibrating the user's trust, for example through training, when necessary (Muir, 1987). This recalibration can be undertaken by experienced drivers, car dealers, or in some cases by the system itself,[19] as proposed in section 2.4.1.2. Additional research by Lee and Moray (1992a; 1994) has indicated that automation is used when trust exceeds self-confidence, and that manual control is used when the opposite is true. These results must be reflected in all possible situations of the concrete driver-automation context and must be balanced according to the intended practical approach to the interaction, so as to minimize negative effects (e.g. complacency or a lack of situation awareness) on both sides (Parasuraman et al., 1993).

The effectiveness of either cooperation or concurrency between social actors and their effects on the individualistic efforts for performance and productivity have been discussed already for many years. In a meta-analysis, Johnson et al. (1981) reviewed 122 studies and compared the relative effectiveness of human-human cooperation, interpersonal competition, and individualistic goal structures in promoting achievement and productivity. The results revealed two interesting findings for the driver-automobile context, first that cooperation is considerably more effective than interpersonal competition and individualistic efforts, and second that there is no significant difference between interpersonal competition and individualistic efforts. Through multiple regression, a number of positive mediating variables such as resource sharing and task interdependence were identified.

Giving designers a context-based guide at hand that would widen the gap between the two sets of results mentioned above by focusing on mediating variables would be a positive step in the direction of the acceptance of cooperative systems by drivers.

2.4.1.5 Indicators for the benefit of cooperative interaction

Before the next two contexts of automobile and environment are discussed, the aforementioned potentials, in summary, shall herein be transferred into indicators for an expected benefit of the cooperative form of interaction for the human. It is now of great interest to determine how the benefit, from a human perspective, can be examined and verified for the interaction based on cooperation compared to other forms of assistance.

As a benefit for human-human cooperation, based on the example of police emergency vehicle operations mentioned in section 2.2 as well as from the experience of such situations itself, a diminished risk, with notably more even and calm driver speed behavior as well as a significantly lower emotional workload, has been demonstrated as a result of such a cooperation (Neukum & Krüger, 2003).

As test criteria, only hypothetical for the time being, the potentials of a cooperative interaction for the driver (see section 2.4.1), which are made up of the submissions of the following sections, are taken into consideration; their indicating potential shall be at least partly verified in the described experiments in chapter 5 and 6.

Thus, experiments must be set up which verify the cogency of the characteristics, basic conditions, premises and indicators contemplated in this chapter.

2.4.2 Supposed potential of an interactive cooperation for the automobile

In the second context, which is important for many automotive suppliers that combine the production of driver assistance systems with the production of many other electrical and electronical devices, the following potential with regard to the complete system - that is the entire technical unit, including software and automobile components - is postulated:

- Simplification and reduction of algorithms.
- Faster system response times. Resulting from the previously listed postulate, requests made by the driver can be more clearly detected due to the common knowledge base.
- Reduction of wear, hence extended automobile durability.
- Improved input by the driver due to improved communication, which in turn helps the system to conduct a more adequate self-diagnosis.
- Increased safety measures, for instance to avoid traffic accidents. This can be achieved by optimally compensating for the driver’s inattention as well as by improving warning strategies. For example, as a matter of prestige, both designer and automotive manufacturer are focused on car safety, and this self-interest can be depicted by the system.
- Improved utilization of energy resources. In this case, a negotiation process prior to commencement of a drive shall be assumed. For instance, as soon as the driver indicates his destination, the automobile can propose to defer the start due to current congestion on the driver's route, as congestion will ideally clear before the driver's preferred time of arrival. Consequently, the driver's resources are saved as he can pursue other tasks at his place of departure, and automobile wear is decreased by not running in idle mode while stuck in congestion.

However, proving this potential is not a subject of the experiments in chapter 5 and 6 because it could not be fully tested in the driving simulator environment.

2.4.3 Supposed potential of an interactive cooperation for the traffic environment

The third context is subject to the potential of the traffic environment; in particular the issues of reducing traffic accidents (e.g. as a result of car-to-car communication) and optimizing traffic flow (e.g. providing and analyzing the appropriate information for self-organizing traffic).

One example of reducing traffic accident numbers shall be discussed in the context of the aforementioned phenomenon of learned carelessness (Frey & Schulz-Hardt, 1997). Contrary to recent interactions, cooperative interactive partners would ideally match the speed deliberately to the potential risk of accident in fog and thus be able, in the event of an emergency, to gradually stop using car-to-car communication.

Another starting point for the high potential entailed through cooperation is the provision and refurbishment of information for self-organizing traffic. A classic example is congestion on a highway. Detours provided statically are soon blocked as well when used by all drivers. In such cases, optimized traffic flow would then be obtained by the state of equilibrium if no road user would assume to shorten his travel time by following an alternative route[20] but staying on his particularly proposed route instead.

Both of these examples of a more complex cooperation than described thus far for dyadic human-automobile interaction highlight the embedding potential of the concept in comparison to other approaches. This will be deeper allegorized on the basis of socio-technical system layers (Rammert, 2002b) in chapter 8, to answer the question of how the frame of reference is defined and to inspire designers with regard to the future design of driver-automobile interaction.

[20] Mathematically the benefit of the choice of a specific route will be shown as a random variable with a systematic (deterministic) component and an error term (resulting from the subjective appraisal). The perceived overall travel time will be described via a probability density function, with which the variance, different behavioral degrees, and degrees of information during route selection can be mapped.

3 Specification of the problem and hypotheses

The concept of “Cooperative Automation in Automobiles” establishes the automobile’s electric and electronic devices with a focus on driver assistance and driver information systems via a software and hardware platform as one interaction partner to the driver. This approach enables therewith the possibility of setting up an integrative model and basic conditions affiliated with the advantages of cooperation.

Derived from this concept, many questions and hypotheses qualify for more sophisticated evaluation.

In the following, a selection of questions and hypotheses will be deduced that are crucial to a better understanding of cooperative interactions. These hypotheses will be tested empirically (methodically controlled and variable varied) to generate and corroborate insights for the design of driver-assistance systems in the outlined field of driver-automobile interaction and to be able to answer the questions (see chapters 5.5, 6.5 and 7).

As such, two driving scenarios “Overtaking on Highways” and “Turning Left on Urban and Country Roads with Oncoming Traffic” were created in a driving-simulator setting. To make the hypotheses comprehensible, these scenarios will be briefly explained below.

In the “Overtaking on Highways” setting as experiment 1, participants had to complete four courses of 29-Km length on German highways, overtaking 12 trucks on either a straight part or a bend on the track (factor road). Each course had either low or high traffic density (factor traffic) combined with low or high visibility (factor weather). Participants were split into four groups, and each group had to interact either with a manual, a cooperative, a half automatic, or an automatic system variant (factor function allocation) regarding the typical activities in such a situation.

In the scenario “Turning Left on Urban and Country Roads with Oncoming Traffic” as experiment 2, participants had to twice drive 35 Km on a combination of urban or country roads, turning left with oncoming traffic, with the task being to turn left ten times each. Here, participants were divided into two groups, interacting with either a manual or a cooperative system regarding the common activities in such a situation.

The following questions will be formulated in a formative and summative manner. Accordingly, they do not refer solely to the individual chapters but also represent an integrative superstructure on the examinations described in chapters 4 to 6. However, the hypotheses refer to the respective experiments due to the dissimilarities between them.

3.1 Questions

Based on the existing concepts and their challenges with regard to designing modern assistance systems in automobiles, a cooperative layout of the driver-automobile interaction raises the following questions:

1. Does cooperation as a form of automation take place in selected driving situations?

It is essential to ask initially whether cooperation in this particular environment with this particular prototype a) can be realized and b) can be experienced by the driver.

2. Is it possible to show in selected driving situations that “cooperation” in this form of an experimental prototype generates a benefit from a subjective point of view?

The response to this question is the main objective of this paper. The instantiation of the concept of “cooperative interaction in automobiles” has not yet been studied or even verified. It is therefore important to determine whether a subjective benefit from this form of interaction can be obtained.

3. Is it possible to show for selected driving situations that “cooperation” in this form of an experimental prototype generates a benefit from an objective point of view?

It is essential to identify and judge the similarities and dissimilarities of different situations in which the technical realization of a cooperative interaction is possible and determining whether implementing this interaction into the driving is desirable and reasonable.

4. What effects do situational characteristics have on the objective parameters and the subjective rating of cooperative systems in automobiles?

This question focuses on situations in traffic that come with different potential for workload, which can be described by the degree of difficulty of the roadway or the traffic density. Also, such environmental factors as the weather and its associated effects on the driver’s line-of-sight obstruction must be analyzed in relation to their effects on cooperative interaction.

3.2 Hypotheses

Based on the above-formulated questions, a selection of hypotheses was derived with inherent special relevance.

3.2.1 Hypotheses for experiment 1

In the following, the hypotheses for the driving simulator experiment “Overtaking on Highways” are formulated:

H1: The four different test conditions of the experiment should differ on the level of the most important objective and observable performance data, respectively, as follows:

H1a: The manual system variant stands out based on the significantly worst results with regard to the most important psychophysiological parameters as well as observable performance data over all four trials.
It is assumed that no assistance at all leads in this driving scenario to the significantly worst objective results.

H1b: The cooperative system variant should differ significantly in a positive manner with regard to the most important psychophysiological parameters as well as observable performance data from the half automatic system variant and should not perform significantly worse than the automatic system variant.
If the theoretical concept of cooperation could be instantiated in the prototype build for this experiment, according to the definition (see section 2.1), system and driver together should objectively perform better than with a half automatic system. As a rule of

programming, the automatic system objectively performs best, but a cooperative interaction should actually perform equally well due to the coordination and communication processes. The automatic system variant will only be compared with regard to the psychophysiological parameters, as the driving parameters must be seen as constant, due to the programming, making comparisons statistically illegitimate.

H2: On the level of the most important subjective, which is behavioral data, the four test conditions should differ as follows:

Compared to the other test conditions the cooperative system variant stands out significantly for the best results regarding the most important subjective and behavioral data, respectively.

If the cooperative prototype tested herein incorporates the theoretical concept of cooperation, drivers should experience in all variables of the model of cooperation established above the significantly best results.

3.2.2 Hypotheses for experiment 2

In the following, the hypotheses based on the driving simulator experiment “Turning Left on Urban and Country Roads with Oncoming Traffic” are formulated:

H1: On the level of the most important objective, which is observable performance characteristics, both test conditions should differ as follows:

The cooperative system variant stands out based on its significantly better results with regard to the most important psychophysiological parameters as well as observable performance data.

Cooperative assistance should lead to significantly better performance than with no assistance at all.

H2: On the level of the most important subjective, which is behavioral data, both test conditions should differ as follows:

In contrast to the subjects of the manual system variant, which only had to imagine a cooperative system, the cooperative system variant stands out by significantly better assessments by the subjects with regard to the most important subjective and behavioral data, respectively.

Cooperative interaction is a very complex form of human-machine interaction. As technical devices do not exist thus far, it cannot yet be experienced in everyday life. It is assumed, however, that interacting with such a system for about an hour will show already significant differences in assessing positive effects of such an interaction then for the participants of the manual condition, that just had to imagine this interaction, as they were instructed to do so.

4 Preliminary investigations for the specification of the experiments

Prior to the empirical core of this thesis, several aspects with regard to the content and form of the planned experiment had to be determined; otherwise, obtaining useful answers to the questions posed above would have been impossible. For example, one of these issues was the analysis of potential driving situations and functions with respect to their potential support by cooperative interaction.[21]

To carry out such an analysis, it was necessary to a) link the specific implementation of the experiment in the simulator to a prototypical surrounding, and b) to find out in which driving situations today's drivers can imagine cooperative interaction, and c) to simultaneously ensure a certain level of quality that would make the operations of the cooperative interaction implemented herein "perceivable" for the test candidates.

4.1 Online survey to determine user demands

As a first step, an online survey was realized to assess the wishes of users with respect to 66 primary, secondary, and tertiary functions and driving tasks in the automobile and to obtain information regarding selection of an appropriate simulation scenario; the limitation to 66 functions was the result of an expert workshop (see Appendix III).

The task of the participants was to appraise the 66 driving situations and functions unidimensionally with regard to the desired degree of assistance and the favored form of assistance. Each item had to be assessed on a seven-step scale ranging from "implementation in the form of manual control" on the one side to "implementation in the form of fully automatic control" on the other side. The participants were given short explanations for each level, being informed that scores in the middle category (around 4) represented "shared control" or cooperative interaction, respectively.

Information was collected via an online survey (semantic differential and free text questions) based on N = 509 participants in total, all of whom were long-time automobile drivers at the time of inquiry.

Figure 7 shows the results of 22 exemplary desired function allocations with the smallest range of answers plotted against the x-axis (for all results see Appendix III).

[21] It must be noted that the incorporated translations for individual items and termini from the application language German into English for the presentation of the preliminary examinations and chapters 5 and 6 serve only to provide a better understanding of how to compile and approach the problems as well as to interpret the results. The incorporated questions must not be applied to different cultures and in particular cross-cultural comparisons including test result interpretations without an anew review of the instrument's validity in the particular language because an implicit acceptance of the method's equality is not justified without an empirical confirmation (Berry, 1980; Van der Vijver & Poortinga, 1997; Watkins, 1989).

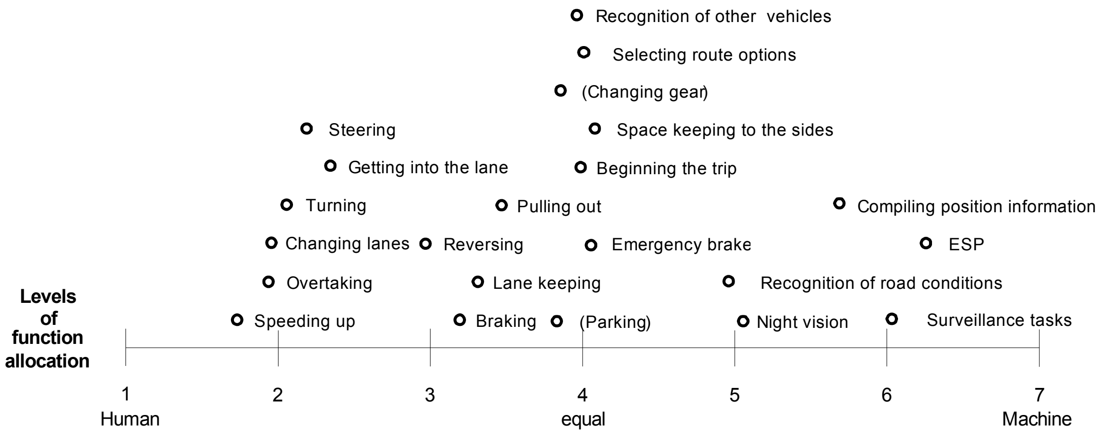

Figure 7: Means of the desired function allocation of 22 exemplary functions in automobiles (values in parentheses have a standard deviation > 2).

The data[22] yield as initial selection criteria for potential driving scenarios that

- the interviewees want to stay in control of direct-manipulative functions such as steering and accelerating,
- the interviewees prefer to delegate those operations to assistance systems that are already a part of today's cars' standard equipment and being executed safely and reliably by the system (for example, avoiding the risk of skidding).

Another criterion of selection should be driving tasks with a high potential for cooperation-based interactions to prove the hypotheses derived from the theoretical concept.

Therefore, particular favorable prototypical situations for the realization of cooperative automation would be driving situations combining several direct-manipulative functions for which the driver wants independent control (see figure 7) with activities that are behind current driver assistance systems for which they desire shared control. This discrepancy of perception in task allocation by the drivers could be successfully bridged by cooperation.

Based on these decision criteria, the two scenarios "Overtaking on highways" and "Turning Left on Urban and Country Roads with Oncoming Traffic" were chosen. Overtaking and turning left facing oncoming traffic correspond with several systems that will soon be introduced to the market, including Blind Spot Detection (BSD) and surround-sensing systems for LKS as well as direct-manipulative activities like turning and lane changing.[23]

In addition, overtaking on highways and turning left facing oncoming traffic are highly interesting from a psychological point of view with respect to the growing number of elderly drivers and their increasing

[22] For continuative results see Biester (2004).

[23] During the selection of the scenarios, others such as parking were discussed. Due to technical as well as psychological reasons, analysis of these scenarios was not pursued.

difficulties in mastering particular driving maneuvers (e.g. these maneuvers will become even more difficult over the years because of increasing traffic densities). Among others, this perspective is supported by results generated by the EU-project AGILE (Panou, Bekiaris, & Palma, 2003). Furthermore, US accident records indicate that traffic crossings make up more than a third of all collisions (Brown, 2005). A special focus in intersection accident research is left-turning due to the presence of oncoming traffic and the resulting special situation with crossing pedestrians (Lord, Smiley, & Haroun, 1996).

After the two driving scenarios were chosen, a selection of functions had to be chosen that formed the interaction platform for the cooperative system. This selection process was undertaken according to the theoretical concept of analyzing driving tasks by Wetzenstein and Enigk (1998). The components of action analyses were assessed in relation to the driving situation.

4.2 Scenario-based interviews for experiment 1 – "Overtaking on highways"

In the context of preliminary trials of experiment one, *N* = 27 participants[24] were asked to test drive the programmed driving simulator route, including its surrounding traffic. All driving tasks including overtaking had to be performed manually. The route matched one of the trials that had to be completed in the experiment and totaled 29 kilometers. On average, it took the subjects approximately 15 minutes to complete the route. Subsequent to the drive, the candidates were interviewed according to the "give-and-take"-metaphor as to what kind of support, through whatever type of system, they would appreciate with respect to the overtaking maneuvers experienced in the experiment.

Results based on absolute frequencies of nominations:

16 nominations: Distance control to car behind, which runs in the target lane in both cases of lane switching (i.e. left and right).

13 nominations: Distance control/brake behavior to the car in front on the target lane, particular for the time span after changing the lane when the individual driver might be busy or distracted by a shoulder check or interior mirror looks while the car in front might decelerate.

10 nominations: Speed management while overtaking; in this case conceptions and needs of interviewee corresponded with the performance characteristics of custom ACC.

9 nominations: Finding proper gaps in traffic and BSD.

8 nominations: Support decision to veer out of lane with respect to time and acceleration.

3 nominations: LKS and LDW.

[24] The participants of both scenario-based interviews faced the same selection criteria as the participants from the experiments. In the preliminary trials, no Bosch employees participated.

These functions were then implemented in the driving simulator, and the scenario was adapted to these specific actions. All other functions were left out and not investigated further.

Additionally it was asked, regarding the addressed support task, if participants would approve a verbal interaction with the system. The answers given showed that the subjects would prefer such an interaction with regard to all mentioned features. This was one reason, besides being a necessary simplification, why primarily verbal communication was chosen for the dialog concept in the two experiments.

Finally, participants were asked whether it would ease their communication with a system if that particular system had a name. Two thirds said that they would want to address the system with a specific or pre-defined name, while the other third did not want a name.

4.3 Scenario-based interviews for experiment 2 – "Turning left facing on coming traffic"

In the context of preliminary investigations of experiment two, *N* = 15 candidates were asked to test drive the programmed route, which included oncoming traffic. Participants had to master all driving maneuvers - including turning left – manually while the route matched a segment of the experiment with high traffic density and totaled 26 kilometers. On average, it took the participants 32 minutes to complete the route.

Immediately after the drive, just as in the first scenario, participants were interviewed regarding the desired system support, taking into consideration the experience of left turning on both country roads and in urban areas.

Results based on absolute frequencies of nominations:

12 nominations:	Oncoming traffic detection such as speed estimation of oncoming cars as well as detection of gaps suitable for a turning maneuver.
8 nominations:	BSD to become aware of pedestrians or cyclists who might move in the relevant junction area.
5 nominations:	Suggestions as to when turning maneuver is best executable.
5 nominations:	Detection of the phases of the traffic light.
4 nominations:	Speed management during the turning maneuver but also during the complete drive through town; again conceptions and needs of users matched with the range of functions that are integrated in commercially available ACC. In addition, users asked for a brake assistant that would support optimal positioning of the car at the junction.
4 nominations:	Flashing assistance interlinked with the navigation system.
4 nominations:	Display of alternative routes when it is obvious that the target road is blocked.
3 nominations:	Fully autonomous turning maneuvers in individual or special cases.
3 nominations:	LKS and LDW understood as a source of information for an optimal race line during the turning maneuver.

These functions, except for the alternative route display and the autonomous turning due to technical and scenario reasons, were then implemented in the driving simulator and the scenario was adapted to these specific actions. All other functions were left out of further investigation.

Additionally it was asked, regarding the addressed support task, if participants would approve of a verbal interaction with the system. Again, answers showed that the participants would prefer such an interaction with regard to all mentioned features.

5 Method of data accumulation and data analysis in experiment 1

The methodological procedures that were applied to answer the complex questions to prove the hypotheses with regard to the three prototypes and the manual automobile constituted the superior and proper psychological challenge. On the one hand, this concerned the choice of paradigmatic access and the composition of adequate measurings parameters and instruments, but on the other hand, also the necessary prospective planning of the analysis with regard to the extensive amount of data, due to the experimental design. The focus was here on parameters with higher relevance for the integrative model of cooperation introduced in section 2.1.

5.1 General Procedure

Paper-pencil surveys as well as the widely used industrial research made up of interviews or focus groups were not favored as the method of choice because above all with these it is impossible to record psychophysiological and performance data; in addition, acquired data with respect to trust and acceptance could hardly get credit for validity since participants (so far) barely could experience "cooperative technique(s)".

It was therefore decided to use online survey and scenario-based interviews only for analysis and selection as well as specification methods for the driving simulator experiments.

Ideally, data should have been acquired by means of a test vehicle or a prototype of a "cooperative interaction vehicle" because every other setting initially reduces the individual sensation and does not match the theoretically assumed immanence of a mutual mastery of tasks. The decision concerning the experiment's paradigm, which favored empirical proving of the hypotheses by collecting data on the driving simulator was fundamental, given the present technical restrictions: this type of data acquisition can be characterized as adequate with regard to the current state of research.

The first scenario chosen for the studies was "Overtaking on a highway" as differentiated by Fastenmeier (2001) (see Appendix IV).

5.2 Operationalization of the question

Preparation for the data collection focused on identifying independent, dependent, and control variables, while difficulties existed with regard to the determination of dependent variables with the alignment of objective measurable data (driving parameters) and the collection of the subjective data (survey questions), especially since the necessary instruments of inquiry were not available for all the different kinds of variables before the experiment.

Therefore, the applied methods, the composition, and the procedures for the first experiment will be described in depth in the following segment.

5.2.1 Independent variables

Compromises regarding the composition of the experiment's design, i.e. its factor structure, had to be effected: on the one hand, with regard to the technical possibilities, and on the other hand, with regard to the degree of complexity and difficulty for the participants. Efforts were aimed at establishing an acceptable and ecologically valid structure of task and act sequences without interfering with their acceptance one way or another.

In the following, the independent variables in their factorial structure for the first experiment will be described. The factors of traffic density, weather/fog, and the course of the route were selected according the classification of Benda (1985) and the results of Hoyos and Kastner (1986), who found that these factors are the most relevant for studies on workload, in addition to the crossing type and road type (e.g. rural or urban), which were investigated in the second experiment. The parameters for these factors were adapted to experiences in everyday life around Stuttgart at that time of year and with regard to the experimental and instructional needs of the experiment.

The combination of the factors of function allocation, traffic density, and road made it possible for all subjects to overtake exactly 12 trucks on their route at the exact same road segments of the road. The demand for overtaking the trucks was induced by the trucks themselves driving 90 Km/h per hour, making an overtaking "necessary" at the segment described below. Figure 8 shows such a typical driving situation during the start of one overtaking trial on a straight highway section, including the driving parameters measured.

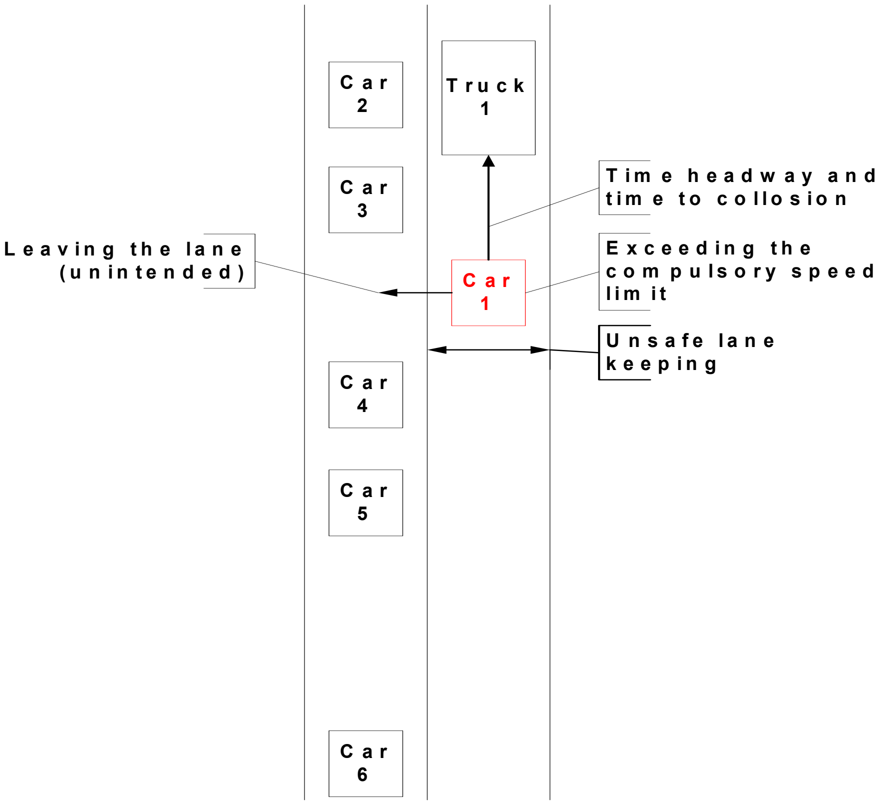

Figure 8: Graphic of the typical overtaking scenario at a straight part of the highway, including the collected driving dynamic parameters.

The gap between car 5 and 6 is, in relation to the German traffic regulations, an appropriate one.

Figure 9 furthermore shows four screenshots of that situation visualizing the video of the driver and his mirror looks, some of the driving parameters, the road (including the interior rear mirror) and the state of the touch screen (see half automatic system variant).

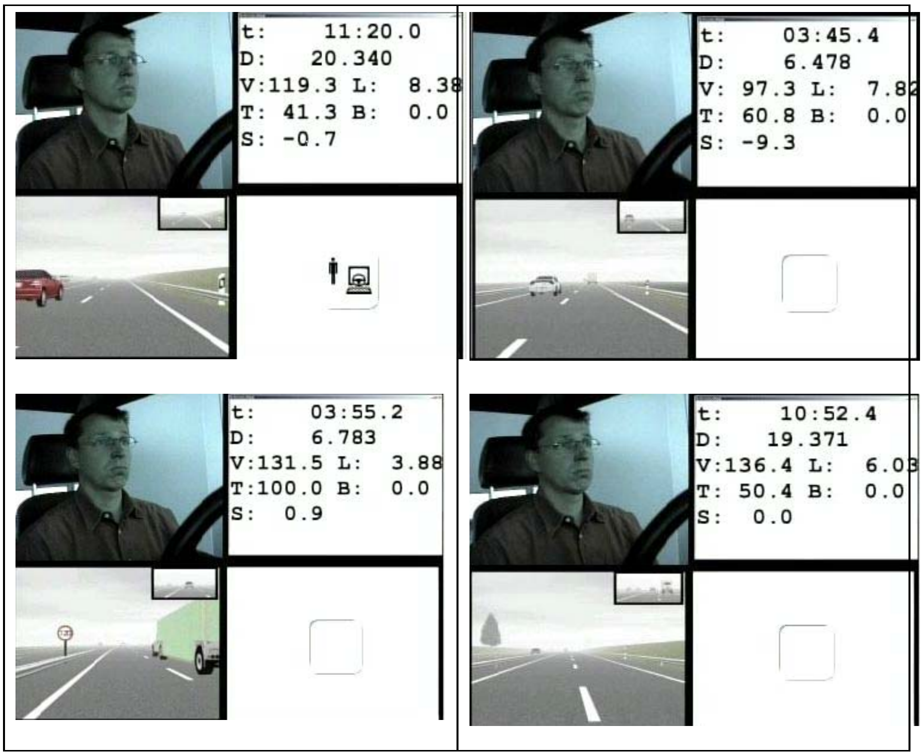

Figure 9: Screenshots of the driving scenario during the high visibility and low traffic density course. Top left: normal drive. Top right: Start of the overtaking task. Bottom left: During the overtaking task. Bottom right: End of overtaking task with truck in rear mirror.

The bottom left screenshot also shows the color of a truck that had to be memorized during the situational awareness questionnaire.

5.2.1.1 Factor function allocation

According to the previously described levels of automation and given the highlighted design tunnel (see figure 3 in section 2.3) of a potential cooperative interaction, it becomes essential to examine such system variants that allow a verification or falsification of the hypotheses by comparing the data concerning performance and acceptance.[25] For this purpose, four "sub-systems" were developed for application in the driving simulator.

5.2.1.1.1 The manual condition

Participants assigned to the manual variant used only the normal driving simulator without any additional functions. The following functions were at the driver's disposal: steering, turn signal, acceleration, brake, interior and exterior mirror, and speedometer.

Overtaking was conducted completely manually, as in everyday life.

5.2.1.1.2 The cooperative system variant

The second system variant stands out due to its cooperative character derived from the concept introduced in chapter 2. The main focus of this system is as stated in section 2.4.1.1.2 in the first step on communication via speech, which is based on the cooperative dialogue concept (Connolly & Pemberton, 1996; Stein, 1995; Wagner, 2002; Winograd & Flores, 1986), as described in the same section and which was differentiated into 270 complete sentences (see figure at section 2.4.1.1.2) concerning its system functionality.

The application of the dialogue concept was based on the Wizard of Oz method (Dahlbäck, Jönsson, & Ahrenberg, 1993). This method features the offering of system functions to the participants that are, as of today, technically not yet realizable (or only with a major effort). In this system variant, these functions included speed management, blind spot and critical situation detection, indicating, time headway detection, and overtaking assistance in relation to all necessary tasks, as differentiated by Fastenmeier et al. (2001). These system outputs were "generated" by the investigator, who was seated, hidden to the subjects, in a control room equipped with, for example, an indicator. Furthermore, the investigator was supported by a visualization tool that displayed the complete traffic situation (see figure 10).

In this way the candidate was made to believe that he was interacting with a fully functioning system, while effectively a person in the control room was interpreting the participant inputs via monitors and headphones and initiating the appropriate system outputs.

[25] It must be discussed to what degree a separation of dialog and interaction is possible because only the cooperative variant has a dialog as well as an interaction concept, while the two other system variants (not counting the manual condition) are based only on an interaction concept. However, due to a lack of space, this discussion must be postponed to future research.

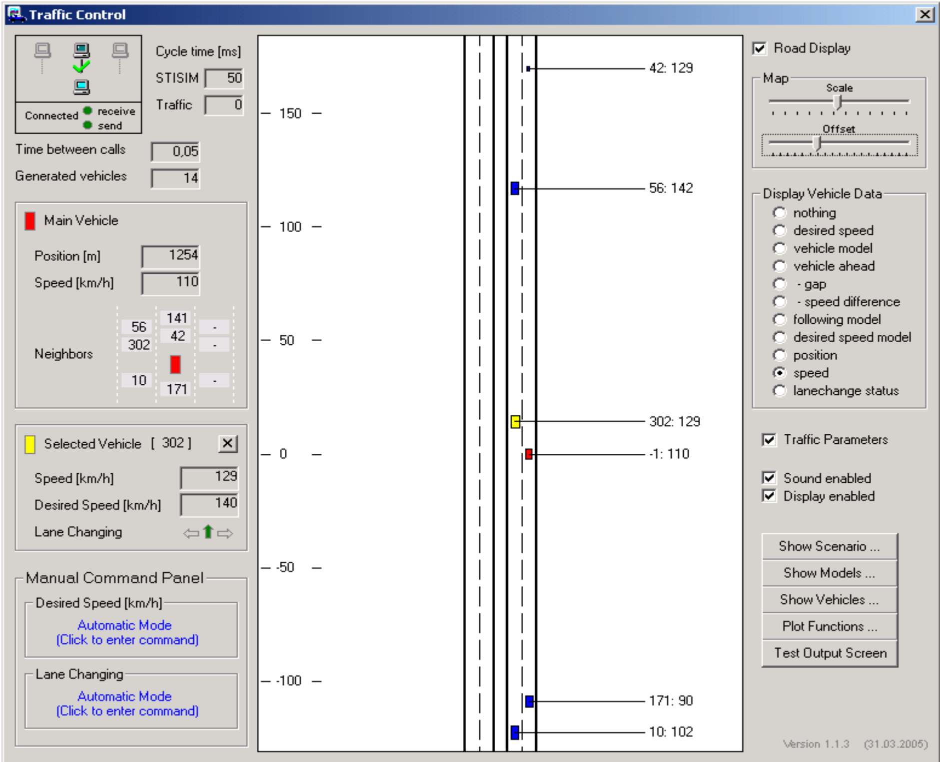

Figure 10: Visualization tool for the traffic situation

Figure 11 indicates how a transition in the dialog network (see 2.4.1.1.2) occurred. The related subnetwork must be traversed from a to c (i.e. conversational stati). So-called moves (i.e. the arrows) are marked with the dialog act type, with which they correspond (e.g. offer (of information), promise (of task execution)) (see bold arrows). They could either exist for one single atomic act (e.g. car: offer) or be recursive, including further moves or subdialogs (e.g. (dialog car, driver), see bended arrows). Optional transitions are marked with a prefix of so-called jumps (see dashed arrows).

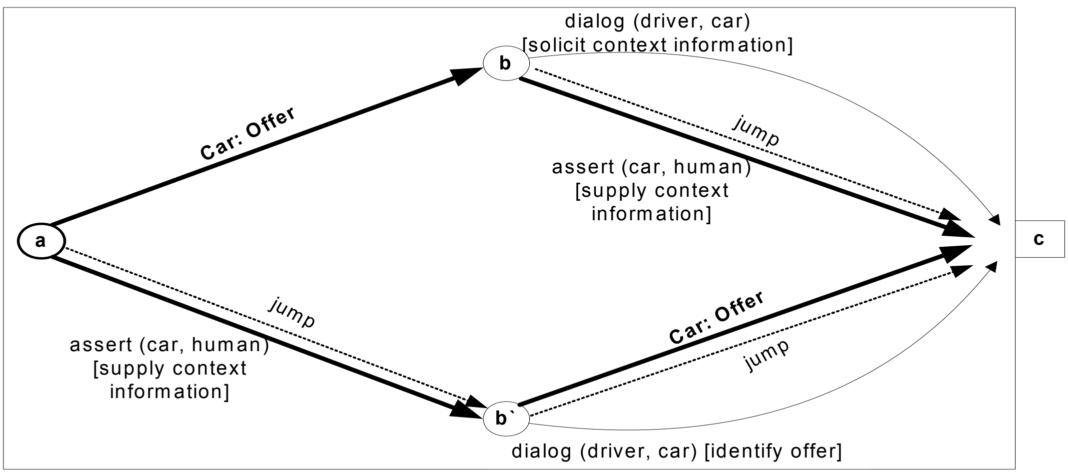

Figure 11: Subnetwork for a move within the dialog network (e.g. an "offer" like "Shall I always set the indicator when you are not doing it?").

Figure 11 shows subnetwork accounts for all possible moves besides “inform” and “assert,” which are structured more simply because the transition a-b`-c omits.

This functional behavior and the communication rules were explained to the participants at the beginning of the experiment (for the instructions see appendix VII).

A basic conversation took place regarding lane keeping, speeding, function allocation, and evaluation of the interaction during regular driving. When the truck arose on the horizon, either system or driver began a dialog regarding the overtaking itself.

That dialog structure proved to be too detailed in preliminary tests. Accordingly, the dialogue patterns concerning the category “withdrawal of system offers,” as proposed in the theoretical part of this thesis were abandoned, particularly due to the time-critical phases of an overtaking maneuver on highways. In the end, 89 sentences (see appendix VII) and 6 functions (see section 4.2) were chosen for the experiment after an evaluation of all sentences by the participants. These choices were made after the preliminary test drive presenting the list of sentences on a computer, with the participants being able to listen to them by pressing the space bar, writing down the sentences that were, for example, redundant, too complicated, or ambiguous.

Exemplary sentences (sorted according to the numbers of the list in appendix VII):

15. The vehicle in front us is driving faster then we are!

28. The vehicle behind us on the target lane has reduced its own speed.

49. After three vehicles is a good gap for a lane change.

67. Shall I always set the indicator when you are not doing it?

88. What would you like to receive more information about next time?

The resulting dialog shall be illustrated by a short example:

Driver: I´am searching for a proper gap to overtake (A: request)

Car: Please, wait… (B: promise)

After three vehicles is a good gap for a lane change (B: inform)

Driver: What is the color of the third car? (A: request)

I would like to get all possible information (speed etc.) (A: assert)

Car: It is a red car. It drives at an average speed of 140 Km/h… (B: inform)

Driver: Thank you (A: evaluate)

After the preliminary tests, the system was named VIRA (Virtual Intelligent Research Automation) and could be called as such by the participants. The naming was in response to the results of the preliminary test participants’ interviews. Since all of the candidates were male, a female name was chosen that would match the system’s female voice and that would, due to its artificiality, not allow direct associations for the subjects.

5.2.1.1.3 The half automatic system variant

As the third variant, a half automatic system was constructed and programmed. Participants involved with this variant were offered an interaction element on the touch screen located in the middle console (press-button, see figure 12 a) which was blank in the other three conditions.

When a driver activated that function of assistance, the system would control and master the relevant functions of the overtaking process such as accelerating, braking, flashing, and lane-change procedures.

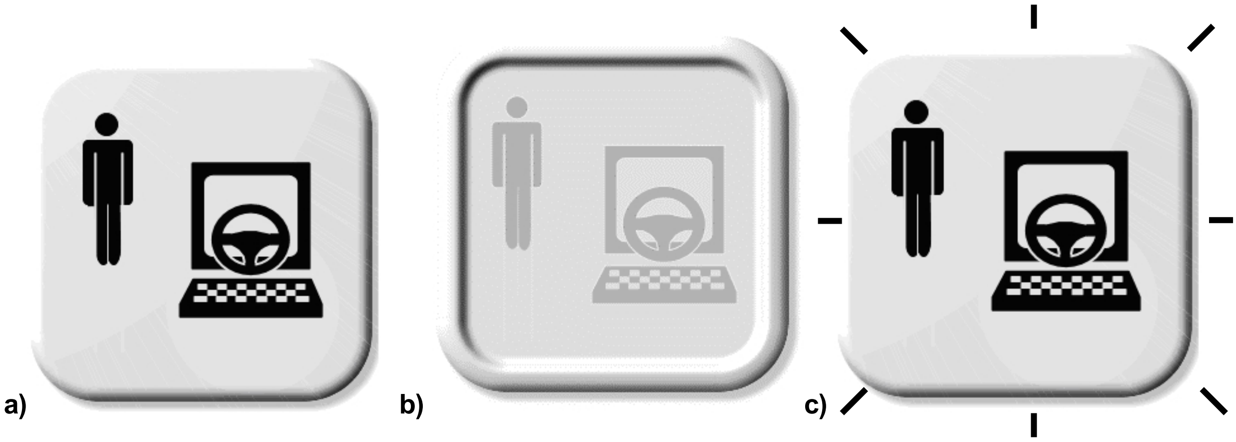

Figure 12: Symbols on the touchscreen (a=deactivated, b=activated, c= transition).

Image a) in figure 12 represents the symbol that signaled via touch screen the system state “driver is in full control.” When touched once, it turned grey (see image b)) signaling that the “system controls the driving processes”. Additionally, when touching the element the driver would hear an acoustic signal similar to a flourish. When the overall control of the system was returned to the driver, which occurred after each overtaking maneuver, the participant could hear an acoustic signal that was similar to the melody MS Windows plays when closing processes or applications. Simultaneously, the symbol would blink for a couple of times (see image c)) to signal that the control was transferred back to the driver. For further information regarding the design of the symbols and signals and their academic embedding see the doctoral thesis of Roßmeier (2005). Subjects were instructed to use the “overtaking assistance” as many times as possible.

5.2.1.1.4 The automatic system variant

As part of this variant, the system was in control of all relevant functions from the very first moment of the experiment (i.e. to blink, to accelerate, to brake, to change lanes, to pigeonhole). The automatic system variant was launched when the subject removed his foot from the throttle control for the first time after the test started. From that moment on, the participant was in charge of supervising the system’s processes.

The overtaking maneuver was undertaken by the vehicle very smoothly. The participants experienced an acceleration phase from 120 to approximately 140 Km/h, the speed of the surrounding traffic. At the end of that phase, the indicator began to blink. The steering wheel then navigated the vehicle observably to the target lane. After overtaking the vehicle, the procedure repeated itself in reverse.

5.2.1.2 Factor traffic density

Traffic density was varied between two different specifications. In two out of four trials, either a high or a low traffic density was simulated. The gaps between cars and other vehicles in the surrounding area served as an indicator for the traffic density, as determined in the preliminary tests[26]. In high traffic density conditions, gaps ranged from 30 to 80 meters compared to 80 to 150 meters in low traffic density conditions.

The surrounding traffic was constantly driving 140 Km/h. When the participant would change lanes, the rear traffic would adapt their speed according to the participant’s speed, maintaining a safe distance.

5.2.1.3 Factor weather/fog

Throughout the complete test drive, which lasted for 5 kilometers, sunny weather was simulated. However, during the four trials of the experiment the range of vision was varied twofold by fog elements. Low visibility was considered to be 250 meters, while higher visibility was 400 meters.

5.2.1.4 Factor road

The total distance to be completed by the subjects was 116 kilometers in four trials of 29 kilometers each. The route permanently consisted of two lanes and simulated systematically four straight lines and 8 bends within each trial. Bends were further subclassified into either two easy and two more difficult lefts or rights. The trucks that had to be overtaken were simulated with regard to speed and occurrence in such a way that it was possible for subjects to overtake the same number of trucks in each segment of the trial (see appendix V for experimental design).

5.2.2 Dependent variables

In the segment to come, the dependent variables that were investigated will be presented.

5.2.2.1 Objective and performance data

In the following, the objective data and the performance data will be described.

[26] Based on the experiences from preliminary examinations the vehicles presented to the subjects in the surrounding traffic were very similar because participants engaged differently in the overtaking maneuver when confronted with motorcycles or trucks.

5.2.2.1.1 Critical situations

The number of critical situations such as collisions or near-collisions, emergency braking, and offenses of the official German traffic regulations were documented (Jagow, Burmann, Hess, Mühlhaus, & Janiszewski, 2005).

Further criteria for critical situations were switching lanes when the gap was smaller than 40 meters as well as coming too close to the front car or thwarting the car to the back.

These situations were documented in a binary manner with a double rating procedure, which means that two raters evaluated the situation independently of the driving parameters as critical or non-critical. Only in the case of mutual consent situations were the ratings assigned as critical or non-critical. This complex human assessment method was necessary due to the many factors linked to the degree of criticality.

5.2.2.1.2 Driving dynamics data of the simulator

The driving behavior was evaluated by selected elements from the method for evaluation of driver interaction systems (see appendix XVI), which was developed within the European project INVENT AP3100 (Böttcher, Nirschl, Schlag, Voigtländer, & Weller, 2004) and which was validated and further developed in the AP3200 (Glaser, Waschulewski, & Schmid, 2005).

First, driving dynamic parameters according to Altmüller and Glaser et al. (Altmüller & Wolf, 2003; Glaser et al., 2005) were logged into the driving simulator that could be compiled to the following driving mistakes. Additionally, these driving mistakes had been selected for Bosch-internal comparability reasons with other studies with good experiences and results by Altmüller and Glaser et al. (Altmüller & Wolf, 2003; Glaser et al., 2005):

- Exceeding the compulsory speed limit:
- An important purpose of this driving parameter is to determine whether the subjects obeyed the instruction to maintain the speed limit. It also, however, allows to observe how participants acted during preparation and in carrying out each single overtaking maneuver when adjusting their speed to the prevailing speed in the left lane (for the calculation formula, see appendix XVI, driving mistake 1).
- Longitudinal distance too small in relation to own speed (Time Headway):
- For this driving parameter, the main interest was to determine whether the subjects approached the truck ahead or the respective car ahead during the overtaking maneuver either too fast or too closely (for the calculation formula, see appendix XVI, driving mistake 2). This is caused, for instance, by a driver who is too intensively concentrated on the rear traffic or who utilizes gaps that are too small when switching to the left lane.
- Longitudinal distance too small for difference speed (Time to Collision, TTC):

- This often-used driving parameter proportions the distance to the car in front to the speeds of both the subject's own car and the car in front (for the calculation formula, see appendix XVI, driving mistake 3).
- Unsafe lane keeping:
- For this driving parameter it was at first of interest how the subjects managed the easy and difficult bends, especially during the overtaking maneuvers. Furthermore, the values here can be taken into consideration for verifying the appropriateness of the programmed lane width (for the calculation formula, see appendix XVI, driving mistake 4).
- Leaving the lane (unintended):
- As with the previous parameter, for this driving parameter it was of interest to determine how the subjects managed the easy and difficult bends, especially during the overtaking maneuvers. Additionally, the values here can be taken into consideration as an indicator of potential critical situations as well as for the quality of the programmed lane width (for the calculation formula, see appendix XVI, driving mistake 5).

The measurement procedure resulting from the AP3200, called I-TSA (Invent Traffic Safety Assessment), is based on the model of the development of driving mistakes and accidents as well as on a driving mistake basis.

For this purpose, four mistake levels were defined for all evaluation parameters. The scale ranges from no mistake through little and average mistake up to a large mistake. For the evaluation, the frequencies of the mistake level values and the mistake level skips were enumerated separated by the specifications of the independent variable, namely the system variant. The frequencies of the mistake level skips represent the number of corresponding mistake episodes.[27] This procedure implies a simple and consistent definition of mistake episodes (Glaser et al., 2005), whereas in the figures in section 5.4 the presentation of the level "no mistakes" is not taken into consideration for the purpose of lucidity.

Data were logged redundantly both with 100hz and 30hz.[28] In order to create an integrative matrix for the analysis, the proceeding was based on the following method:

By means of a collective trigger signal, both sets of data were interpolated on a conjoint timeline. In doing so, some missing interim values were also interpolated in two possible variants:

1) On continuative signals (e.g. lane position), a linear interpolation was undertaken.

[27] An episode is always specified as a sequence of equal mistake levels, which are either not interrupted at all or which continue after being interrupted by a higher mistake level. For all driving mistakes in which the duration is relevant, the route sections with higher mistake levels are logically nested in sections with lower mistake levels.

[28] For a complete list of the recorded parameters and their units of measurement see appendix XV, and for definitions of the driving mistakes that were analyzed in this experiment see appendix XVI.

2) On discrete signals (e.g. gear, blinker), a “nearest neighbor interpolation” was undertaken.

To be consistent with Glaser et al. (2005), it would have been interesting to also extract the parameters “brake retardation” and “acceleration” from the log files. However, due to time constraints as well as to the plentitude of data, this extraction was not carried out for either experiment.

5.2.2.1.3 Mirror and speedometer looks

Analysis of the participants’ looks into the mirror seemed to promise major insights. These were documented per video camera, which was installed on the dashboard (see photo in section 5.3.3, as well as connection scheme in appendix XIV) and analyzed via a double rating procedure[29]. Looks in the left mirror were distinguished from looks in the right or interior mirror, and from those at the speedometer.

Background for the analysis is the insight that up to 90% of the perceived information with respect to vehicle guidance is of a visual nature. Accordingly, the research literature provides proof for examinations that draws conclusions from the analysis of eye-glance behavior with regard to the way information is perceived and processed (Schweigert, 1999).

Additionally, it can be assumed that looks into the mirror are an indicator of the degree of acceptance of a system variant: accordingly, fewer looks stand for a higher acceptance, though they can also indicate complacency.

5.2.2.1.4 Indicating behavior

The indicating behavior also turned out to be a promising factor in the preliminary tests. In addition, this interest in the indicating behavior was fostered by the marginal scientific discussion in regard to this parameter. Therefore, it was not only recorded if and how long subjects indicated, but also who (system or driver) had blinked, which is particularly relevant with regard to the cooperative variant. This recording was amended by the documentation of noticeable problems by the investigator.

5.2.2.1.5 Workload – objective measurement

The physiological measurement instrument MP 150 by Biopac Systems Inc. (www.biopac.com) was used to gauge the workload of the subjects through skin conductivity (SKT) and heart rate. These two parameters were taken due to Bosch-internal comparability of studies and recent results of internal research.

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[29] Each trial was evaluated by a rater with regard to looks into the mirrors and at the speedometer. The mean of both yielded the value for that particular trial. If the difference between the two evaluations was bigger than 4 gazes, a third evaluation was carried out.

[41] This passive method has a problem, in that voltage cannot be held exactly constant. Optimization can be achieved with active circuits based on operation amplifiers (Boucsein, 1988), but this method was unfortunately not available for this experiment series.

Skin conductivity is the most commonly used method of inquiry to assess physiological correlates of psychological states (Boucsein, 2001). However, thus far, its basic mechanisms have not been fully understood (Ladstätter, 2006).

The skin conductivity values were taken palmar using the constant voltage method and are included in the report as skin conductivity in microsiemens (μS). For an explanation of the choice of the specific locus of dissipation, the reader is advised to turn to the detailed discussion by Boucsein (1988).

An SKT signal is composed, as a rule, of tonic and phasic elements. In the present study, the raw signal, after preprocessing, was low-pass filtered (at 10 Hz) for reasons of noise suppression as well as to filter the tonic proportion. Afterwards, the signals were high-pass filtered (at 0,04 Hz) so as to stabilize the baseline. Remaining was the phasic proportion of the skin conductivity, within which no single events were counted, but the skin conductivity was measured as an indicator of emotional perspiration.

Adjacent, a relativization of the signal for the maximal occurring value was carried out. That is, that every single value was divided by the intraindividual maximal skin conductivity value.

Relativization formula: SC(i) = SC(i)/SCmax

As the interpretation axiom applies: the closer the observed value comes to 1, the higher the conductivity of the skin, and thus the more the subject is aroused.

The heart rate belongs also to the most applied peripherphysiological parameters. This is justified by the artifact immunity, the simple dissipation, and the generally good results in workload measurement. The heart rate was assessed via a three-point electrocardiogram as a standard dissipation based on Einthoven I (Ladstätter, 2006). The focus of interest was especially the heart frequency and the variability of the same described as beats per minute (bpm).

According to previous psycho-physiological experiments, it is recommended that the climate of the room be measured so as to consider external influences of the environment for the analysis (Fahrenberg, 2001). To keep the surrounding temperature constant is crucial, especially in case of peripheral measurements. In the given experiment, temperature was maintained via an air-conditioning control.

The BIOPAC measurement system utilized in the study is a modular system that offers the possibility of determining special amplifiers for each recording channel. The MP 150 is capable of recording physiological data up to 200 kHz. Based on the main questions of the present thesis, a sample rate of 100 Hz was chosen. Two digital input channels were used to store 8 bits of reference time-axes information. The reference time-axis was Gray encoded to avoid data overrun in cases of simultaneous data acquisition and changing time information.

5.2.2.2 Subjective and behavioral data

The subjective or behavioral data were assessed based on a survey (paper-pencil test and structured interview). Since there were no particular methods available that could have been used for the special questions related to this thesis, new questionnaires had to be developed that were based in part on existing instruments.

The composition of the new survey was realized according to common procedure-diagnostic rules. However, these steps will not be described in detail and the documentation of formulated pre-forms or attached item values is neglected on purpose. Nevertheless, it was ensured that the individual parts or sub-stages of the applied and in the following documented survey can be treated as scales of a validated psycho-diagnostic procedure. Altogether, the survey consisted of 15 segments, 18 scales, and 139 items (see appendix VI and VIII).

5.2.2.2.1 Acceptance

Determining the degree of acceptance of innovations or new products is essential for producers. It is therefore not surprising that there are as many models and methods to measure consumer acceptance as there is discussion about it. In the first driving simulator experiment of the present work, the degree of acceptance was assessed by a scale that was developed within DaimlerChrysler's R&D (Kandale, 2002), which can be considered to be very reliable (see appendix VIII, part C).

5.2.2.2.2 Risk awareness

For an automobile components supplier it is also essential to know whether consumers experience a new technology as beneficial with regard to individual road safety or as too risky. However, if consumers experience new technologies as beneficial, it might in the long run result in the development of an observable undesirable behavior leading to such phenomena as "learned carelessness" (Frey & Schulz-Hardt, 1997). The so-called risk awareness was assessed via two items that were especially developed during in-house examinations and validated (see appendix VIII, part C).

5.2.2.2.3 Trust

Participants were also asked questions with regard to the construct of trust based on the concept of trust in cooperative systems discussed in the theoretical part of this thesis. Since no widely accepted and used instrument is known to assess this concept, a new collection of items was assembled.

For the process of operationalization, items and insights from the diploma thesis "Do you trust your butler? – Correlations between trust and acceptance in a language-based assistance system in cars" (Kandale, 2002) were combined with the illustration of the idea of cooperation based on the text "Interpersonal trust, trustworthiness, and gullibility" by Rotter (1980). In addition, new items were generated.

However, according to Kandale (Kandale, 2002), just the item "Do you trust in technology?" would be sufficient to generate a valid measurement result. This statement leads to the question as to whether trust in technology over time is at all measurable, and which instrument is best suited to such measurements.

Since this discussion cannot be concluded at this point in time, other items were also used for the present thesis. Those items referred to road safety in a wider sense than in the former segment on risk awareness, and to trust in the context of cooperation. In the end, six items were used for the inquiry and are described in appendix VIII, part C.

5.2.2.2.4 Situation awareness

Research assumes that good drivers have a better perception of the surrounding external and internal environment of the car, partially because the ability to observe important and necessary information during driving is essential to good driving performance (Bolstad, 2001).

This ability is embedded in the construct of situation awareness, which is defined as the “internal conceptualization of the present situation” (Endsley, 1995b).

Following the research regarding situation awareness, it is of interest for the present thesis whether the driver is able to perceive, comprehend, and understand his surroundings in order to derive his future acts based on his understanding of the current situation, and whether this ability varies according to the system variant.

Therefore, as recommended by Bolstad, a task analysis of the simulation-implemented scenario of “Overtaking on Highways” was conducted in order to determine the key elements of potential situation awareness. As a result – following the Situation Awareness Global Assessment Technique (SAGAT) by Endsley (1999) – a new scale based on seven items was generated (see appendix VIII, part A).

5.2.2.2.5 Workload – subjective measurement

In industrial-psychological research, information related to the state of workload of an individual person with regard to coping with tasks is of great importance (Hacker & Richter, 1984; Ulich, 1994). To obtain such information, in addition to the already described physiological measurement procedures, one can consult validated scales such as the NASA Task Load Index (NASA TLX) (Hart & Staveland, 1988). The latter was integrated into the current test battery, with its 15 items being presented as a pair comparison (see appendix VIII, part A).

5.2.3 Control variables and boundary conditions

The following variables were established and controlled:

- The **age range** of the participants was established at between 25 and 40 years. This was done with the wish to obtain the most homogeneous group with comparable behavior. As an indicator of the homogeneity within this age range, in addition to in-house experiences with this range, is the relatively homogeneous accident statistics of this age range compared to younger or older individuals (Evans, 2004).
- **Kilometers traveled** by the subject had to be between 10000 and 20000 kilometers per year.
- Only **male persons** were invited: this decision was made so as to ease the application of the ECG measurements.

- Only **German native-speaking** participants were invited due to the complex communication, most of all with the cooperative system, the necessary instructions, and questioning inventories.
- The **team orientation value** scored on the BIP should be at least 40.
- The control belief in technology was assessed.
- The **system language** was constantly female.
- The **room temperature** was held steady by air-conditioning.

5.2.3.1 Team orientation

The decision to use parts of the “Bochum inventory for an occupational description of the personality” (BIP) by Hossiep and Paschen (2003) was due to the wish to assess the potential participant’s general willingness to cooperate prior to the experiment. A disadvantage of the use of this test is that team orientation can be seen as a cognitive style variable for which the domain dependency must be clarified.

Since no test is available that evaluates the disposition to cooperate when exposed to technology, team orientation questions from the BIP were utilized. The 13 questions are conceptualized in such a manner that a high score represents a great degree of appreciation of teamwork and cooperation as well as an active support of team processes and a willingness to step back from opportunities to distinguish in favor of the team (see appendix VI, part 5).

The scale was composed without a specific underlying psychological construct but was rather derived from an everyday life understanding of the term (Hossiep & Paschen, 2003).

Participants who were not able to score a value of 40 or more on a scale of 70 on the team orientation scale of the BIP were not invited to participate in the experiment, regardless of the system variant. It was assumed that those persons cooperate too little with others in work and life and therefore would have a low interest and capability in the experiment to cooperate with the cooperative system variant, regardless of the system quality.

5.2.3.2 Control belief and technology

The 8-question survey for control belief in association with technology (KUT) was applied to assess the technology-related personality traits in the context of human-machine interaction (Beier, 1999). The aim was to identify the subjective influence with regard to individual evaluation of the experienced system in each case and to make it measurable (see appendix VI, part 4).

5.2.4 Experimental design

The first experiment was carried out with a multivariate, multifactorial between subject experimental design with uneven level numbers (see appendix V) and complete trials. For this, the two route types (straights and bends), the two levels of traffic density, and the two levels of visibility were systematically varied and balanced in relation to the single factors over the four trials in order to avoid sequence effects. From the combination of 4 x 2 x 2 x 2 factor levels, the experimental design originated with a total of 32 cells (due to experiment failure, only 112 data sets instead of 128 are available).[30] Assignment of the subjects to one of the four system variants (factor function allocation) took place randomly.

5.2.5 Experimental procedure

The complete experiment lasted for approximately 2 to 2.5 hours; a lump sum of 30 Euro for participating was granted to the subjects. The 112 subjects from the first experiment participated in the study as follows:

- An initial survey by means of e-mail questionnaires.
- General instructions for the driving simulator.
- Wiring for the ECG and SKT.
- A 5-kilometer test drive in the driving simulator including an overtaking maneuver analogous to the experiment.
- Baseline survey of biophysiological parameters.
- Specific instructions depending on the test condition.
- Four trials with a freeway route of 29 kilometers each and 12 overtaking maneuvers each.
- Between-trial questionnaires.
- Post-questioning regarding the dependent variables.

In the following the issues shall be described in more detail.

5.2.5.1 Prequestioning by means of e-mail questionnaires

Within the scope of the e-mail-based prequestioning, the acquired subjects were selected based on test-relevant characteristics. Due to the design of the experiment and the technical resources, a lack of vulnerability to so-called simulator sickness as well as fulfillment of the control variables was considered to be one of the main requirements for participation.

Furthermore, questions were asked about the subject’s own automobile, or that driven most frequently, and about the technical equipment generally used (e.g. radio, parking pilot, or navigation device) and the usage frequency of single functions and components; based on the above, the affinity

[30] For the calculation of the ideal sampling scales for experiments, see discourse Biester/Moosburger (see appendix XVII) or refer to standard literature covering this topic (Bortz & Döring, 2002; Cohen, 1988; Mulaik, 2001). It must be pointed out that the eventuality emerges that incidental effects as such may become significant with too sizable samplings taken (for a science theoretical discussion cf. for example Mulaik, 2001).

of subjects to new technologies in the automobile was surveyed. The subjects needed approximately 10 minutes to answer the questions.

5.2.5.2 General instructions for the driving simulator and for the connection of the electronic measuring equipment

First, the subjects were provided with standardized instructions in the form of a printout manual. Herein the principle differences between real driving and simulation-like braking and steering were pointed out. Shortly after, the participants were prepared for the recording of the relevant psychophysiological parameters (ECG and skin conductivity) by a trained assistant. After connection and correct installation, a quick function test as well as calibration of the testing apparatus was conducted. This portion of the experiment took approximately 15 minutes.

5.2.5.3 Test drive in the driving simulator

As a preparation for the upcoming trial run, the participant was required to complete a test track of 5 kilometers, which matched the following test track in relation to the significant route characteristics. In addition, the participants had to carry out an overtaking maneuver and a braking maneuver during the test drive. The test drive lasted 7 minutes, on average.

5.2.5.4 Specific instructions depending on the test condition

Depending on the respective system variant, the participants, became familiarized after the test drive with the significant interaction elements and the dialog potentials of "their" testing environment. This included, for example, the operation of the touch screen in the half automatic variant or the specifics of the dialog in the cooperative variant (see appendix VII). The duration of the instruction averaged 4 minutes.

5.2.5.5 Actual experiment

After a short break, the participants completed four trials in the main experiment with a highway length of 29 kilometers, with 12 overtakings for each trial (duration of each trial approx. 15 minutes).

Before starting the first trial, during the three breaks and after the fourth trial, the participants were required to complete a questionnaire concerning the subjective workload, as well as to rate the system (see appendix VIII, part A).

5.2.5.6 Post-questioning

Due to the four system variants, the post-questioning was separated into two sections. First, there were questions that remained the same for all 112 subjects. Following this, there were questions that had been prepared for either a single condition or multiple test conditions.

5.2.5.6.1 Questions on all test conditions

This first section, which was equally presented to all 112 subjects, solicited answers to the following topics:

a) Situation awareness

As conducted during the experiment, the method to survey situation awareness by Endsley (Bolstad, 2001) as described in section 5.2.2.2.4 contained 7 items in total, which were designed as a five-level rating with unipolar question scales.

b) Workload – subjective measures

Again, as in the survey conducted during the experiment, the paired comparison of the NASA TLX served for the inquiry of workload (see also section 5.2.2.2.5).

c) Simulator sickness

Although only those who indicated in the initial survey that they were not likely to suffer from pseudokinetosis, the so-called simulation sickness, were allowed to participate in the study, all were asked about possible spontaneous breakouts or symptoms of the simulator sickness after the experiment (for a list of simulator sickness-causing factors see appendix XVII). By applying the Simulator Sickness Questionnaire (SSQ) by Kennedy (1993), symptoms like nausea or dizziness or other hints were acquired (see appendix VIII, part B).

d) Disturbance variables: Distraction

In addition to the SSQ, open questions regarding general disturbance variables were asked, such as whether the participants had felt any distractions or whether they had experienced any difficulties with the system itself during the simulator drive.

5.2.5.6.2 Specific questions depending on the condition

The main differentiation characteristic in the test condition-related questioning section was that the participants operating under the manual condition had essentially experienced no system. Therefore, these persons were asked in the instructions to imagine a cooperative system and then to hypothetically evaluate it. Furthermore, there were questions that were asked for only one variant. The duration for answering averaged 10 minutes.

a) Acceptance

The same questions asked in the surveys administered during the experiment were also asked herein. The questionnaire consisted of 16 items and 4 scales (see appendix VIII, part C).

b) Trust

Again, the same questions included in the surveys administered during the experiment were also asked herein. In the end, the method consisted of 6 items in total (see appendix VIII, part C).

c) Risk awareness

As with for the constructs of acceptance and trust, the same questions were asked as those included in the survey administered during the experiment (see appendix VIII, part C).

d) Questions regarding change of abilities and skills

At the end of the experiment after a 1-hour drive with the respective system, it was of interest to learn what positive and negative changes the drivers believed would be made in their own driving skills after longer usage of the system. These questions again were formulated hypothetically for the manual system (see appendix VIII, part C).

e) Ergonomic design of the system

For this part of questioning the participants were asked to provide information regarding the usability of the specific system according to DIN EN ISO 9241 part 10 (Timpe et al., 2000), as well as to prove the design of the prototype according to the process characteristics of cooperation (see section 2.3.3).

Additionally, a hypothetical question was asked as to whether the participants would have wanted to change between multiple variants of the system (See questions in appendix VIII, part E and results in appendix IX).

f) Variant-related analysis

The participants were also asked to describe, in their own words, how the system had acted during the drive in order to verify that the participants were aware of the actual system behavior.

1) Manual condition

Questions regarding the ergonomic design of the system formulated in the aforementioned section were not asked of persons who were manually driving, as they had not experienced the system in the operationalized sense. Only the question regarding variation of the system states was asked herein.

Questions regarding acceptance and trust were only asked hypothetically for the manually driving subjects; this means that the participants, as briefly mentioned above, were asked to imagine and accordingly evaluate a cooperative system according to the good experiences with this method by Beier et al. (Beier, Enigk, & Renner, 2002), which was described to them briefly.

For the same reason the communication behavior[31] (Faschingbauer, 2002) of the system was assessed based on questions regarding the favored mode of an interaction (language or touch screen) as well as the requested type of dialog (imperative or colloquial).

2) Cooperative system variant

In relation to the cooperative system behavior, 11 question pairs and 3 questions regarding distraction through communication, the favored mode of interaction, and the favored type of dialog were asked.

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[31] Communication behavior signifies the process of transmitting denotations or meanings by the system using language, graphical representations, and optical or acoustical signals.

Additionally, eight questions regarding cooperation were asked in this variant in reference to the structure characteristics, broken down to the single action levels (see section 2.2.3).

These questions were followed by six questions from the Halden Human-Automation Cooperation Questionnaires (Skjerve & Skraaning, 2004). These questions are a formulation of the cooperative principles by Grice (1975), which were introduced in the theory part of the dissertation, transferred to the context of cooperation between human and machine (see appendix VIII, part H).

3) Half automatic system variant

The participants in the half automatic system variant were asked 26 questions regarding the optical signals on the touch screen (see system description in section 5.2.1.1.3) as well as the acoustic signals (Roßmeier, 2005), which emanated from speakers (see appendix VIII, part OA).

To evaluate the communication behavior, 11 question pairs were presented, which were then followed by 3 more questions regarding the experienced communication (for the complete inventory see appendix VIII, part E).

Here, like in the cooperative variant, eight questions regarding collaboration and cooperation in reference to the structure characteristics were also asked.

4) Automatic system variant

For the automatic test condition, the 11 question pairs regarding the communication behavior of the system were also asked which were then followed by three more questions regarding the experienced communication with the system (for the entire inventory, see appendix VIII, part E). As no specific interaction took place within this condition, the questions regarding cooperation were not asked.

5.3 Data inquiry

In the current experiment, which was carried out in the form of a computer-simulated inquiry in combination with administered paper-pencil surveys and interview data, none other than the control or basic conditions mentioned thus far were intended. The data inquiry was carried out anonymously and exclusively in locations of the ROBERT BOSCH GmbH. Only trained and experienced experts were deployed as investigators. The data collected from the computer simulation as well as from the psychophysiological measurements were logged online in the ASCII-format and were stored on nonvolatile storage mediums after the experiment.

5.3.1 Acquisition of the sampling

Participant acquisition was carried out in many different ways. As such, a large number of applicants for the experiment were found and, thus, the selection criteria such as driving experience, age etc. could be optimally fulfilled. In detail, the acquisition process proceeded as follows:

- A sketch of the experiment and the participant selection criteria were attached to e-mails and sent to the Bosch internal mailing lists for interns, trainees, and doctorates with a request for forwarding the e-mail also to people who were not related to the company.

- Postings were also placed in window displays at the Bosch site where the driving simulator is located.
- Newspaper advertisements were published in the Stuttgarter Nachrichten and the city magazine Lift.
- Additionally, postings were frequently placed at university sites as well as at the larger public facilities in and surrounding Stuttgart.

Moreover, all participants were asked to contact all persons from their circle of friends who also would have met our criteria.

5.3.2 Characteristic of the sample

The main test of the first experiment was participated in by *N* = 112 persons, with the participants being divided and then subjected to different experimental conditions,[32] as shown in Table 2.

Table 2: Frequencies of the four experimental conditions.

	frequency	percentage
Manual	30	26.8
Cooperative	31	27.7
Half automatic	29	25.9
Automatic	22	19.6
Total	112	100.0

Sample characteristics

Forty-five percent of the participants were employed by Robert Bosch GmbH in some capacity, and the other participants were from outside the company.

- The team orientation score of the BIP was between 41 and 70 (52.69 on average)
- The age was between 25 and 41 years (30 years on average)

The responses to the question regarding equipment and usage of different technical systems in the automobile showed no abnormalities. Accordingly, the majority of the participants reported that they do not call a navigation device, an ACC, or even a voice control their own. In contrast, only 2 people stated that they do not own a radio (for the results see appendix VII).

[32] The low number of test participants in the automatic system variant was agreed upon with the first supervisor Prof. Wandke, as only little variance in the results was expected due to the programming. Vice versa as in the other three test conditions more variance was expected a greater amount of subjects were tested. The other differences arise from the random allocation of conditions.

Table 3 shows that 87 percent of the subjects stated that they have had a good to very good experience with the systems integrated into their automobile. No one reported very bad or even bad experiences.

Table 3: Frequency of questions in sum and percentage for the question regarding the participants' experience thus far with the systems they named.

	frequency	percentage
so-so	13.0	11.6
good experiences	51.0	45.5
very good experiences	48.0	42.9
Total	112.0	100.0

Table 4 shows only 22 percent stated that they show little or at least so-so inclination towards new technologies, whereas almost 78 percent are positively affected by new systems in the automobile.

Table 4: Frequencies of questions in sum and percentage for the question regarding how high the participants would rank their inclination toward new technologies in the automobile.

	frequency	percentage
little inclination	1	0.9
so-so inclination	24	21.4
high inclination	46	41.1
very high inclination	41	36.6
Total	112	100.0

5.3.3 Data fixation

A driving simulator mounted on a fixed platform was used for the experimental series. For controlling and visualizing the driving task, the simulation STISIM 500W from STISIM Technology, Inc. was applied (see figure 9). The driver sat in a completely equipped Fiat Coupe 2.0 (only the front half to the B-pillar, incl.) and controlled the car with automatic transmission by a steering wheel with force feedback, brakes, and an accelerator pedal. The animated driving scenes were projected on a 135-degree screen using three video projectors.

Figure 13: Picture of the Bosch driving simulator with touch screen and surveillance camera.

The car's driving sound and the system's acoustic output in the half automatic variant were transmitted over two speakers mounted in the footwell on the left and right of the car chassis.

The driving simulator system is based on a local network with four Intel Pentium IV computers with a speed between 2.0 and 2.4 GHz (for the configuration, see XIII).

On the same computers a Visual Basic script ran and calculated the driving dynamic parameters, which ensured an extraction of the available static and dynamic automobile parameters for online calculation as well as data logging.

5.4 Results of experiment 1

In the following section, the results from the first experiment "Overtaking on Highways" with regard to their descriptive and inferential statistics are presented. For the data analysis, the software programs Matlab, SPSS, and Excel as well as video tapes for reference were deployed.

For calculation of the driving parameters, the limiting values of the Glaser experiments - adjusted in relation to the measurements of the simulation environment - were deliberately applied in order to be able to compare the frequencies (for the calculation formula, see appendix XVI definitions 1-5).

Due to the large amount of evaluated data within this experiment, the following section shall be limited to the most relevant and most exemplary results as related to the presented hypotheses as well as to carry out the most possible aggregated observation. In the cooperative, the half automatic, and the automatic test conditions, the interaction with the respective system did not take place only during overtaking, and the results shall be displayed for the complete tracks. Where necessary, extracts relating only to the overtaking are made.

The structure was taken from the order of the descriptions in section 5.2. The experimental design served as the second structuring characteristic. This approach will be taken throughout the appendix in order to more easily consult the questions in the construct and questionnaire parts. All other results will be presented in the appendix due to their extent (see appendix IX). This includes the results of the physiological baseline measurements and the control variables, TO-value, KUT, and age, which are also displayed with a short interpretation in the appendix (see appendix IX). In addition, the results regarding the ergonomic design as a control, if the system variants were understandable and if there was transparent system behavior, can be found in the appendix (see section IX).

Pre-drawing the results for the control variables as an interpretation basis of the other results, it can be stated that no noteworthy influence on the dependent variables can be assumed for the three control variables, TO-value, KUT, and age, besides a few exceptions. As such, this driving situation can be interpreted as a potential uniformly designed cooperative system for this target group. In further experiments, however, it would have to be clarified how the objective dependent and control variables change, for example, with women, less or more control convinced persons, younger or older participants, and less team-oriented drivers.

Additionally, for the results of the pseudokinetosis, it is assumed in the following that they have no influence on the objective and subjective results, as no distinctive features occurred.

In section 5.5, interpretations and discussions related to answering the questions about this driving situation are then answered on the basis of the gathered descriptive cognition and statistical inference.

5.4.1 Statistics

This statistical section serves the purpose of proving the drawn hypotheses in section 3.2.1 on the basis of the acquired data.

First, the normal distribution of the inquired parameters was proven (by Kolmogorov-Smirnov-Test); in all cases, the normal distribution of data can be assumed.

This was followed by verification of the hypotheses H1 and H2 by means of an ANOVA, whereas the subjective parameters were merged into one index due to the cognitions reached in the descriptive analysis for all four measurement points. Furthermore, for hypotheses 1b and 2b, a multicomparison was conducted. The effect sizes were calculated according to Cohen (Cohen, 1988; Cohen, 1994). All corrections were undertaken by Bonferroni correction.

The starting point for the analysis on the most important objective and subjective data focused on the means of the critical incidents of each condition so as to determine if a global effect existed.

5.4.1.1 Results for the critical incidents

A differentiation between the critical incidents mentioned in section 5.2.1.1.1 was not undertaken due to the complexity of the incidents in relation to their number and occurrence, but instead the incidents were separated into regular drive and overtaking tasks over all trials. The revision of the experimental records, however, shows that the critical incidents of the half automatic system variant mainly occurred when the assistance was switched on or switched off. For the manual condition and also for the cooperative system variant, no special situations for commonly made mistakes was noted.

The number of critical incidents, as depicted in figure 14, shows that the participants of the half automatic system variant experienced the most mistakes, and this with the highest standard deviation. The manual drivers had to cope with the second highest number of critical incidents, also with a high standard deviation. The drivers of the cooperative system experienced the second lowest number of critical incidents.

This finding is underlined by the fact that the subjects of the half automatic system variants experienced a maximum of 6 critical incidents, while the manually driving subjects only experienced a maximum of 5 of such incidents and the subjects of the cooperative system variant only a maximum of 3. These findings partly match the results from real automobile tests, like those reported by Koziol (Koziol, 1999) briefly illustrated in section 2.1. According to these results, one could have expected that the manual condition would produce the largest number of critical incidents.

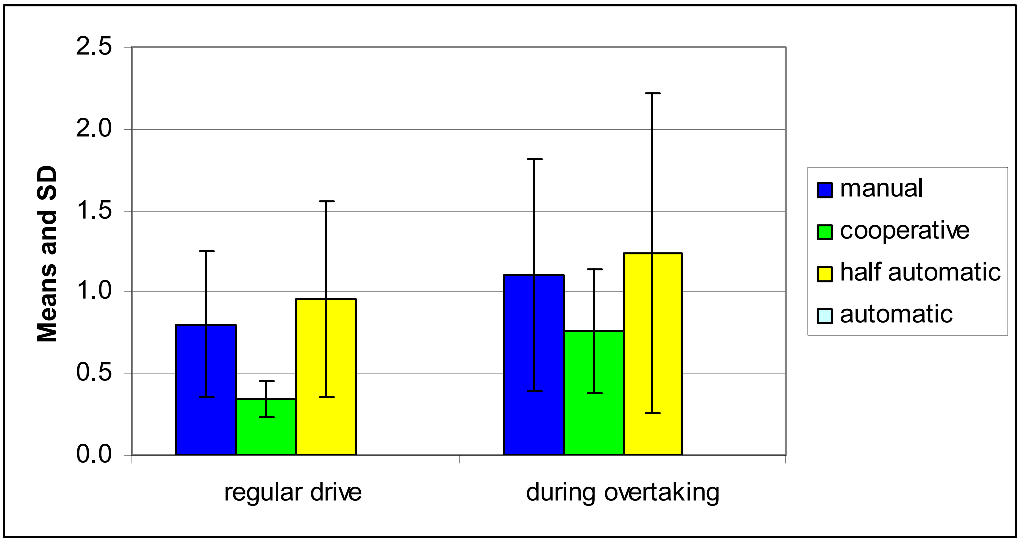

Figure 14: Means and standard deviation of critical incidents for all subjects of each condition over all four trials separated into regular drive and overtaking tasks.

The results for the automatic variant implicitly serve the testing of the programming. Each value larger than zero would have implied faulty programming, according to the definition in which the machine chooses the ideal routes and overtaking maneuvers. Therefore, as a constant it was not included in the significance test.

The ANOVA shows no significant differences between the conditions (F = 4.898; df = 3, 111; p = .203) or phases in driving (*F* = 6.227; *df = 3, 111*; *p* = .310), which means that the initially stated global effect seems not to exist.

Altogether, herein, the results of the critical situations on average in relation to the complete course of the experiment of 60 minutes in an unfamiliar environment can be deemed as rather negligible. Only the peak values of the manual and half automatic condition are to be considered as critical in terms of the overall evaluation.

However, these incidents also mirror the results for the psychophysiological parameter and the driving mistakes, which will be discussed next to determine whether one can find statistical effects on a lower data level. The hypotheses and subhypotheses are therefore as follows.

5.4.1.2 Results of the hypotheses

In the following, the results related to the hypotheses in section 3.2.1 are first descriptively displayed and then statistically tested by inferential means.

H1: The four different test conditions of the experiment should differ on the level of the most important objective and observable performance data, respectively, as follows:

H1a: The manual system variant stands out based on the significantly worst results with regard to the most important psychophysiological parameters as well as observable performance data over all four trials.

In the first hypothesis, the results of the automatic system are compared to the other conditions regarding the psychophysiological parameters of heart rate and skin conductivity, but not regarding the driving parameters due to their by definition constancy.

Psychophysiological parameters

It is assumed that no assistance at all leads, in this driving scenario, to the significantly worst objective results.

Workload – objective measures

First, the mean values and standard deviations for the individual conditions were calculated in order to confirm that the recorded values make sense and that the measuring system worked well (see appendix IX figures A IX – 2 and 3).

Furthermore, it is assumed that the evaluated parameters are not subject to the circadian rhythm; if circadian rhythm had been a fact, measurements taken at different times of the day[33], as carried out here, i.e. in the morning, in the afternoon, and in the late afternoon, would have led to distortion of the results (for baseline results see appendix IX table A IX - 2).

Heart rate

The mean values and standard deviations of all measured heart rates for the manual condition were subject to a declining tendency throughout the trials with a delta *d(bpm)* = 9.47 percent between trial 1 and 4. The manual participants of the first trial showed the highest values, and thus experienced the

[33] However, a relationship is known between the body core temperature and the circadian rhythm when the nightly sleep commences, whereas this moment is accompanied by a reduction of the core temperature (Kräuchi, Cajochen, Werth, & Wirz-Justice, 2000).

biggest strain, although all participants had to undergo the same test drive. This result can only be explained by the reaction of this group to the difficult first trial with high traffic density.

The same pattern occurs for the mean values and standard deviations of the participants of the cooperative (*d(bpm)* = 7.82 percent) and half automatic system variants (*d(bpm)* = 7.12 percent). The same tendency can be recognized for the automatic system variant as well, but the values do not drop as significantly as with the other conditions, but instead rise slightly at the end of trial 2 and remain at a high level until trial 4 and therefore show the lowest delta *d(bpm)* = 3.08 percent between the first and last trials.

Figure 15 shows this development of heart rate over time and therefore confirms the assumptions that for all participants an adaptation to the overall situation took place (for standard deviation see appendix IX figures A IX – 2).

Consequently, it becomes evident that not being able to do something or being forced to do something in the automatic system variant negatively affects circulation and thus the common well being. This, for instance, is depicted in a marginal drop of the heart rate, which in comparison to the manual condition is almost 10% and therefore a triple reduction. If it is the case that an adaptation to the situation and the respective system takes place, then it can be stated herein, that this is accomplished best by the cooperative system variant.

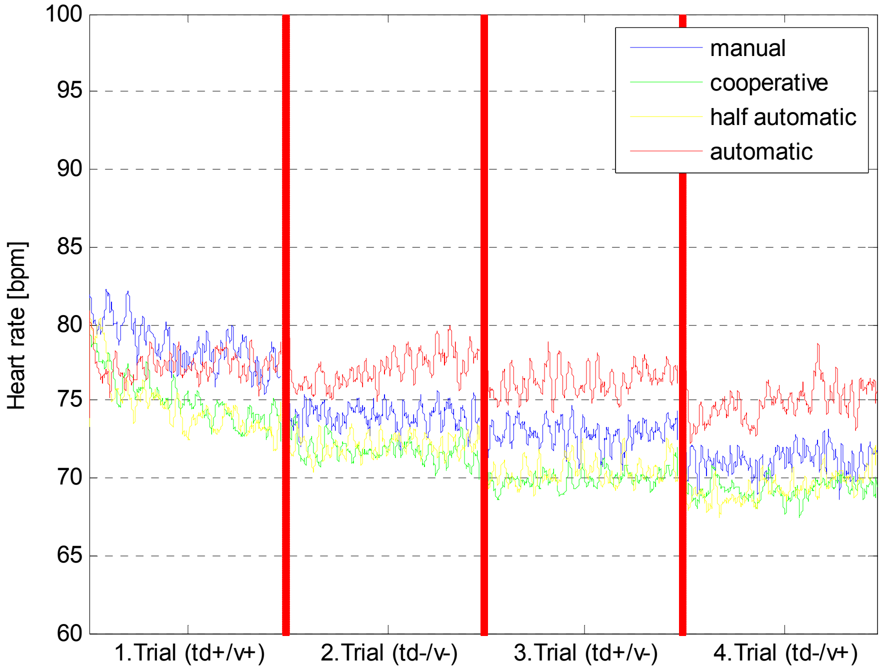

Figure 15: Means of heart rate for all subjects of each condition and each trial

(traffic density high/low (td+/td-) and visibility more than 450 meters/lower than 250 meters (v+/v-))

Due to clarity in the following, only one example shall be briefly presented in order to show that the highest heart rates come along with situations shortly before (section 4 to 18), during, or directly after the overtaking maneuver (section 32 to 49). Figure 16 shows the course of the heart rate of all subjects driving between between kilometer 18.9 and 20 attending overtaking task 9 during the first trial.

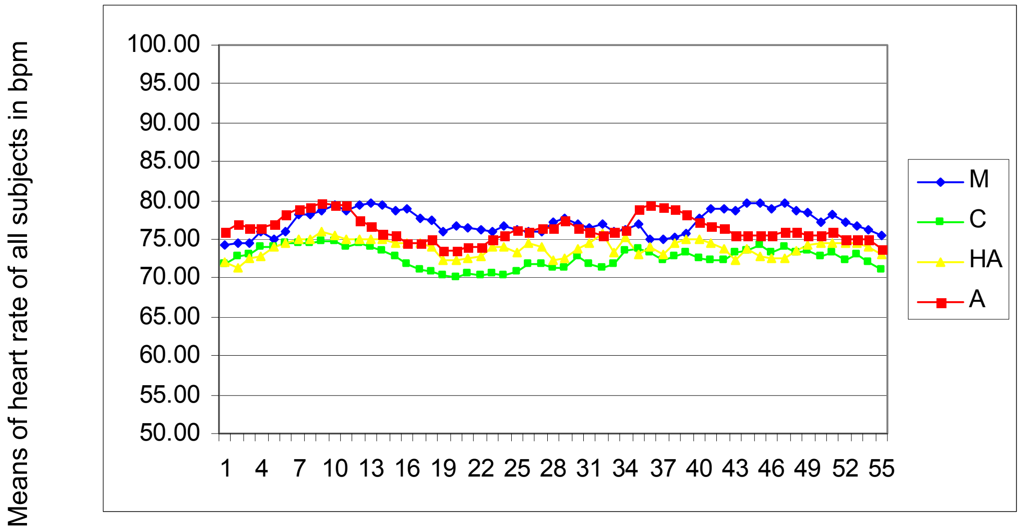

Figure 16: Course of the heart rate of all subjects of each condition between 18900 and 20000 meters during trial 1

(M=manual; C=cooperative; HA=half automatic; A=automatic) (overtaking task 9) (x-axis scaling 1-55 are 20 meters each).

The course of the heart rate in this figure can be seen as exemplary for all overtaking trials. The heart rate of the automatic condition is the first one to rise, due to their slightly earlier approach to the truck and their “immediate” overtaking. Additionally, having especially in trials 2-4 the highest heart rates, the participants of the automatic condition have the shortest peak plateaus during these two phases. In contrast, the participants of the manual condition show the longest plateaus during these two phases of the overtaking task, indicating that the overtaking is most stressful for these participants. The participants of the cooperative and the half automatic system variant show the lowest heart rates, with a medium duration of higher heart rate during the stated phases.

Moreover, it can be seen that the values do not reach the tachycardia range of above 80 bpm.

For the heart rate parameter, it seems to be that there is an independence of traffic density and visibility, at least for the range of values realized herein. This, amongst others, can be explained by the constancy of the parameters of both independent variables during the trials, as direct influences on the heart have been proven in other experiments with sudden changes in visibility (Ladstätter, 2005). Even with different routes, as with the two difficulty levels for driving through bends, there was no rise in the averaged heart rates.

The ANOVA for the factor condition shows no main effect for the psychophysiological parameter heart rate (F = 3.187; df = 3, 111; p = .611), contrary to the hypotheses, between the values of the manually driven subjects and the other three conditions.

Table 5 shows the means and significance results in relation to the trials.

Table 5: Means and ANOVA significance results for the comparison of the manual condition with the three other conditions relating to heart rate for each trial

	Mean M/C ; p-value M/C	Mean M/HA ; p-value M/HA	Mean M/A ; p-value M/A
Heart rate Trial 1 (td+/v+)	76.06/76.46 ; <1.000	76.06/74.85 ; <1.000	76.06/77.14 ; <1.000
Heart rate Trial 2 (td-/v-)	72.12/72.71 ; <1.000	72.12/71.06 ; <1.000	72.12/72.35 ; 0.674
Heart rate Trial 3 (td+/v-)	70.85/71.06 ; <1.000	70.85/70.64 ; <1.000	70.85/76.29 ; 0.375
Heart rate Trial 4 (td-/v+)	68.87/70.97 ; <1.000	68.87/69.59 ; <1.000	68.87/74.82 ; 0.326

(M=manual; C=cooperative; HA=half automatic; A=automatic) (level of significance: ** = $p \leq 0.01$; * = $p \leq 0.05$), corrected by Bonferroni.

Overall, the heart rate data match the other findings like NASA TLX (see results of hypotheses 2) and skin conductivity, which are presented in the following.

Skin conductance

Figure 17 shows the course of the mean values of the skin conductance in microsiemens (μS) for all participants of the respective condition over time (for the standard deviation, see appendix IX figures A IX – 3). The mean values and standard deviations of all measured skin conductivities for the manual condition were subject to a declining tendency between trials 1 and 2 and remained constant from then, whereas the participants in this condition were the most aroused throughout all trials. Nonetheless, these participants show between trial 1 and 4 the highest delta, with a 20.65 percent reduction in skin conductivity values. The same pattern occurs at first for the mean values and standard deviations of the skin conductance for the participants of the cooperative condition. However, in the last two trials, the mean values slightly increased again, resulting in a delta of only *d* microsiemens *(μS)* = 2.90 percent between the first and last trials. For the automatic system variant, also, the same tendency as that of the cooperative variant can be recognized (*d (μS)* = 0.59 percent). The mean values and standard deviations for the participants of the half automatic variant have a comparatively large drop instead, namely by *d (μS)* = 16.19 percent, between trial 1 and trial 4 like in the manual condition, conform to the tendency of the heart rates.

Here, the question arises as to what is the optimal arousal. Assuming that the arousal optimum is reached as soon as the organism is supplied with its effective dose of stimuli, and further hypothesizing that this optimum in the case discussed herein is approx. 0.09 (comparable to findings by Ladstätter, 2006), one could argue that the interaction with the automatic system variant leads to underarousal and that the interaction with the manual system variant leads to overarousal, whereas the arousal of the subjects from the cooperative variant would be ideal. Nonetheless, these findings regarding skin conductivity are contrary to the heart rate results, especially for the fourth trial (see figure 17).

Moreover, incidents (such as overtaking maneuvers, but also critical incidents) can also be recognized for these psychophysiological parameters. As for the heart rate evaluation, the same route section was exemplarily scanned for each condition and trial.

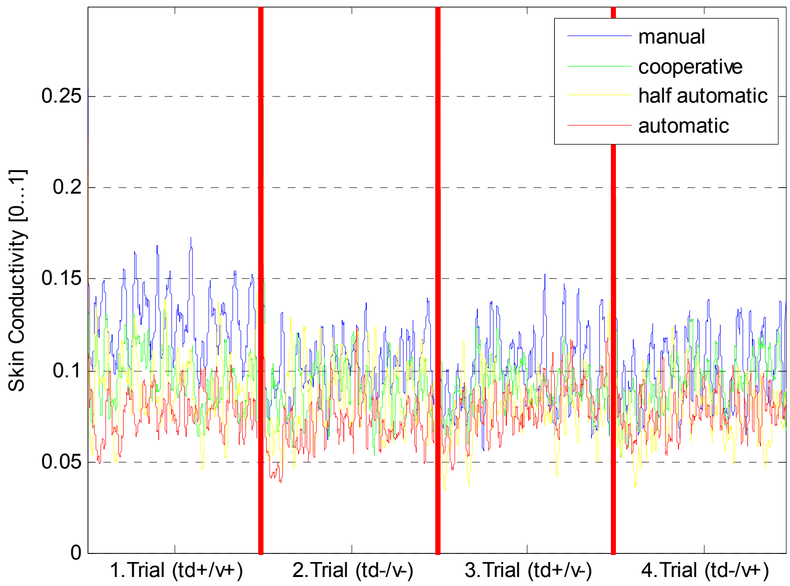

Figure 17: Means of skin conductivity for all subjects of each condition and trial

(traffic density high/low (td+/td-) and visibility more than 450 meters/lower than 250 meters (v+/v-))

The arousal commenced, in the same pattern as the heart rate shown in figure 16, with the first appearance of the truck on the horizon, and the arousal weakened shortly after the executed overtaking maneuver.

In addition, for the skin conductivity there is only a weak dependence on the traffic density recognizable, but no dependence on visibility could be found. A taxonomy for the change in skin conductivity as depending on the difficulty level of the route is not recognizable at first sight.

A comparison of these objective results with those of the subjective measuring of workload shows that a similar tendency of the psychophysiological parameters with the values of the NASA TLX (see results of hypotheses 2) can be identified for the dimension effort.

This similarity can in turn be manifested by the results of the automatic system variant, in particular with the performances of the subjects on the benefits of the presumed development with regard to their own skills, which were adopted by none of the 20 participants of this system variant.

The ANOVA for the factor condition shows a main effect for the psychophysiological parameter skin conductivity ($F(3;109) = .041$), but as shown in table 6, for skin conductivity there is in most cases no significant difference between the values of the manually driven subjects and those of the other three conditions throughout the four trials.

Table 6: Means and ANOVA significance results for the comparison of the manual condition with the three other conditions relating to skin conductivity for each trial

	Mean M/C ; p-value M/C	Mean M/HA ; p-value M/HA ; Cohen d	Mean M/A ; p-value M/A ; Cohen d
SKT Trial 1 (td+/v+)	0.12/0.10 ; 0.147	0.12/0.09 ; 0.041* ; 1.12***	0.12/0.08 ; 0.001* ; 1,18***
SKT Trial 2 (td-/v-)	0.09/0.09 ; 1.000	0.09/0.09 ; 1.000	0.09/0.07 ; 0.029* ; 1.14***
SKT Trial 3 (td+/v-)	0.09/0.09 ; 1.000	0.09/0.08 ; 1.000	0.09/0.08 ; 1.000
SKT Trial 4 (td-/v+)	0.09/0.09 ; 1.000	0.09/0.08 ; 0.592	0.09/0.08 ; 1.000

(M=manual; C=cooperative; HA=half automatic; A=automatic) (level of significance: ** = $p \leq 0.01$; * = $p \leq 0.05$) (effect size (Cohen d)): *= small effect, **=medium effect, ***=large effect) , corrected by Bonferroni.

Only significantly higher values in the first trial can be seen for the participants of the manual condition than for those of the half automatic condition (F = 5.308; df = 3, 111, p = .041; d=1.12) and even higher significant values than for those of the automatic condition (F = 2.929; df = 3, 111; $p \leq$ .010; d=1.18), and in comparison to the subjects of the manual condition in the second trial as well (F = 1.934; df = 3, 111; p = .029; d=1.14). All of these results come with a high effect size.

Driving parameters

The driving parameters show certain patterns in relation to the hypotheses. As an example, the results of the parameter *exceeding compulsory speed limit* shall be presented here (Result figures and tables for all other driving parameters can be found in appendix IX in the section results for hypothesis 1a).

The automatic system variant shows according to its programming exactly 12 cases of speeding in mistake episode 1 and 2 each; this is one case per overtaking maneuver. Hence, this can be referred to as guide value for interpretation of the other values (see Figure 18).

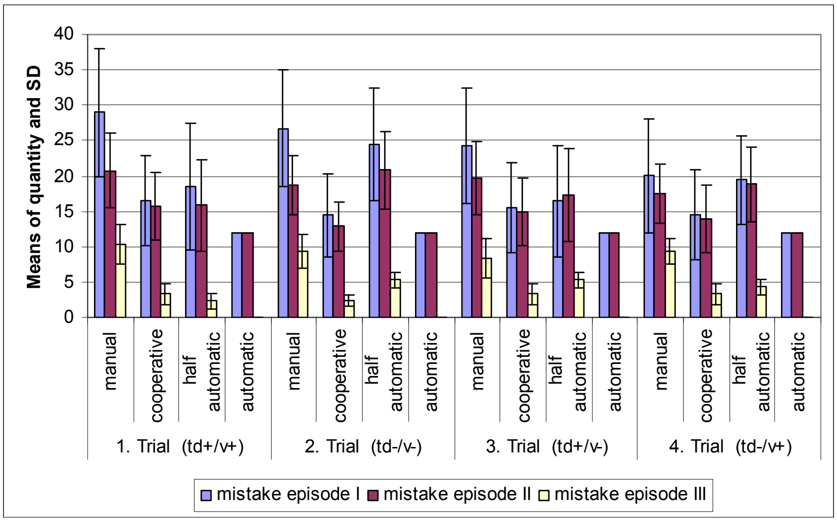

Figure 18: Means of quantity and standard deviation of mistake episode 1-3 of the driving parameter exceeding the compulsory speed limit per trial and condition

(M=manual; C=cooperative; HA=half automatic; A=automatic) (level of significance: ** = $p \leq 0.01$; * = $p \leq 0.05$) (effect size (Cohen d)): *= small effect, **=medium effect, ***=large effect) , corrected by Bonferroni.

For the other three conditions, a tendency comparable to the psychophysiological data can be observed. Only for the half automatic variant in the second trial is the number of mistakes declining on the individual levels throughout the four trials. This tendency also applies to the spans of the standard deviations. Here an adaptation effect is assumed. Additionally, in comparison to the other two variants the subjects of the cooperative system variant consistently produced the lowest number of mistakes on all three mistake episodes, with the exception of the first trial on the third mistake episode.

The driving performance data show in relation to the subjects of the manual condition for the cooperative condition for the parameters *Longitudinal distance to small in relation to own and difference speed* and mistake levels highly significantly lower values, as table 7 indicates for the parameter *Exceeding the compulsory speed limit* (for the first two driving parameters mentioned see the results in appendix IX in the section results for hypothesis 1a, for the calculation formula, see appendix XVI).

Table 7: Means and ANOVA significance results for the comparison of the cooperative manual condition with the two other conditions relating to the driving parameter exceeding the compulsory speed limit of each trial and all three mistake episode levels

	Mean M/C ; p-value M/C	Mean M/HA ; p-value M/HA
Speed E1 Trial 1 (td+/v+)	28.96/17.06 ; <0.001**	28.96/19.82 ; <0.001**
Speed E2 Trial 1	20.81/16.23 ; <0.001**	20.81/17.54 ; 0.133
Speed E3 Trial 1	10.26/3.48 ; <0.001**	10.26/1.86 ; <0.001**
Speed E1 Trial 2 (td-/v-)	26.78/15.03 ; <0.001**	26.78/25.32 ; 0.870
Speed E2 Trial 2	18.75/13.14 ; <0.001**	18.75/22.46 ; 0.072
Speed E3 Trial 2	9.35/2.42 ; <0.001**	9.35/5.04 ; <0.001**
Speed E1 Trial 3 (td+/v-)	24.24/16.19 ; <0.001**	24.24/17.31 ; <0.001**
Speed E2 Trial 3	19.67/15.42 ; <0.001**	19.67/18.01 ; 0.658
Speed E3 Trial 3	8.35/3.31 ; <0.001**	8.35/6.12 ; 0.451
Speed E1 Trial 4 (td-/v+)	20.03/15.06 ; <0.001**	20.03/20.54 ; 0.999
Speed E2 Trial 4	17.59/14.72 ; 0.037*	17.59/20.14 ; 0.259
Speed E3 Trial 4	9.22/3.98 ; <0.001**	9.22/4.21 ; <0.001**

(M=manual; C=cooperative; HA=half automatic; A=automatic) (level of significance: ** = $p \leq 0.01$; * = $p \leq 0.05$) (effect size (Cohen d)): *= small effect, **=medium effect, ***=large effect) , corrected by Bonferroni.

In relation to the half automatic condition, performance in the manual condition is significantly worse only in half of the cases at all different mistake levels.

These results correspond to findings from real vehicle tests with or without support systems like Glaser et al. (Glaser et al., 2005) and the reported results in section 2.1.

For the parameter *Unsafe lane keeping,* the three conditions (besides automatic) show, in addition to the just illustrated results, a certain dependency on the traffic density, which is paired with a slight adaptation effect with regard to the respective two trials with high and low traffic density. All in all, the relatively high values of this mistake are to be attributed to the difficult left and right bends in combination with high speeds while driving through these bends (see appendix IX).

Furthermore, with an average of one mistake per driving minute, the subjects of the manual condition made the most lane-keeping mistakes, whereas in the trials 2 and 4 the subjects of the half automatic variant produce approx. the same number of mistakes. The subjects of the cooperative system variant make the fewest mistakes in all cases.

Only for the parameter *unintended lane leaving* in the trial with high traffic density and good visibility is there no significant difference between the manual and the cooperative conditions for all three mistake levels. The participants of the cooperative condition indeed made the fewest mistakes and provoked, in fact, twice no mistakes of level 3; however, even for these participants the error rate increased throughout the four trials and reached a peak in trial four with low traffic density and high visibility. These results can be explained by the effects of fatigue and a resulting decline in concentration.

The comparison of the manual and the half automatic condition for all driving parameters shows that only 30 of the 60 driving performance data-mistake level-combinations are significantly different; only in 4 cases, however, does the half automatic condition produce significantly worse results.

H1b: The cooperative system variant should differ significantly positive with regard to the

most important psychophysiological parameters as well as observable performance data from the half automatic system variant and should not perform significantly worse than the automatic system variant.

As the relevant parameters have already been described in more depth for the conclusion of the previous hypothesis, here only the inferential statistical results shall be presented so as to prove the hypothesis just stated.

As shown in table 8, for the psychophysiological parameters there was in most cases no significant difference between the values of subjects from the cooperative system variant and those of the half automatic and automatic system variant based in all four trials.

Table 8: Means and ANOVA significance results for the comparison of the cooperative system with the two other systems relating to the psychophysiological data of each trial

	Mean C/HA ; p-value C/HA	Mean C/A ; p-value C/A ; Cohen d
Heart rate Trial 1 (td+/v+)	76.46/74.85 ; 1.000	76.46/77.14; 1.000
Heart rate Trial 2 (td-/v-)	72.71/71.06 ; 1.000	72.71/72.35 ; 0.500
Heart rate Trial 3 (td+/v-)	71.06/70.64 ; 1.000	71.06/76.29 ; 0.232
Heart rate Trial 4 (td-/v+)	70.97/69.59 ; 1.000	70.97/74.82 ; 0.672
SKT Trial 1 (td+/v+)	0.10/0.09 ; 1.000	0.10/0.08 ; 0.147
SKT Trial 2 (td-/v-)	0.09/0.09 ; 1.000	0.09/0.07 ; 0.048* ; 0.99***
SKT Trial 3 (td+/v-)	0.09/0.08 ; 0.428	0.09/0.08 ; 0.378
SKT Trial 4 (td-/v+)	0.09/0.08 ; 0.126	0.09/0.08 ; 0.278

(C=cooperative; HA=half automatic; A=automatic) (level of significance: ** = $p \leq 0.01$; * = $p \leq 0.05$) (effect size (Cohen d)): *= small effect, **=medium effect, ***=large effect), corrected by Bonferroni.

The participants of the cooperative system variant show in the second trial even significantly higher skin conductivity values than the subjects of the automatic condition (F = 4.897; df = 3, 111; p = .048; d = 0.99).

Driving parameters

Figure 19 shows exemplary performance for the driving parameter *small longitudinal distance in relation to own speed* with no mistakes for the automatic system variant for all three episodes, which can once again be seen as an indication the quality of the programming.

The drivers of the manual variant followed by the drivers of the half automatic variant make the most mistakes, whereas the number of mistakes made by the subjects of the manual condition is proportionally the highest. This driving parameter shows that throughout all three conditions more mistakes in the trials with high traffic density occur than in the trials with low traffic density.

Furthermore, the values for the cooperative and half automatic variant in the third trial lie above those in the first trial (both high traffic density), and in the fourth trial above those in the second trial (both low traffic density) so that in this case it is not possible to refer to an adaptation effect. Here it is assumed that in these trials there is an increase in feelings of security due to the interaction with the system.

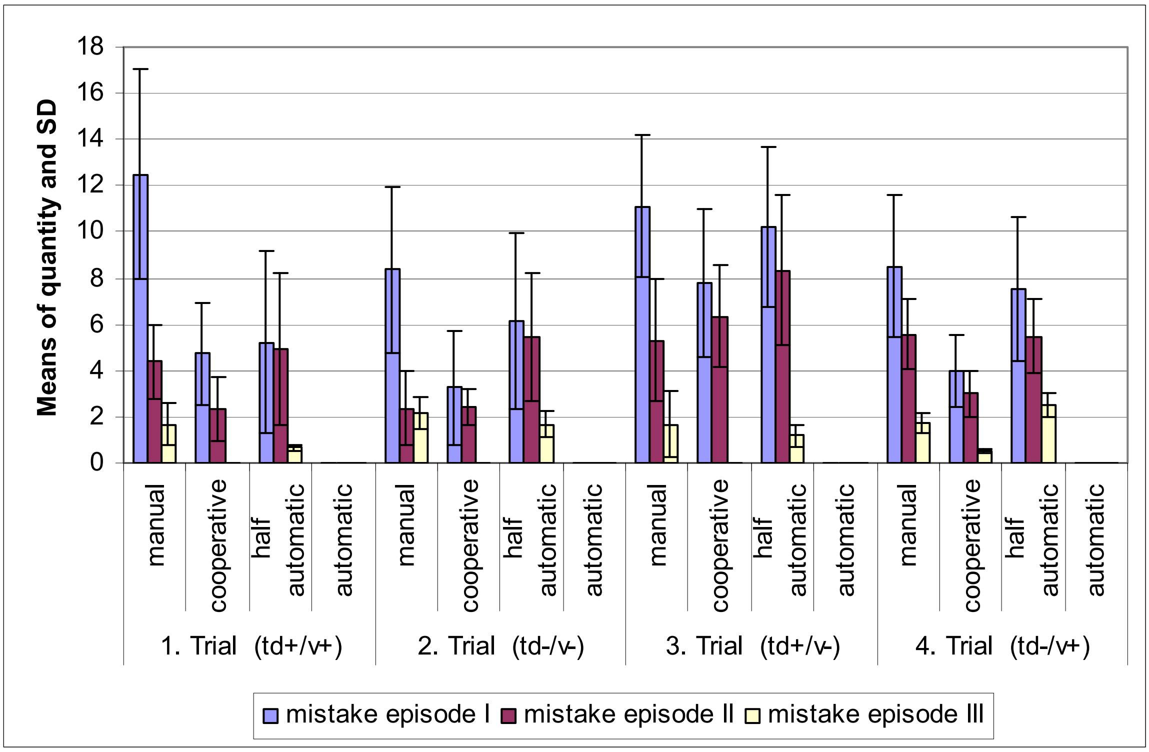

Figure 19: Means of quantity and standard deviation of mistake episode 1-3 for the driving parameter too small longitudinal distance in relation to own speed per trial and condition (Time Headway)

(traffic density high/low (td+/td-) and visibility more than 450 meters/lower than 250 meters (v+/v-)).

Inferentially, the driving performance data for the comparison of the cooperative and the half automatic condition statistically show very heterogeneous results. In only 28 of 60 driving performance data-mistake level-combinations, the subjects of the cooperative condition show significantly or highly significantly fewer mistakes than those of the half automatic condition. For the cooperative condition, table 9 shows exemplary results in comparison to the half automatic condition for the positive parameter *longitudinal distance too small in relation to own speed.*

Table 9: Means and ANOVA significance results for the comparison of the cooperative system with the half automatic system relating the driving parameter longitudinal distance too small in relation to own speed of each trial and all three mistake episode levels

	Mean C/HA ; p-value C/HA
LongDist1 E1 Trial 1 (td+/v+)	5.00/5.61 ; 0.867
LongDist1 E2 Trial 1	2.48/6.57 ; 0.004**
LongDist1 E3 Trial 1	0.00/3.61 ; 0.002**
LongDist1 E1 Trial 2 (td-/v-)	3.55/7.46 ; 0.010**
LongDist1 E2 Trial 2	2.52/5.07 ; 0.011*
LongDist1 E3 Trial 2	0.00/1.86 ; <0.001**
LongDist1 E1 Trial 3 (td+/v-)	8.26/9.23 ; 0.242
LongDist1 E2 Trial 3	6.43/8.14 ; 0.239
LongDist1 E3 Trial 3	0.00/2.79 ; <0.001**
LongDist1 E1 Trial 4 (td-/v+)	4.16/9.32 ; <0.001**
LongDist1 E2 Trial 4	3.10/5.54 ; 0.028*
LongDist1 E3 Trial 4	0.52/1.96 ; 0.013*

(M=manual; C=cooperative; HA=half automatic) (level of significance: ** = $p \leq 0.01$; * = $p \leq 0.05$), corrected by Bonferroni.

However, in 8 cases of all driving performance data-mistake level-combinations, the values of the cooperative condition are above even of those of the half automatic variant. In turn, the positive significances are given in particular for the serious mistake levels 2 and 3, whereas the participants of the cooperative condition constantly drove with no mistakes on level 3.

All non-displayed result figures and tables for all other driving parameters can be found in appendix XI in the section results for hypothesis 1b.

Mirror looks and looks at the speedometer

In the following, the results for the doubled rating method (for procedure see section 5.2.2.1.3) for the three different types of mirrors and the speedometer shall be presented for the overall means.

A clear distribution ratio becomes obvious between the three mirrors and the speedometer. While the participants of all conditions rarely look into the left and even more rarely into the right rear mirror, they look more frequently into the interior rear mirror as well as at the speedometer. Hence, this pattern must be regarded with the exemplification of the absolute values like, for instance, an average overall look number of the subjects from the cooperative condition of 313 looks, which in terms of a trial duration of approx. 15 minutes represents one look every 2.87 seconds into one of the three mirrors or at the speedometer.

Figure 20 shows that the participants of the half automatic system variant most frequently out of all conditions look into the left rear mirror and at the speedometer, while the participants of the automatic system variant most rarely look into the left rear mirror and at the speedometer. On the other hand, the participants of the automatic system variant look most frequently into the interior rear mirror, whereas the participants of the half automatic system variant most rarely use this mirror.

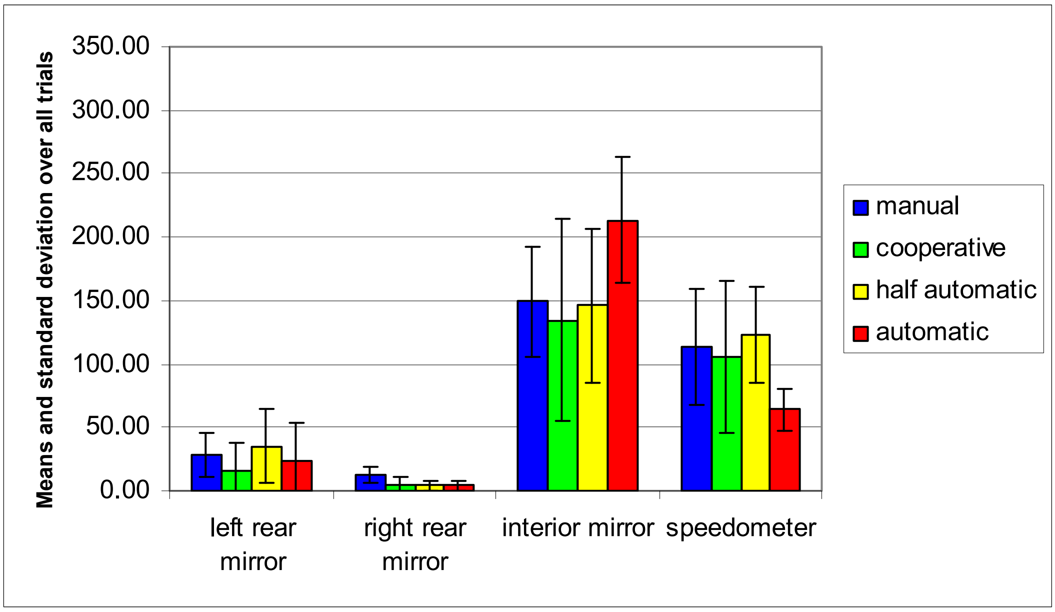

Figure 20: Means and standard deviation of looks for the three different mirrors and the speedometer for over all trials

This result is underlined by the highest psychophysiological values of these conditions in the fourth trial (see results of hypothesis 1a) as well as a high workload indicated by the NASA TLX (see results of hypothesis 2) in contrast to the other conditions.

Statistically, the values of the four conditions for the left rear mirror show no significances. Regarding the right rear mirror, the manual condition has in relation to all other conditions a significantly larger number of mirror looks; in contrast, the automatic condition has in relation to all other conditions a significantly larger number of looks to the interior mirror. For the speedometer, only the mean difference between half automatic and automatic condition becomes significant (for results see appendix IX in section results for hypothesis 1b).

For the interpretation of these results, it is assumed that there is, for example, due to time restrictions a maximum capacity[34] for the four examined look frequencies in sum, and that the mirror and speedometer looks can be considered as indirect indicators for trust and acceptance of a system variant. As such, fewer mirror looks imply a higher acceptance. This leads to the assumption of highest, albeit slightly, acceptance of the cooperative system variant, as this variant, on average, showed the fewest looks over all trials and mirrors.

Unfortunately no comparable results from other studies could be found.

[34] This argument complies with the two most widespread theories of attention, i.e. the capacity and structuring models.

Results for the signaling behavior

For analysis of this interesting parameter, no sufficient methods and standards were found in the literature. For this reason, as well as because the knowledge gained during the experiment that signaling behavior is a relatively complex parameter that is therefore also vulnerable to interpretation, the illustration of the results is waived here for the purpose of evaluative-economical reasons.

However, as a finding from the revision of the investigator's records, it can be stated that the task of signaling was carried out by the driver himself as well as by the system. As such, no behavior pattern for either the individuals or for the participants of the cooperative condition in total can be detected. It can be concluded that a form of trading of the task, in the sense of postulated cooperation, took place. In future, research experiments should be designed to focus on this parameter alone, with hypotheses being developed regarding how often the driver or system, respectively, initiate signalings.

H2: On the level of the most important subjective that is behavioral data for the four test conditions should differ as follows. Compared to the other test conditions the cooperative system variant stands out significantly for the best results regarding the most important subjective and behavioral data, respectively.

Due to the multitude of items, the question regarding a reasonable presentation of the subjective and behavioral data arises. In accordance with Ajzen (2002; 2004) and Arndt (2004), it is, therefore, in the following at first assumed that all direct measurements can be summed up to indices (for a connection of which question is assigned to which construct, see appendix VIII).

Furthermore, for the following illustration of the results, it must be considered that the subjects from the manual condition imagined a cooperative system that was described to them briefly.

Acceptance

When examining the results of the acceptance index, which was built from the gross values of two items, a relatively constant image appears throughout the four measuring periods (see figure 21). Apparent effects from the traffic and fog density are not recognizable. The cooperative system variant is consistently positively accepted and thus the most accepted variant.

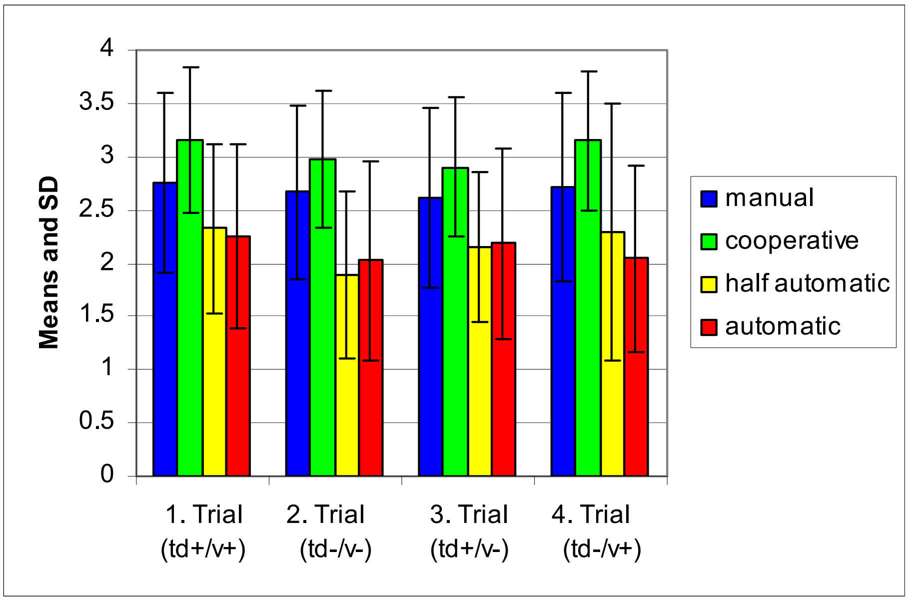

Figure 21: Means and standard deviation of the acceptance index for each condition and trial

(traffic density high/low (td+/td-) and visibility more than 450 meters/lower than 250 meters (v+/v-)).

Due to the experienced incidents, the participants from the manual condition could also well imagine the acceptance of a cooperative system. Almost equally lower is the acceptance of the half automatic and the automatic system, which is rated as mediocre.

The ANOVA for the factor condition shows a main effect for the index on acceptance (F = 11.825; df = $3, 111$; $p \leq .010$). Table 10 shows the inferential statistical results for this index.

Table 10: ANOVA significance results for the comparison of the cooperative system with the imagined system by the manual condition participants and the two other conditions regarding subjective data index acceptance for each condition over all trials

	Mean C/M ; p-value C/M	Mean C/HA ; p-value C/HA ; Cohen d	Mean C/A ; p-value C/A ; Cohen d
Index acceptance	3.04/2.69 ; 0.351	3.04/2.09 ; <0.001** ; 1.51***	3.04/2.13 ; <0.001** ; 1.29***

(M=manual; C=cooperative) (level of significance: ** = $p \leq 0.01$; * = $p \leq 0.05$) (effect size (Cohen d)): *= small effect, **=medium effect, ***=large effect), corrected by Bonferroni.

The rating differences between the cooperative and half automatic as well as the automatic system variants become highly significant with high effect sizes. Only the rating difference of the imagined and the real cooperative system do not become significant.

Affective attitude

When examining the results of the index for the affective attitude, which was built from the gross values of five items, again an almost constant image appears throughout the four measuring periods (see figure 22). The same proportions between the test conditions occur, as with the acceptance results.

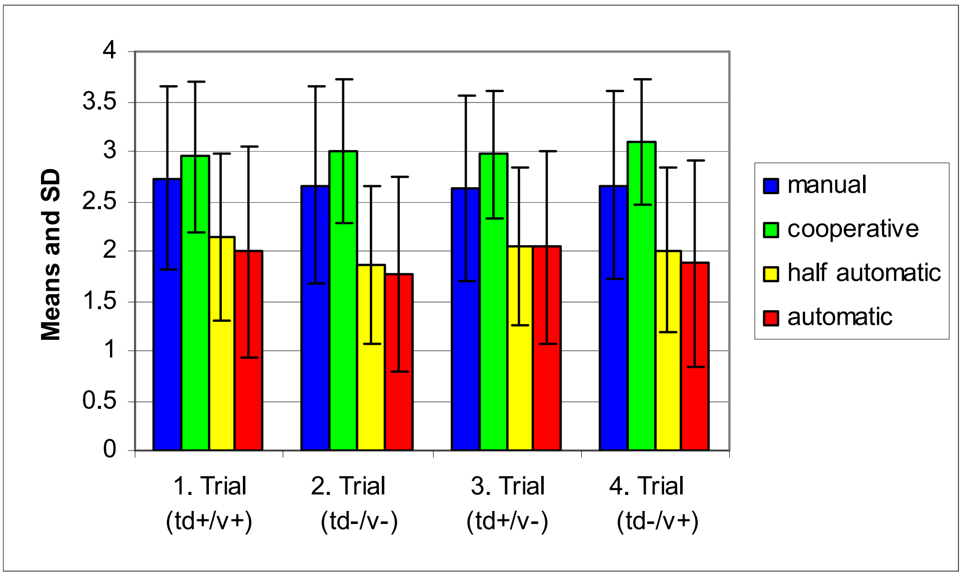

Figure 22: Means and standard deviation of the affective attitude index for each condition and trial

(traffic density high/low (td+/td-) and visibility more than 450 meters/lower than 250 meters (v+/v-)).

Here also the affective attitude towards the half automatic and the automatic system, which is also rated as mediocre, is almost equally lower.

The ANOVA for the factor condition shows a main effect for the index on affective attitude (F = 11.328; df = 3, 111; $p \leq .010$). Table 11 shows the inferential statistical results for this index.

Table 11: ANOVA significance results for the comparison of the cooperative system with the imagined system by the manual condition participants and the two other conditions regarding subjective data index affective attitude for each condition over all trials

	Mean C/M ; p-value C/M	Mean C/HA ; p-value C/HA ; Cohen d	Mean C/A ; p-value C/A ; Cohen d
Index affective attitude	3.00/2.67 ; 0.495	3.00/2.01 ; <0.001** ; 1.41***	3.00/1.92 ; <0.001** ; 1.33***

(M=manual; C=cooperative) (level of significance: ** = $p \leq 0.01$; * = $p \leq 0.05$) (effect size (Cohen d)): *= small effect, **=medium effect, ***=large effect), corrected by Bonferroni.

Again, the rating differences between the cooperative and half automatic as well as the automatic system variant become highly significant with high effect sizes. Only the rating difference of the imagined and the real cooperative system do not become significant.

Cognitive attitude

Also, when examining the results of the index for the cognitive attitude, which was built from the gross values of six items, a relatively constant image throughout the four measuring periods and the trials appears, whereas the half automatic and the automatic system variant in relation to the other conditions do not perform quite as poorly as is the case with the other subjective results (see figure 23). The cooperative system variant generated the consistently best cognitive attitude. The participants from the manual condition as well show an above-average positive cognitive attitude towards the rated cooperative system.

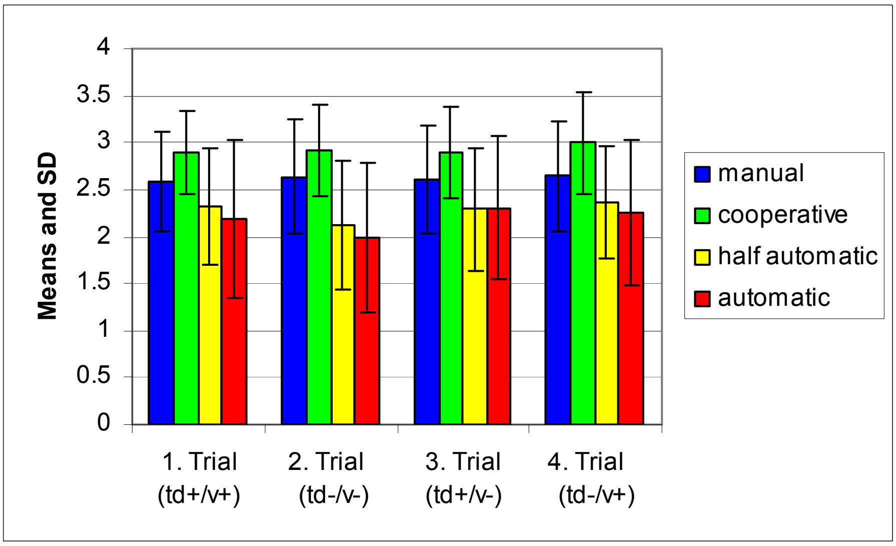

Figure 23: Means and standard deviation of the cognitive attitude index for each condition and trial

(traffic density high/low (td+/td-) and visibility more than 450 meters/lower than 250 meters (v+/v-)).

Almost equally lower is the cognitive attitude towards the half automatic and the automatic system, which is rated as mediocre, though there is a slightly upward slope in trials 3 and 4.

The ANOVA for the factor condition shows a main effect for the index on cognitive attitude (F = 10.032; $df = 3, 111$; $p \leq .010$). Table 12 shows the inferential statistical results for this index.

Table 12: ANOVA significance results for the comparison of the cooperative system with the imagined system by the manual condition participants and the two other conditions regarding subjective data index cognitive attitude for each condition over all trials

	Mean C/M ; p-value C/M	Mean C/HA ; p-value C/HA ; Cohen d	Mean C/A ; p-value C/A ; Cohen d
Index cognitive attitude	2.92/2.62 ; 0.233	2.92/2.27 ; <0.001** ; 1.26***	2.92/2.18 ; <0.001** ; 1.24***

(M=manual; C=cooperative) (level of significance: ** = $p \leq 0.01$; * = $p \leq 0.05$) (effect size (Cohen d)): *= small effect, **=medium effect, ***=large effect), corrected by Bonferroni.

Here as well, the rating differences between the cooperative and half automatic as well as the automatic system variant become highly significant with high effect sizes. Only the rating difference of the imagined and the real cooperative system do not become significant.

Personal norm

When examining the results of the index for the personal norm, that is to say, for the three aggregated items, an almost constant picture appears throughout the four measuring periods, like that already shown by the previously presented results (see figure 24).

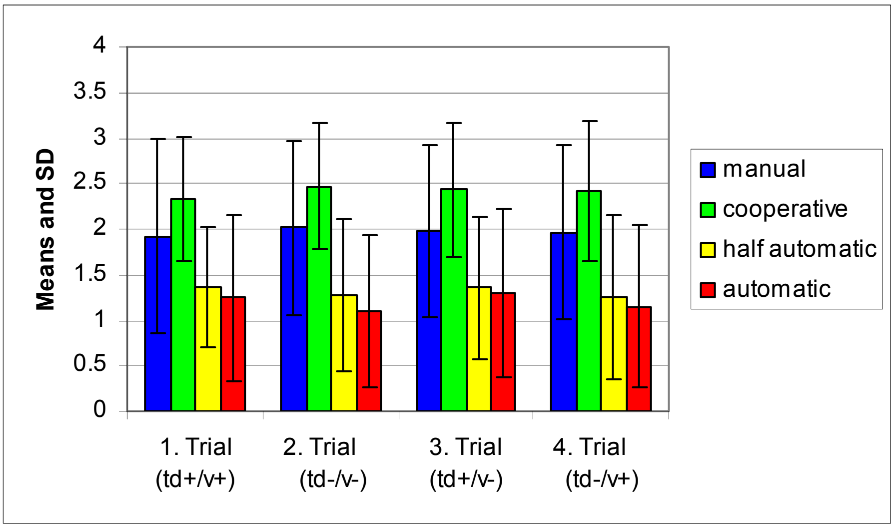

Figure 24: Means and standard deviation of the personal norm index for each condition and trial

(traffic density high/low (td+/td-) and visibility more than 450 meters/lower than 250 meters (v+/v-)).

The cooperative system variant is only rated as slightly above average. The participants from the manual condition show a personal attitude slightly below average towards the imagined system. Again, the personal attitudes towards the half automatic and the automatic system are almost equally lower and thus are rated as poor for this index.

The ANOVA for the factor condition shows a main effect for the index on the personal norm (F = 14.322; $df = 3, 111$; $p \leq .010$). Table 13 shows the inferential statistical results for this index.

Table 13: ANOVA significance results for the comparison of the cooperative system with the imagined system by the manual condition participants and the two other conditions regarding subjective data index personal norm for each condition over all trials

	Mean C/M ; p-value C/M	Mean C/HA ; p-value C/HA ; Cohen d	Mean C/A ; p-value C/A ; Cohen d
Index personal norm	2.41/1.97 ; 0.197	2.41/1.31 ; <0.001** ; 1.60***	2.41/1.20 ; <0.001** ; 1,61***

(M=manual; C=cooperative) (level of significance: ** = $p \leq 0.01$; * = $p \leq 0.05$) (effect size (Cohen d)): *= small effect, **=medium effect, ***=large effect), corrected by Bonferroni.

Again, the rating differences between the cooperative and the half automatic as well as the automatic system variant become highly significant with high effect sizes. Only the rating difference of the imagined and the real cooperative system do not become significant.

Risk awareness

The results obtained from participants related to the risk awareness index indicate that, on average, the cooperative system variant throughout all four measuring periods provided the highest feelings of safety with the lowest standard deviation. Furthermore, figure 25 shows that the manual variant provided the second best results throughout all four measuring periods. In interpreting these results, however, it is important to bear in mind that these subjects in their evaluation were only imagining a cooperative system.

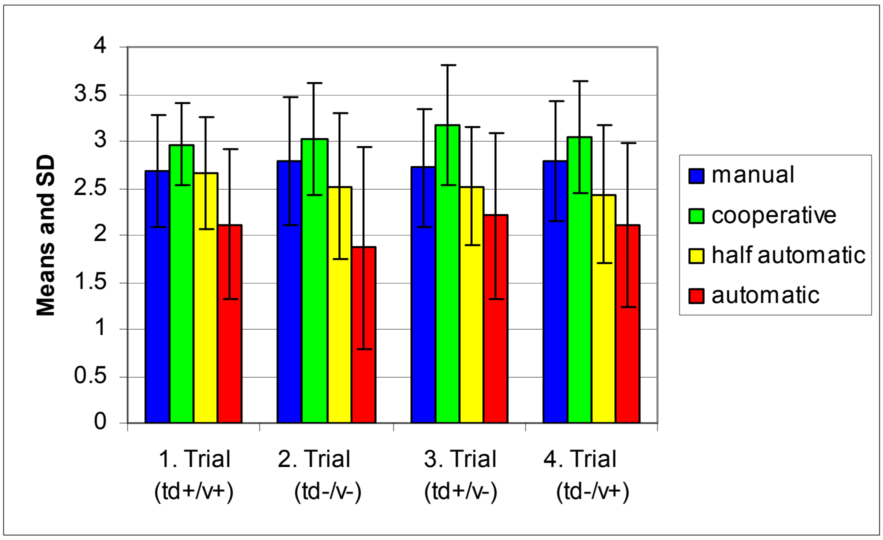

Figure 25: Means and standard deviation of the risk awareness index for each condition and trial

(traffic density high/low (td+/td-) and visibility more than 450 meters/lower than 250 meters (v+/v-)).

The half automatic variant received the third highest safety values. In the risk awareness, the automatic system variant throughout all four measuring periods is the last in line, with the results being particularly low for the second trial with thick fog. As mentioned in section 5.4.1.1, however, no critical incidents occurred with this system. As such, one would have expected higher feelings of safety than, for example, in the half automatic variant, in which up to 6 critical incidents took place. The low values regarding feelings of safety in the automatic system variant, however, correspond to the high psychophysiological values obtained for this variant.

The ANOVA for the factor condition shows a main effect for the index on risk awareness (F = 11.731; df = 3, 111, $p \leq .010$). Table 14 shows the inferential statistical results for this index.

Table 14: ANOVA significance results for the comparison of the cooperative system with the imagined system by the manual condition participants and the two other conditions regarding subjective data index risk awareness for each condition over all trials

	Mean C/M ; p-value C/M	Mean C/HA ; p-value C/HA ; Cohen d	Mean C/A ; p-value C/A ; Cohen d
Index risk awareness	3.05/2.74 ; 0.290	3.05/2.53 ; 0.007** ; 0.98***	3.05/2.07 ; <0.001** ; 1.47***

(M=manual; C=cooperative) (level of significance: ** = $p \leq 0.01$; * = $p \leq 0.05$) (effect size (Cohen d)): *= small effect, **=medium effect, ***=large effect), corrected by Bonferroni.

Here as well, the rating differences between the cooperative and the half automatic as well as the automatic system variant become highly significant with high effect sizes. Only the rating difference of the imagined and the real cooperative system do not become significant.

Trust

The illustration of the results for the trust index for six items shows that the participants of the cooperative system variant on average rated the system with the highest level of trust throughout all four measuring periods.

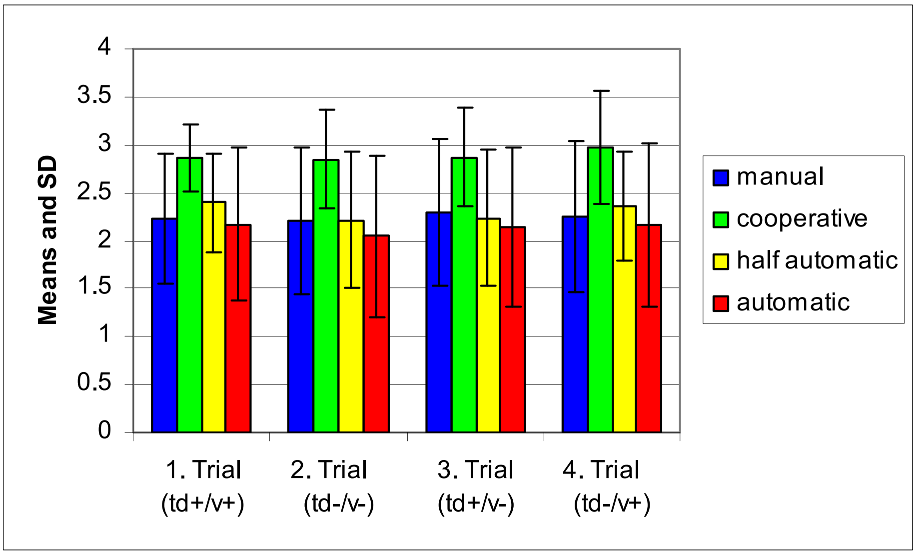

Figure 26: Means and standard deviation of the trust index for each condition and trial

(traffic density high/low (td+/td-) and visibility more than 450 meters/lower than 250 meters (v+/v-)).

Figure 26 also shows that the half automatic system variant performs second best throughout all four measurement periods. The third highest trust values were given by the subjects of the manual condition, who based their ratings on an imagined cooperative system. Throughout all four measurement periods, the automatic system variant was the last in line. In this case, the last three mentioned system variants differ only slightly from each other.

The ANOVA for the factor condition shows a main effect for the index on trust ($F = 9.157$; $df = 3, 111$; $p \leq .010$). For inferential statistical results for this index see table 15.

Table 15: ANOVA significance results for the comparison of the cooperative system with the imagined system by the manual condition participants and the two other conditions regarding subjective data index risk awareness for each condition over all trials

	Mean C/M ; p-value C/M ; Cohen d	Mean C/HA ; p-value C/HA ; Cohen d	Mean C/A ; p-value C/A ; Cohen d
Index trust	2.88/2.22 ; <0.001** ; 1.14***	2.88/2.30 ; <0.001** ; 1.18***	2.88/2.11 ; <0.001** ; 1.26***

(M=manual; C=cooperative) (level of significance: ** = $p \leq 0.01$; * = $p \leq 0.05$) (effect size (Cohen d)): *= small effect, **=medium effect, ***=large effect), corrected by Bonferroni.

Regarding this index, all rating differences between the cooperative and the other conditions become highly significant with high effect sizes.

In relation to the subjective data results displayed thus far, it can be stated that these results are coherent in the means as well as in the variances.

Situation awareness

The descriptive results for the situation awareness reflect a certain kind of separation of the question pool. Although the questions were tested in a pre-examination in terms of their sense, and the procedure for developing the questions was chosen analogously to Bolstad (2001), it became obvious that there were 3 questions which all participants of the experiment had difficulty in answering. In contrast, there were 4 questions, which seemed relatively easy to answer since they were answered correctly by most of the participants.

This separation is important first because the majority of participants stated, at the latest after the third trial, that they had concentrated on the traffic situation as they expected a repeat of the questions.

The questions most likely answered correctly in the SAGAT were:

- Question 2: What was the color of the last truck that you had overtaken?
- Question 3: Did you just travel …(faster, same, slower) than the actual speed limit?
- Question 4: What does the route look like for the next 300 meters?
- Question 7: How many kilometers are left until the whole drive ends?

Figure 27 shows the mean values and standard deviation of the percentage of correct answers for all participants of the respective condition. Here, it can be noted that the participants of the cooperative system in the first two trials gave, on average, the most correct answers. The participants of the other three conditions, however, gave almost equally fewer correct answers. In the third trial, the number of correct answers increased within all conditions, even though in this trial participants had to cope with a high traffic and fog density.

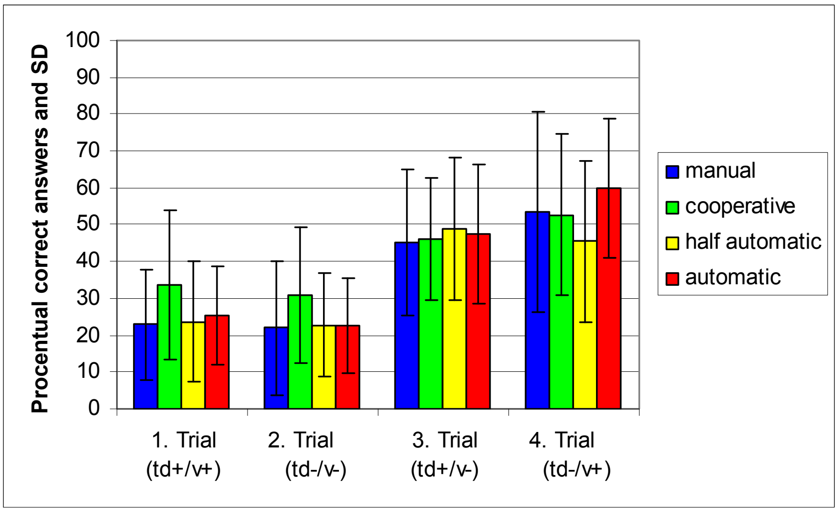

Figure 27: Means and standard deviation of the procentual correct answers of the SAGAT results for each condition and trial

(traffic density high/low (td+/td-) and visibility more than 450 meters/lower than 250 meters (v+/v-)).

The number of correct answers in the fourth trial of the manual and cooperative conditions remained almost constant, while in the automatic condition the number increased and in the half automatic it declined somewhat. The mean values of all participants of the respective condition in the fourth trial, however, are to be considered against the background that, therein, only 6 questions were asked, as the question regarding the estimated distance to the destination became obsolete (this had been one of the questions most frequently answered correctly). This result signifies that in relation to trial 3, a further increase in correct answers was achieved.

The present results as well as comparable results regarding situation awareness in traffic indicate that the current methods, retrospectively, are not satisfying. It was therefore decided to not calculate the inferential statistics on this aspect. At the time the experiment was carried out, however, no other methods were available. Due to the results, it is necessary to evaluate whether different measurement procedures for visual and cognitive distraction are needed (Underwood, 2004), which would have still to be developed.

Workload – subjective measures (NASA TLX)

In this section, the results for the subjective measuring of workload are presented, which in each case took place after the four trials by means of the NASA TLX. The z-transformed mean values of the items according to Thurstone's (1927) throughout the four trials independent of the condition show that the items performance and mental demand throughout all four trials by far obtained the lowest rating (see appendix IX in section results of the hypothesis 2). The item physical demand obtained the highest value, but frustration also has constantly high values, similar to the item effort and somewhat below the item temporal demand. These results clearly show that the tendency of the item effort overlaps with the psychophysiological parameters.

In order to come up with a statement why, of all possibilities, the item physical demand obtains such high values, it is first of interest to examine the mean values for the workload of the subjects throughout the four times of measurement in relation to the condition or system variant respectively. These values are diagrammed in figure 28.

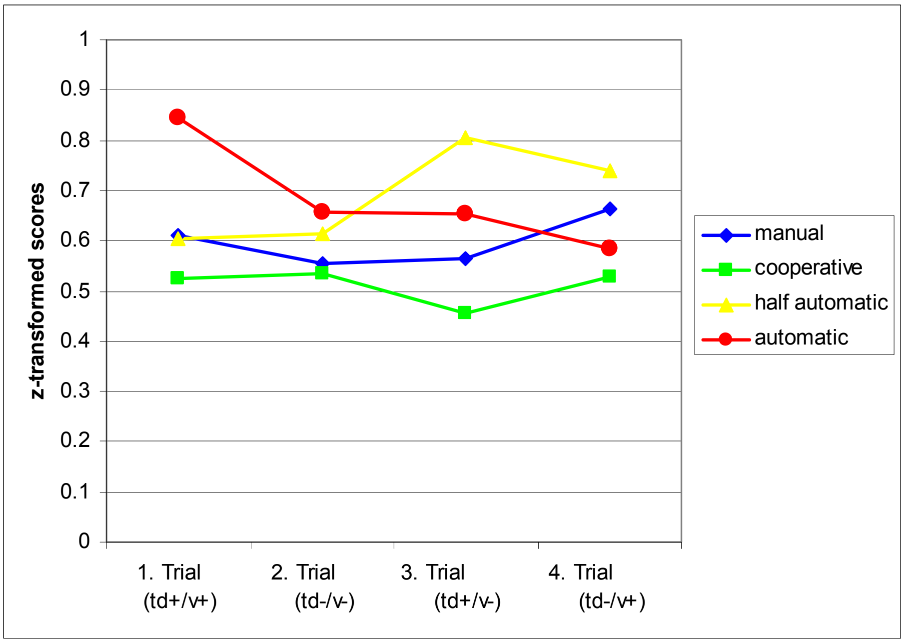

Figure 28: Gradient of workload for the means of all subjects of each condition and for all four trials

(traffic density high/low (td+/td-) and visibility more than 450 meters/lower than 250 meters (v+/v-)).

It can be seen that all test conditions show a relatively high subjective workload, but that the participants of the cooperative system variant consistently reported the lowest workload. The workload also declined over time for the automatic system variant, while at the same time the participants of the manual variant reported an increasing workload. The participants of the half automatic variant also reported an increased workload with the same tendency as that for the manual variant, whereas these perceived the highest workload in trials 3 and 4. These findings for the subjective measures do not match those for the objective measures.

The ANOVA with repeated measurement shows no significances for trials and conditions (F = .714; *df = 3, 111*; p = .555). Only the differences of the values of the automatic condition between trial 1 and 2 and the differences of the values of the half automatic condition between trial 2 and 3 become almost significant.

As such, the present results indicate that the NASA TLX is not, as commonly argued, suitable for such experiments. This lack of suitability can be explained in several ways. First, for the participants, a certain difficulty lies in the interpretation and differentiation of the items, even with a written explanation like that already applied by Seifert (2002), which could lead to wrong answers. As a result, an optional measurement procedure, the BLV by Künstler (1980), will be applied for the second experiment.

Results for the individual conditions

The different system variants led to the decision that question blocks had to be developed that were applied only to one of the four systems each.

The corresponding results shall be presented in the following.

Results for the expected change of abilities and skills

Manual condition

As expected, advantages from cooperation with the imagined system with regard to the abilities of the participants of the manual test condition only named up to two functional complexes at a time. The most frequent entries were not the ones named in the scenario-based interviews (see section 4.2) but abilities which are made up of many other abilities, like the potential of traveling longer distances as related to the increased interaction quality as well as the ability to perform several tasks simultaneously, and this, above all, due to multimodality.

As the expected disadvantages with regard to the abilities an increasing complexity in the interaction in connection with a presumed error sensitivity of the system were assumed by the participants.

According to the participants, advantages related to skill development would appear for the functions of lane keeping and speed management, but also through shorter response times in critical incidents as well as in routine situations.

Disadvantages related to skill development were not expected from a cooperative system by any of the participants of this condition.

Cooperative system variant

Participants of the cooperative test condition named at least three issues at a time related to the expected advantages from a longer cooperation with the experienced system. The most frequent nominations were, in general, the development of an anticipatory driving style (this also referred to the overall traffic, e.g. by means of "self-organizing traffic") and in addition the speed management in particular. Furthermore, advantages with regard to all surveillance tasks like blind spot detection were assumed.

As expected disadvantages with respect to abilities, in connection with presumed interpretation difficulties of the system information due to an increased interaction complexity, a declining sense of responsibility and the handling of the consequences resulting from this were named most frequently. However, 9 out of 31 participants stated that they did not expect the development of any disadvantages.

According to the participants, advantages for the functions lane keeping, speed regulation, and all kinds of distance-control systems would be expected, although, 8 participants stated that they did not expect any advantages.

Furthermore, 30 participants stated that they did not expect any disadvantages related to skill development in terms of system handling. Only one person expected consequences occurring over time due to some kind of "blind trust."

Half automatic system variant

As expected, participants of the half automatic test condition named only up to two advantages coming from a longer collaboration with the experienced system with regard to abilities. Among the most frequent entries was, in general, the potential for a more relaxed arrival at the destination due to a calmer drive as well as all types of distance measurements. The majority of the participants, however, expected no advantages.

Disadvantages with regard to the abilities were feared as a result of diminishing attention of the driver to ensure a comprehensive overview of the driving situation.

The participants of this test condition expected no advantages for the skill development.

The participants of this condition expected negative skill development with regard to situations of the tasks switching between human and system, which underlines the assumptions made regarding the critical incidents.

Automatic system variant

As expected, the participants of the automatic test condition named only up to two issues at a time as advantages coming from a longer collaboration with the experienced system with respect to the abilities. Amongst the most frequent nominations was, in general, the potential for a more relaxed arrival at the destination due to a calmer drive which, however, does not match with the psychophysiological results, and especially not with the results for the fourth trial and the NASA TLX. The majority of the participants, however, expected no advantages at all.

Disadvantages with regard to the abilities were feared in all relevant sectors because of a lack of driver involvement and the inattention resulting from this. However, here also 6 participants presumed no negative effects at all.

Advantages with regard to their own skills were assumed by none of the 20 participants of this system variant, which matches with the results from the psychophysiological and acceptance data.

The majority of the 20 participants stated an expectation of negative skill development due to the loss of the driving experience and driving practice.

Results regarding communication behavior

To obtain data regarding the communication behavior of the systems, 11 question pairs in relation to cooperative, half automatic, and automatic system behavior were asked.

The ANOVA for the factor condition shows a main effect for the index on communication behavior (F = 13.331; $df = 3, 111$; $p \leq .010$). Figure 29 shows the answers from all participants of the respective test condition for the 11 question pairs as a semantic differential. The cooperative system is rated as significantly more direct, informative, and humanized than the other systems, which speaks in favor of the quality of the dialog concept. In contrast, the automatic system was rated as the most unappealing, unpleasant and uninformative system. For all 11 pairs, the half automatic system takes consistently the middle position between the two other system variants. These results match the feedback of the participants regarding the development of abilities and skills as well as the ergonomic design.

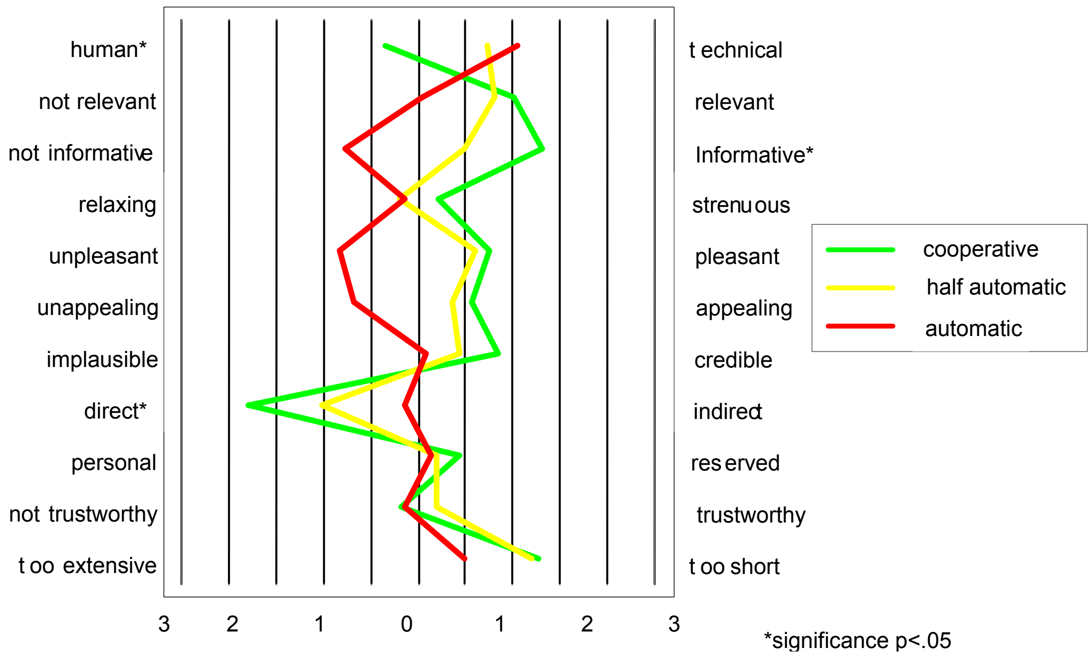

Figure 29: Semantic differential for the judgment of the communicative behavior of all subjects of the cooperative, half automatic, and automatic test condition.

Forty-six percent of all interviewees indicated that they would prefer to lead a dialog with mutual imperative language, while 47 percent would prefer natural language instead; the remaining participants were indecisive.

Cooperative system variant

The voice and the articulation of the cooperative system were mainly rated from "rather good" to "good." Furthermore, 95 percent of the participants felt "rather not" or "not at all" distracted by the communication with the system.

Results for the questions regarding structural characteristics of the interaction

Assessment of effects stemming from interplay with the experienced system with respect to the structural characteristics - broken down to the individual action-levels - throughout all 8 questions, shows a distinct result for the interviewees of the cooperative and half automatic system variant (see figure 30).

All participants of the cooperative system rated the cooperation for all eight action-levels as above average (see theory part 2.3.2).

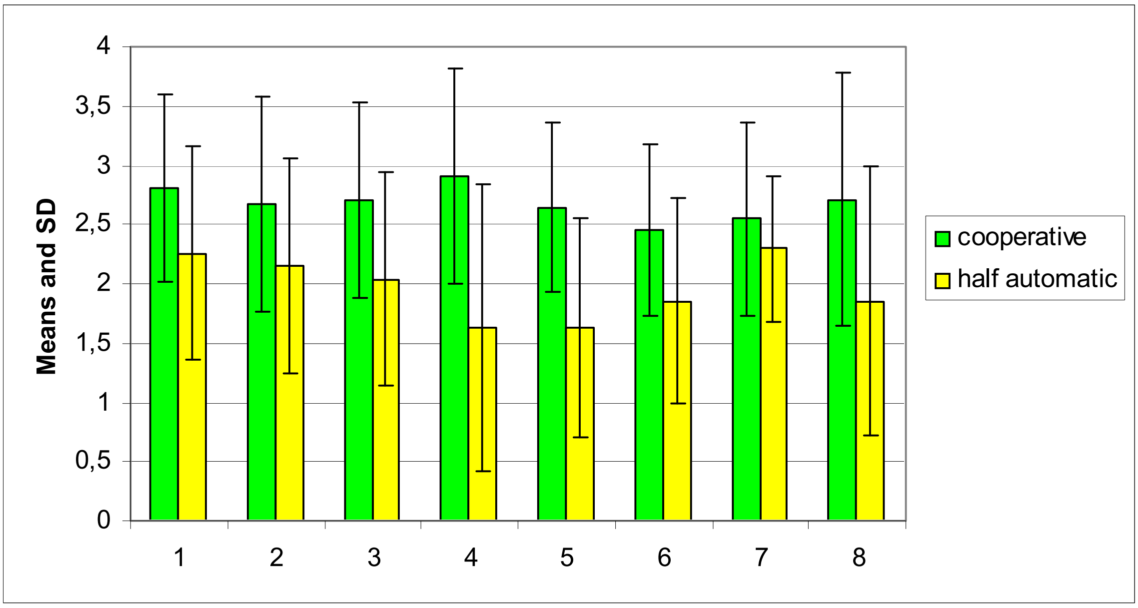

Figure 30: Means and standard deviation of the eight action levels for each condition

(1=situation awareness; 2=motivation for task execution; 3=ability for decision making regarding driving tasks; 4=surveillance and control of driving situation; 5=information integration for decision making; 6=coordination of partial actions; 7=mutual processing feedback of action results; 8=quality of action execution).

The situation awareness, the motivation regarding task execution, and the mutual processing feedback for the half automatic system variant were also rated above average. In contrast, the other characteristics received below-average ratings.

The present results suggest that the structuring of the interaction for the cooperative system variant was superior to that of the half automatic system variant, although the structure of the interaction for this variant was static. For the cooperative system variant, this difference was significantly positive for all action levels significantly positive except of the seventh (see appendix IX in section results of hypotheses 2, table A IX - 17).

Results for the cooperative system variant

For this variant-related analysis, the participants of the cooperative system variant were able to easily reflect the system complexity with their own words. Moreover, they described the system with unique cooperative attributes.

Halden human-automation-cooperation questionnaire

For this experiment, the Halden human-automation-cooperation questionnaire shows high inter-item reliability, as the Cronbach alpha coefficient is 0.81.

Table 16: Means and standard deviations for the six items of the Halden Co-operation Scale (N= 31 ; 0 = not relevant; 4 = relevant).

Question:	Means	Standard deviation
1. To what extent did the system provide relevant information about its activities?	2.97	0.912
2. To what extent did you receive relevant information from the system on time to benefit from it?	2.61	0.803
3. To what extent did you immediately understand the information that the system provided?	3.52	0.626
4. To what extent did the automatic system perform the activities you requested of it (e.g. answer questions)?	2.97	1.08
5. To what extent did the system perform the activities you expected it to do?	2.81	0.910
6. Overall, how would you characterize the cooperation between you and the system?	2.97	0.706
Total Mean	**2.98**	**0.840**

The results in table 16 show for all items show a tendency (with 0 = not relevant; 4 = relevant) toward acceptance of the dialog concept. The lack of multimodality and the sparse functional range of the cooperative system could be seen as the main reasons for not having even higher scores.

Results for the half automatic system variant

In the following, the most important part of the results regarding the one visual and the two auditory symbols that were integrated into the half automatic variant shall be presented. This includes the results from the variant-related analysis. For further results, please refer to the dissertation of Roßmeier (2005).

The answers regarding the suitability and the appealing appearance of the visual symbol (see section 5.2.1.1.3) correspond closely to the percentage shares: 36.6% of the participants rated the visual symbol as nearly up to highly suitable/appealing, 30% as fairly suitable/appealing, and 33.3% as not up to less suitable/appealing. The reasons for these results become obvious in the answers regarding the positive and negative aspects of the visual symbol. Nine of the 29 participants felt positively attracted to the applied pictographs, which were commended as “well viewable” by seven participants (e.g. concerning size or contrast). The simple design was rated very positively by four participants, and four other participants perceived the symbol as intuitionally coherent.

Furthermore, as an indication of the memorableness of the visual symbol, the question as to how many of the participants could remember details from the visual symbol was of interest. The five details of the symbol were a human, a monitor/computer, a keyboard, a steering wheel, and a rectangular frame surrounding these elements. Only one participant was able to remember all five details. The majority only remembered one detail. The most frequent answer from participants was the human (16 participants), followed by the steering wheel (14 participants) and the monitor/computer (11 participants).

These results suggest that the symbol included too many details. Two participants had already mentioned this drawback in their feedback and criticized the detail overload of the visual symbol.

For the first auditory symbol corresponding to system activation, the following scenario occurred. Herein, according to the suggestion of Campbell et al. (2004) the assignment of answers was carried out with regard to symbol understanding within a nine-level category pattern.

In accordance with this answer pattern, 17 answers received a value of 1, and 6 answers a value of 2. Campbell et al. (2004) have pooled values 1 and 2 into a category that expresses a good understanding. Thus the symbol was correctly interpreted by 76.7%. Taking into consideration that the utilization context positively influenced understanding and at the same time that the modification of the visual symbol supported this understanding, this value can be seen as satisfactory.

A similar overall picture occurred for the second auditory symbol, the "Windows Shut-Down." Here also, a high symbol understanding of 76.7% by the participants became apparent (values 1 and 2) which continued in the reaction towards the symbol.[35] With each given answer, it was expressed that control over the automobile was again taken over by the participant. As the situation for returning control back to the driver is by far more urgent than is the case for handoff of the control from the driver to the system, it is not surprising that 24 of the participants took over the "control" immediately. Five participants stated that they took over the control "a little later."

5.5 Interpretation of the results and conclusions

When contemplating the descriptive and inferential statistical results for the individual hypotheses drawn in the preceding section, the following interpretations of the first experiment can be made with respect to the formulated questions in section 3.1.

A second structuring characteristic of this interpretation shall be the in the premises formulated in section 1.2 regarding the rating of an enhanced concept of interaction and the indicators formulated in section 2.4.1 for the benefit of the cooperative interaction.

1. Does cooperation as a form of automation take place in the driving situation "Overtaking on highways"?

The answer to this question can be divided into two parts. First the question of the ability to realize cooperation in this environment at all shall be discussed.

Only the comprehensive analysis carried out before the experiment itself made it possible to create a prototype on the basis of the described limitations. Additionally, it can be assumed that only the

[35] Higher symbol understanding values were expected here, as the "Windows Shut-Down" melody in everyday life should be more familiar for men aged 25 to 40 years.

combination of the Wizard of Oz-method and real technical solutions made the cooperative "prototype" possible.

The answering of the question as to whether cooperation can be experienced at all by drivers constitutes the second part of the answer.

In order to prove the criterion of the development of practical knowledge, questions regarding the anticipated change in abilities and skills were asked. Here, the participants of the cooperative condition expected more advantages in general compared to the other conditions. The main prediction was an expected anticipatory driving style, improved speed management, and an improved accomplishment of surveillance functions by the driver. Here, of main interest are the responses of the participants from the manual condition, who could imagine an increase in the multitasking potential for the interaction with a cooperative system.

The results of the Halden Human-Automation-Cooperation-Questionnaire, which were consistently above average, can be regarded as an indicator for a statement regarding the support and improvement of communication. First, 95 percent of the cooperative participants stated that they were not distracted by the communication with the system. In addition, evaluation of the experiment protocols showed very few communicative misunderstandings.

Finally, to answer this question it would have been helpful to be able to analyze the communication between the cooperative prototype and the driver as well as a certain specific task like the indicating behavior, with its trading patterns, in more depth.

If all results are taken into consideration in answering the question – keeping the mentioned restrictions regarding the previous system complexity in mind – for the experiment scenario "Overtaking on Highways," in principle a technical realization and the chance of a practical experience of a cooperative system by drivers can be assumed. This assumption is supported by the variant-related analysis in which the participants of the cooperative system variant described the system with distinct cooperative attributes. These findings include an understanding that a single system was successfully implemented as an "interaction partner," just as demanded for the interaction with the driver in section 1.1. Consequently, subsystems received less attention.

2. **Is it possible to show for the driving situation "Overtaking on Highways" that "cooperation" in this form of an experimental prototype generates a benefit from a subjective point of view?**

The response to this question is the main objective of this paper. The instantiation of the concept of "cooperative interaction in automobiles" has not yet been studied or even verified. Therefore, it is important to determine whether a subjective benefit from this form of interaction in relation to the developed experimental prototype can be achieved.

A potential optimization of the exchange processes between human and automobile can be proven by the results regarding situation awareness. The situation awareness of the participants of the cooperative system variant in the first experiment was at first more improved than for the other three conditions, but this improvement was by the end of the experiment counterbalanced by the results obtained under the subsequent conditions.

A further indicator for the optimization of the exchange processes is the look behavior. Here, the participants of the cooperative condition took fewer looks in the interior rear mirror and in the left rear mirror, which are most important for the overtaking procedure, than the participants of the other three conditions.

The descriptive statistical results in their sum show that the participants of the cooperative system variant rated the cost-benefit calculation stated in the definition for cooperation implicitly positive.

The results for the action levels show that the structuring of the interaction based on the cooperative dialog concept is in 7 of 8 levels rated significantly higher than for the half automatic system variant. This can be rated as an increase in the interaction quality, which is to be analyzed against the background that on the one hand the interaction of the half automatic test condition was static and for the participants of the cooperative condition unusually dynamically-flexible, and on the other hand that the participants of the cooperative test condition had to interact with a so far unknown and comprehensive communication.

Furthermore, the results of the subjective measures of workload show the lowest values, though not significantly.

With regard to the inferential statistical results for hypothesis 2 - the most important subjective or behavior data respectively - the cooperative system variant compared to the half automatic and the automatic system variant shows significant differences. This result signifies that the interaction with the cooperative system in connection with these parameters provides a larger, or at least some, benefit related to the questions asked, compared to the other system variants.

This finding in particular applies to the comparison of the potential indicator acceptance between the three system variants. Here, the cooperative variant shows significantly higher acceptance values than the half automatic or automatic system variant.

For the comparison between the cooperative and the manual system variant, the cooperative system shows a highly significant difference only for the rating of trust, with the participants of the cooperative condition trusting the system even more. Further, it signifies for this driving situation that there is only a significant difference with regard to the construct of trust if one experiences the system oneself or only imagines it. In addition, it is important to keep in mind in the interpretation of results that here, only 15 minutes passed before the first ratings regarding trust development were obtained. For all other seven dependent variables, however, no significant difference between the manual and the cooperative condition was noticeable. Accordingly, both experienced and imagined systems do not score significantly different on the positive scale.

For the subjective rating of the interaction quality, the cooperative, the half automatic, and the automatic system variants differ in trend with only a slightly positive direction for the cooperative condition. This result is in contrast to all other descriptive and inferential statistical results. This construct shall be examined in more detail with regard to the following experiments.

If all results are taken into consideration for answering the question – keeping the mentioned restrictions on the previous system complexity in mind – for the experiment scenario "Overtaking on

Highways," in principle a benefit of cooperation in this form of the prototype can be assumed from a subjective point of view.

3. **Is it possible to show for the driving situation "Overtaking on Highways" that "cooperation" in this form of an experimental prototype generates a benefit from an objective point of view?**

In order to answer this question, the results for the most important psychophysiological parameters as well as the driving performance data from hypotheses H1a and H1b shall be discussed.

First, the hypothesis was constructed stating that the manual system variant would score the worst when comparing the most important psychophysiological parameters and the driving performance data. This hypothesis can be confirmed for the manual and the cooperative system variant, except for the nonsignificant differences for the parameter *unintended lane leaving*.

As a next step, the hypothesis was constructed stating that the cooperative system variant compared to the "half automatic system variant" would differ in a significantly positive manner in terms of the most important psychophysiological parameters and driving performance data, and that this variant would score significantly worse than the "automatic system variant".

This hypothesis, however, was not confirmed with regard to the psychophysiological parameters.

For the driving performance data, the hypothesis can only be partly confirmed for the comparison with the half automatic condition; for the comparison with the automatic variant it can only be confirmed for the mistake level 3, even though only due to the programming of this variant. On the other hand, compared to the results for the manual and half automatic system variants, the trend of better results for the driving parameter-mistake level-combinations for the participants of the cooperative system variant, however, can be confirmed by the statements made regarding abilities and skills.

The non-significant results are, among other reasons, assumed to be due to the lack of multimodality. Therefore for upcoming experiments, the driver should be provided with even more functionality.

Here also, if all descriptive and inferential statistical results for answering the question are taken into consideration - with the mentioned restrictions with regard to the previous system complexity and for the individual results for the experiment scenario "Overtaking on Highways" - the system can then be regarded as having an objective benefit.

4. **Which effects do situational characteristics have on the objective parameters and the subjective rating of a cooperative system in the automobile for the driving situation "Overtaking on Highways "?**

This question shall be answered based on the results described in section 5.4. The course of the route with its different degrees of difficulty seemed to have no influence on the objective parameters and subjective ratings or were overlain by the effects of the occurred adaptation.

The traffic density alone appears to have a self-evident influence on objective parameters like *time headway*, *time to collision*, and *unsafe lane keeping*. This influence, however, is not large enough to lead to a significant difference between the test conditions, which again can be explained by the overlying through the occurred adaptation.

The visibility seems to have no influence on either objective or subjective results, at least with the limiting values realized herein.

In summary, these results signify that the programmed situational characteristics for this experiment show no noteworthy influence on the objective parameters and the subjective ratings; or they can be referred to as a differentiation characteristic between the cooperative system variant and the other two systems as well as between the manual test condition.

Thus it is necessary in the analysis of the second experiment to further examine situational characteristics such as buildings at roadsides or other courses of the road like crossings as well as the from both characteristics resulting visibility ranges.

6 Methodology of data acquisition and data analysis for experiment 2

As in the first experiment, the real challenge was the methodical process for answering the relatively complex questions and the verification of the hypotheses.

For the following explanations the focus shall be on the innovations and the modifications compared to the first experiment. These improvements first of all derive from the results of the preceding experiment, further developments, and cognitions from other Bosch internal experiments, as well as from the relocation of the driving simulator to a different Bosch site.

6.1 General procedure

The incitements for the choice of method for the second experiment were the same as those for the first experiment (see section 5.1).

The decision regarding the experimental paradigm was essential because of the still existing technical restrictions. Here, the decision was also made in favor of an empirical proving of hypotheses by data inquiry on a driving simulator.

The scenario "Turning Left on Urban and Country Roads with Oncoming Traffic" was chosen as the scenario for this second experiment, as explained in chapter 4.3. The necessity of the analysis for this driving situation in the context of the cooperative interaction is emphasized by the currently increased research interest in intersection assistants, as is the case, for example, with the German project INVENT[36].

6.2 Operationalization of the question

The preparation for the data inquiry was concentrated on the adaptation of the enhancement and improvement potentials for the independent, dependent, and control variables. Therefore, the applied methodology, the design, and the sequence of the second experiment shall be explicitly described in the following.

6.2.1 Independent variables

Compromises were made regarding the construction of the experimental design and the factorial structure: this, on the one hand, was due to the reasonable differentiation from the first experiment so as to respond to the questions and hypotheses as well as to the existing technical possibilities and on the other hand in respect of the complexity and the degree of difficulty for the participants. The efforts again were aimed at establishing an acceptable and economically valid structure for task and action sequences without, at the same time, influencing the acceptance in one or the other direction.

[36] The subproject "active anticipatory safety" of the BMBF-project INVENT (INVENT-Bericht, 2005) referred to assistance systems which would provide help for lane switching, turning, and turning across oncoming traffic.

To be able to comprehend the experimental setting, it shall be briefly characterized in the following. Figure 31 shows an example of an inner city full crossing with the start and end points of a turning task, including the measured driving parameters. The white arrow sign indicates that the participant shall turn left at the next crossing. For this task the traffic light was initially always set to green.

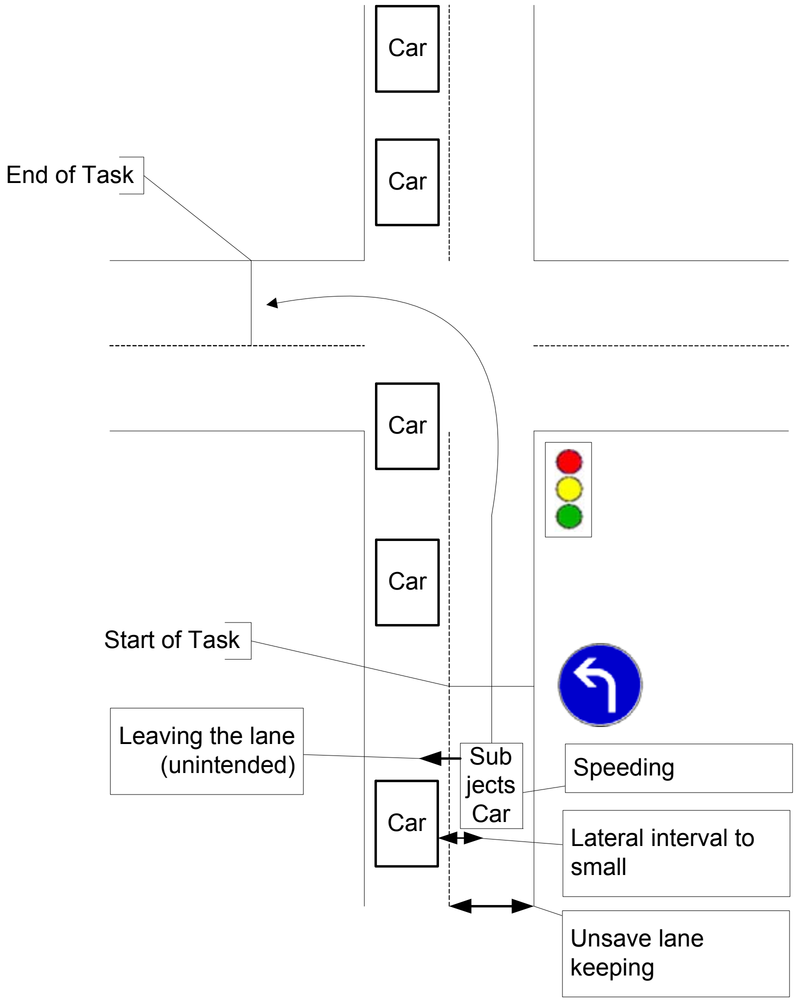

Figure 31: Graphic of the beginning and end of the task left turning (inner city) at a full crossing, including the collected driving dynamic parameters.

Participants of both conditions had to find proper gaps in between the oncoming traffic to turn left. Figure 32 shows three screenshots of such a typical turning situation showing the inner city buildings as well as the country road setting.

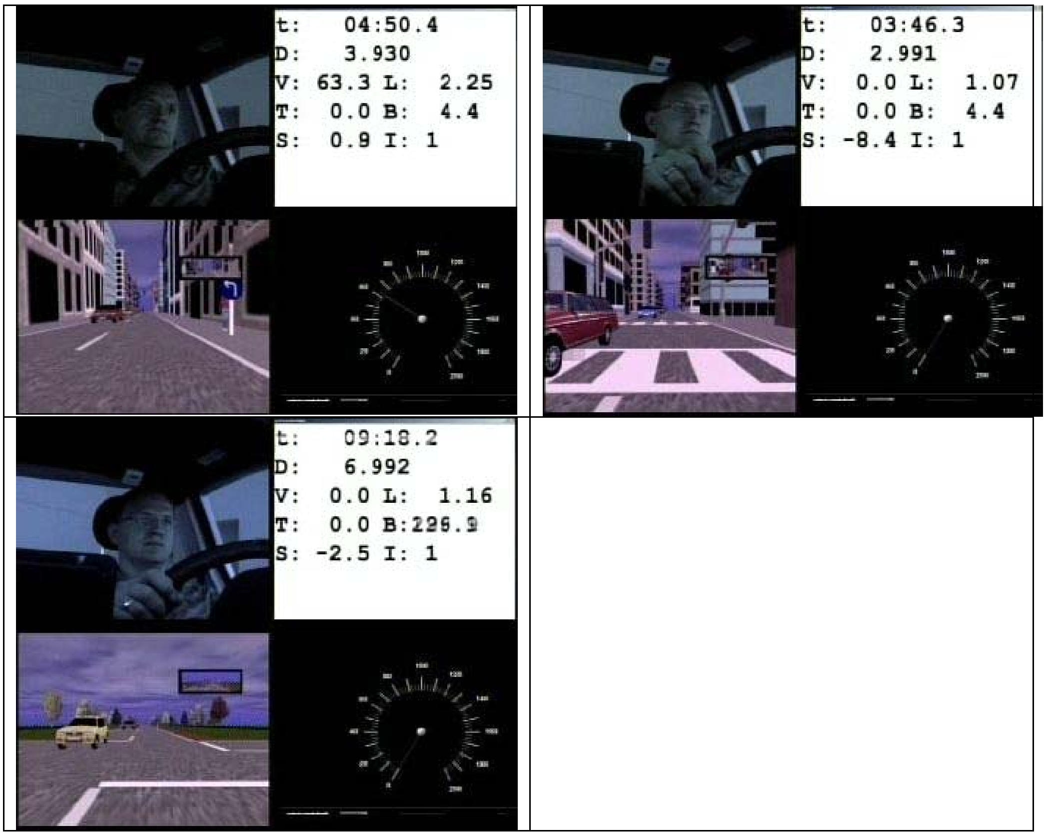

Figure 32: Screenshots of the driving scenario. Top left: start of the task in an urban environment with oncoming traffic. Top right: Inner city with T-crossing. Bottom left: Country road with full crossing with stop line.

In the following, the independent variables for the second experiment are described in their factorial structure. These factors were selected and refined in the same manner as in the first experiment (see 5.2.1).

6.2.1.1 Factor function allocation

Analogous to the shown spectrum of a possible cooperative interaction in the first experiment, the purpose of the second experiment was also to examine such system variants that enable a verification or falsification through the comparison of performance and acceptance data. Whereas because of the relocation of the driving simulator and the time restrictions resulting from this as well as the incompatibility of parts of the new simulation software version with the previous system programming, the automatic and half automatic system variant, unfortunately, could not be recreated. This is the reason why only the following two test conditions were developed for application in the driving simulator.

6.2.1.1.1 The manual condition

For the manual test condition, the participant used the general driving simulator without additional functionality. The following functionalities were at the driver's disposal: steering, signaling, gas pedal, brake, interior and exterior rear mirrors, and a speedometer. Shifting was not necessary due to the automatic transmission. In addition, the driver's own driving noises as well as the noises of the oncoming traffic were audible.

Turning was conducted fully manually, as in everyday life.

6.2.1.1.2 The cooperative system variant

As in the first experiment, the second system variant was distinguished by its cooperative character - the cooperative dialog concept described in section 2.4.1.1.2 (Stein, 1995) served as a basis - and with respect to the system functionality was differentiated in 190 complete sentences (see graphic in section 2.4.1.1.2).

The Wizard of Oz method (Dahlbäck et al., 1993) was also consigned to this dialog concept. In order to achieve this method, the investigator at the control panel in another room and hidden from the participants generated the just mentioned "system outputs." The participants were told in the instructions to interact with a cooperative system, which was speech-based. The functional behavior and the communication rules were explained in the beginning (for the instructions see appendix XII).

Again, in preliminary tests, a complete structure proved to be too detailed. In particular, due to the time-critical periods of a left turn crossing oncoming traffic, differing from the proposed dialog patterns in the theory section, the category "withdrawing system offers," for example, was not taken into consideration. After a rating of all sentences in the preliminary tests by the 15 participants themselves, 63 sentences and 6 functions (see therefore 4.3) were adopted in the experiment according to the method used in experiment 1 (see 5.2.1.1 for a discussion of the separability of dialog and interaction).

Exemplary sentences (sorted according to the numbers of the list in appendix XII):

7. Yes, I can do this

13. You have to take bigger gaps to be able to turn properly

19. Shall I check the gaps between the vehicles of the oncoming traffic?

38. The oncoming traffic is stopping

The resulting dialog shall be illustrated by a short example:

Driver: I'm searching for a proper gap to turn left (A: request)

Car: Please, wait… (B: promise)

After three vehicles is a good gap for a turning (B: inform)

Driver: What is the color of the third car? (A: request)

I would like to get all possible information (speed etc.) (A: assert)

Car: It is a green car. It drives at an average speed of 60 Km/h… (B: inform)

Driver: Thank you (A: evaluate)

Unfortunately, the visualization tool illustrated in section 5.2.1.1.2 with which the investigator could monitor the surrounding traffic and therefore act and react more conveniently could not be realized anymore due to the relocation of the driving simulator and thus the upgrading and reconfiguring of the computers. These changes, however, did not influence the interaction quality of this setting.

As in the first experiment, the system was called and could be addressed by the name VIRA (Virtual Intelligent Research Automation). Here, the language software was a new version of the voice used in the first experiment. This new voice was characterized by improved articulation and stress quality.

6.2.1.2 Factor traffic density

In this experiment as well, the traffic density was varied with regard to two characteristics. In each of the two experimental trials, either a low traffic density or a high traffic density was simulated. In the preliminary test, defined gaps between the automobiles of the oncoming traffic functioned as an indicator of the traffic density[37]. The gap widths in high traffic density were between 20 and 60 meters in the inner city and 40 to 100 meters on country roads. In contrast, in low traffic density the gaps were between 30 and 75 meters in the inner city and 50 to 120 meters on country roads.

6.2.1.3 Factor road

On the test track, which was 54 kilometers in total and was separated into two trials of 27 kilometers, 10 inner city crossings and 10 country road crossings were systematically simulated in each trial. Furthermore, the crossings were in each case presented as 5 T-crossings and 5 full crossings.

Furthermore, the velocities with which the respective crossings were approached differed due to practical logic but also the visibility differed due to the presence of buildings at the respective crossings. An urban speed of 50 km/h was to be observed; the speed limit on country roads was 70 km/h at crossings, whereas on some sections of the country road acceleration up to 100 km/h was allowed. Additionally, there were no buildings or obstructions at the country road; in the city there were buildings directly situated at the crossings, so that one had to approach the stop line in order to have a view of the target street.

6.2.2 Dependent variables

In this section the dependent variables surveyed during the experiment are introduced.

6.2.2.1 Objective and performance data

In the following the objective and performance data are described first. In the second experiment, the survey of the look-in-the-mirror behavior was eliminated for several reasons, but primarily for evaluative-economical reasons.

[37] Here, analogous to the experiences of the first main experiment, it was taken into consideration that comparatively identical automobiles for the oncoming traffic were deployed because the participants showed a different turning behavior when motorcycles or trucks approached.

6.2.2.1.1 Critical incidents

The number of critical incidents, including near collisions with oncoming cars and braking mistakes as well as offenses against the official German traffic regulations (Jagow et al., 2005), were surveyed. Critical maneuvers when turning and disproportional speeding were also assessed for the critical incidents.

These situations were binary acquired by a double rating procedure, in which two raters had to categorize an incident as critical or non-critical, independently from the driving parameters. Only with a matching rating was such an incident valued as either critical or non-critical.

6.2.2.1.2 Driving dynamic data of the driving simulator

For the driving dynamic data, the same selection was recorded as described in section 5.2.2.1.2 and evaluated by the same logic as that described in the same section (a complete list can be found in appendix XVI).

Analogous to the first experiment, the following driving dynamical parameters were protocolled in the driving simulator in accordance with Glaser (Glaser, Waschulewski, & Schmid, 2005). For interpretation of the first three parameters, see section 5.2.2.1.2:

- Exceeding the compulsory speed limit
- Unsafe lane keeping
- Leaving the lane (unintended)
- Lateral interval too small when passing the oncoming traffic (only measured in second experiment):
- For this last parameter, which was surveyed only in the second experiment, the focus was on determining whether participants, when approaching the respective crossing after the oncoming traffic had set in, were steering reasonably and were able to steer and manage to come to a halt in the default limits before the traffic light.

These driving mistakes were selected for Bosch-internal comparability reasons in relation to other studies as well as with regard to the good experiences and results of Altmüller as well as Glaser et al. (Altmüller & Wolf, 2003; Glaser et al., 2005).

6.2.2.1.3 Signaling behavior

Signaling behavior revealed itself as an interesting parameter from the preliminary tests, as in the first experiment. Part of its interest value lies in the lack of literature reports for this factor. Thus, it was not only recorded if and how long the turning was indicated, but, as was of particular relevance for the cooperative system variant, who was indicating (system or driver). However, like in the first experiment, the evaluation was abandoned for evaluative-economical and complexity reasons. On the other hand, after analyzing the experiment protocols for this experiment it can also be said that some type of task-trading took place in terms of the herein postulated cooperation.

6.2.2.1.4 Workload - objective measurement

Again, for the objective measurement of workload, the physiological measuring system named MP 150 by BIOPAC Systems Inc. was used in order to measure the heart rate at the ear as well as the skin temperature at the finger. These two parameters were taken due to Bosch-internal comparability of studies as well as to recent results of internal research. For example, Ladstätter (Ladstätter, 2006) has found a correspondence between heart rate and skin temperature in his research on fatigue. Having a higher skin temperature combined with a lower heart rate corresponded to a significant increase in the risk potential for drowsiness in participants (Ladstätter, 2006). Ladstätter was able to show that skin temperature is a good indicator for drowsiness detection (Ladstätter, 2006). Furthermore, both physiological criteria - skin temperature even more then heart rate - excel through their minor interindividuality.

Using plethysmographic, transcutaneous methods, the pulse can be measured simply and with artefact reduction at different parts of the body. Thus, for this experiment the pulse was measured at the lobulus via an ear clip. This method was used in order to increase the experiment economy, as the application of the ECG electrodes in the first experiment was quite time-consuming.

The skin temperature was measured distally with thermistors[38] at the fifth finger of the left hand. The change in skin temperature in relation to aroused drivers has already been contemplated by Fahrenberg (1979). However, according to literature reports, no standardized derivation methods have yet been developed (Ladstätter, 2006). For this reason, it seemed to be of interest to survey this parameter in the present experiment.

Skin temperature is strictly linked to skin blood circulation. The regulation of skin blood circulation takes place differently according to the region of the body. In the distal, acral sections (hand, foot, ear, nose) the regulation takes place via vascoconstrictor nerves that are innervated via the sympathicus of the central nervous system. An activation of these nerves accordingly proceeds with a constriction of the arteries and thus with a decrease in blood supply. As a consequence, skin temperature declines at this position. Even under thermo-indifferent surrounding conditions, these nerves show strong tonic activity (Schmidt, Lang, & Thews, 2004).

In this experiment as well, the recommended simultaneous measurement of room temperature covered in the psychophysiological experiments was conducted, and the ambient temperature was kept steady by air conditioning.

As in the first experiment, a sample rate of 100 Hz was chosen based on the questions being addressed in this thesis. The difficulty regarding calculation of the values in the second experiment was that the participants in general came to a stop at the white line of the crossing (see task

[38] Thermistors are electric components that temperature-dependently change their ohmic resistance (Port, 2003). Due to their low size (<2 mm), temperature congestion did not develop under the measuring place, which would affect the measurement results.

description 6.2.1.3). Therefore, this time the psychophysiological parameters were not evaluated for the complete route, as in the first experiment, but were aggregated over route sections, as otherwise only one value at a location for the stop would have been referred to for the calculation.

6.2.2.2 Subjective data and behavior data

The subjective or behavior data were acquired by means of a questioning inventory (paper-pencil surveys). As no psychological method battery exists that could have been applied to the questions and hypotheses of the second experiment, it had to be self-developed on the basis of experience with and results from the first experiment and by partly resorting to existing instruments. Another goal was to be able to compare the results of this experiment with other internal studies. As such, it was necessary to change some parts of the questionnaire according to recently gained insights, for example to Bosch-internal acceptance studies. In total, the questioning interview of the second experiment consisted of 15 sections, 18 scales, and 139 items. Questions regarding situation awareness were not taken into consideration due to the results of the first experiment (see section 5.4.1 results for hypothesis 2).

6.2.2.2.1 Acceptance

In this second driving simulator experiment, unlike in the first experiment, a scale for measuring acceptance was applied that had been developed within the scope of research and advanced development by the Robert Bosch GmbH (Arndt, 2004) and that, based on first results from preceding experiments applying this instrument, can be signified as very reliable and valid. Elements of this inventory are attractiveness, acceptance, behavior intention, and their control, as well as the subjective norm (see the acceptance model by Arndt under section 2.4.1.3).

6.2.2.2.2 Risk awareness

For the rating of a system, it is also important how the perceived features of the system can contribute to safety. It is assumed that acceptance of a system also increases with increases in the safety that such a system can offer. In this experiment, the so-called risk awareness was only acquired based on one item, which was the question asking whether the system increases traffic safety. This single-item questioning complies with the logic of the results of Kandale (2002) presented in section 5.2.2.2.3.

6.2.2.2.3 Trust

In this second experiment, questions were directed to the participants regarding the construct of trust in accordance with the introduction of the concept of trust in cooperative systems discussed in the theory section.

For operationalization, the results for the six items from the first experiment as well as suggestions from the thesis by Arndt (2004) were referred to.

Finally, three items were used in the measurements.

6.2.2.2.4 Workload – subjective measurement

While in the first experiment the NASA TLX was applied, here, the "Belastungsverlauf-Test" (BLV) by Künstler[39] (1980) was utilized due to evaluation economy but also to the handling difficulties of the NASA TLX for the participants. The latter was integrated into the questioning inventory with its 46 items, the four subscales (psychological strain, current performance, fatigue, and achievement motivation).

6.2.3 Control variables and boundary conditions

Analogous to the first experiment, the following variables were established and controlled:

- The **age range** of the participants was determined to be between 25 and 40 years.
- K**ilometers traveled** by the subject had to be between 10000 and 20000 kilometers per year.
- Only male persons were invited.
- Only German native-speaking participants were invited due to the complex communication with the cooperative system, the necessary instructions, and question inventories.
- The **team orientation** value scored on the BIP should be at least 40.
- The control belief in technology was assessed.
- The **system language** was constantly female.
- The room temperature was held steady by air conditioning.

6.2.3.1 Team orientation

Also in the second experiment a part of the BIP by Hossiep and Paschen (2003) was applied. In doing so, the willingness of potential participants to cooperate was evaluated in advance of the experiment.

6.2.3.2 Control belief and technology

For the acquisition of technical related personality characteristics within the framework of the human-machine interaction, the questionnaire for the KUT with its eight questions was again used (Beier, 1999). The reason for the utilization of the KUT is the desire to make the share of the subjective influences on the rating of the respective experienced system measurable (see appendix VI).

[39] According to today's definition of the terms objective workload and subjective workload, the BLV would have to be called the subjective workload trend test.

6.2.4 Experimental design

The second experiment was realized as a multivariate, factorial experimental design with even level numbers (see appendix X) and complete trials. For this, the two route types, the two levels of traffic density, and the two levels of crossing types were systematically varied over the two trials in order to avoid sequence effects. From the combination of 2 x 2 x 2 x 2 factor levels, the experimental design originated with a total of 16 cells that were filled with 3 to 4 subjects each. The assignment of the subject to one of the two system variants (factor function allocation) was realized randomly.

6.2.5 Experimental procedure

The complete experiment lasted between 2 and 2.5 hours, mainly depending on the time it took to fill out the questionnaires. The subjects were granted an incentive of 30 Euro for participating. The 32 subjects from the second experiment passed the testing procedure as follows:

- Prequestioning by means of e-mail surveys.
- General instructions for the driving simulator.
- Applying the cables used for measuring the skin temperature at the finger and the pulse as well as applying the sea bands to prevent pseudokinetosis[40].
- An 8-kilometer test drive in the driving simulator including several left turn maneuvers crossing against oncoming traffic, like in the experiment.
- Baseline questionnaire of the BLV.
- Baseline survey of biophysiological parameters.
- A specific instruction depending on the test condition.
- Two trials with changing inner city and country routes of 27 kilometers and 20 left turn procedures each.
- A questionnaire regarding the dependent variables in between trials.
- Post-questioning on the dependent variables.

[40] Pseudokinetosis, also called simulator sickness, is one of the most common reasons for cancellations of driving simulator experiments. For the second experiment it was decided that all subjects should wear sea bands on the wrist as a prevention method (Wesley, Sayer, & Tengler, 2005), as for this main experiment it was assumed that the subjects would easily feel nauseous because of a static driving simulator, especially while turning across oncoming traffic. The acupressure bands are two flexible bands with one button each that are worn on the P-6 acupressure points of both wrists. The Nei-Kuan-Point (P-6) is easy to find even for laypersons. The point is on the inside of the wrists, just three fingers (of the subject’s own fingers) away from the wrist crease arm upwards, between the two central tendons.

In the following, the issues shall be described in more detail, with particular highlighting of changes in relation to the first experiment.

6.2.5.1 Prequestioning

Like in the first experiment, the acquired participants were selected by e-mail prequestioning using the same test of relevant characteristics. Answering the questions required approximately 10 minutes of the participants.

6.2.5.2 Post-questioning

Due to the two system variants, the post-questioning was separated into two sections. First, there were questions that remained the same for all 32 participants. Following this, there were questions regarding communication with the system, in general, and regarding cooperation, in particular, which had to be answered only by the participants of the cooperative test condition.

6.3 Data inquiry

In the second experiment, which was carried out in the form of a computer-simulated survey in combination with administered paper-pencil-surveys, none other than the so far mentioned control or boundary conditions were intended. The data inquiry was carried out anonymously and exclusively in locations of the ROBERT BOSCH GmbH at the Schwieberdingen site.

6.3.1 Acquisition of the sampling

As in the first experiment, the acquisition of participants was carried out in several ways and iterations. For details regarding the procedure, see section 5.3.1.

Moreover, after the experiment, all participants were asked to contact all persons from their circle of friends who also would meet our criteria. Additionally, reservation clauses were agreed upon in which a non-disclosure agreement was set up, for example, in order to not influence new participants.

6.3.2 Sample characteristics

The main test of the second experiment had 32 participants[41], with this 32 being divided randomly between the two experimental conditions, at 16 persons each.

Sample characteristics

Sixty-five percent of the participants were employed by Robert Bosch GmbH in some way, and the other participants were from outside the company.

[41] The participants no. 14 and no. 30 (from the number 32 already subtracted) were excluded from further calculations due to technical problems and recording difficulties.

- The team orientation score of the BIP was between 40 and 64 (51.16 on average)
- The age was between 25 and 40 years (30 years on average)

The question regarding equipment and usage of different technical systems in the automobile showed no abnormalities (see appendix XIII). It was found that the majority of participants did not have a navigation device, an ACC, or even a voice control on their own automobiles. In contrast, all persons stated that they owned a radio.

Table 17: Response frequencies in sum and percentage for the question as to how the participant's experience had been so far with the systems they named.

	frequency	percentage
poor experiences	1	3.1
so-so	4	12.5
good experiences	17	53.1
very good experiences	10	31.3
Total	32	100.0

Table 17 shows that 84 percent of the participants stated that they had good to very good experiences with the systems integrated into their cars. Only one reported bad experiences.

Table 18: Response frequencies in sum and percentage for the question as to how high participants would rank their inclination to new technologies in the automobile.

	frequency	percentage
very little inclination	1	3.1
little inclination	4	12.5
so-so inclination	7	21.9
high inclination	11	34.4
very high inclination	9	28.1
Total	32	100.0

Only 16 percent stated that they had little or very little inclination towards new technologies, whereas almost 63 percent stated that they are positively affected by new systems in the automobile (see table 18).

6.3.3 Data fixation

In the second experiment a modified driving simulator was applied because of the relocation of the simulator from the Schillerhöhe site of the Robert Bosch GmbH to the Schwieberdingen site. The essential modifications were the now possible audible driving noises of the oncoming traffic, the automatic snap-back of the turn-signal lever, and a 180-degree round screen.

In the driving simulator, the infrastructure of which was formed by a network of four computers, a physiological measuring system for data acquisition from the company Biopac was integrated into the overall system (see also the overall design in appendix XIV).

In the following, it is assumed that these technical modifications had no significant influences on the data inquiry.

6.4 Results of experiment 2

In the following section the results from the second experiment "Left Turn Crossing Oncoming Traffic" on Urban and Rural Roads" regarding their descriptive and inferential statistics are presented. For the analysis of the experiment, the software programs Matlab, SPSS, and Excel were deployed, as well as video tapes for reference.

For this second experiment it is important to keep in mind that, contrary to the first experiment, half of the participants of each test condition at first had to manage with low traffic density and then high traffic density, while the other half experienced these two traffic densities in the opposite direction in order to prevent sequence effects.

Again, for the calculation of the driving parameters, the limiting values of the Glaser experiments – adjusted in relation to the measurements of the simulation environment - were deliberately applied in order to achieve a comparability of the frequencies (for the calculation formula, see appendix XVI definitions 1-5).

Also, due to the large amount of evaluated data within this experiment, the following section shall be limited to the most relevant and most exemplary results as applied to the hypotheses as well as to carry out the most aggregated observation possible.

The structure was taken from the order of the descriptions in section 6.2. The experimental design served as the second structuring characteristic. This logic will be followed throughout the appendix in order for the reader to consult the questions regarding the construct and questionnaire parts more easily. All other results will be presented in the appendix due to their extent (see appendix XIII). This includes the results of the physiological baseline measurements and the control variables, TO-value, KUT, and age, which are also displayed in the appendix with a short interpretation (see appendix XIII). In addition, the results regarding the ergonomic design conducted as control, whether the cooperative system variant was understandable and had transparent system behavior, can be found in the appendix (see section XIII).

Pre-drawing the results for the control variables as an interpretation basis of the other results, it can be stated that no noteworthy influence on the dependent variables can be assumed for the three control variables, TO-value, KUT, and age, aside from a few exceptions. As such, the interpretation of a potentially uniformly designed cooperative system for this target group is possible in this driving situation. In further experiments, however, it would have to be clarified how the objective dependent and control variables change, for example, with women, fewer or more control convinced persons, younger or older participants, and less team-oriented drivers.

Additionally, regarding the results of the pseudokinetosis, it is assumed in the following that they had no influence on the objective and subjective results, as no distinctive features occurred.

In section 6.5, interpretations and arguments for answering the questions related to this driving situation are then carried out on the basis of the gathered descriptive cognition and statistical inference.

6.4.1 Statistics

This statistical section serves the purpose of proving the drawn hypotheses in section 3.2.2 on the basis of the acquired data.

It was examined beforehand whether sequence effects occurred when the participants at first drove the trial with low traffic density and then high traffic density, or the other way round. The calculated effects can be ignored for further calculations. Furthermore, the inquired parameters were examined regarding normal distribution (by Kolmogorov-Smirnov-Test). Here, also the results for the following effectuations can be ignored.

Next, verification of the hypotheses H1 and H2 was carried out by means of an ANOVA, whereas the subjective parameters were merged into one index based on the conclusions reached in the descriptive analysis throughout the two times of measurement. Furthermore, for hypotheses 1b and 2b, a multicomparison was conducted (due to lack of space only the result tables with the most hypothetical relevant results are depicted; for all other results see appendix XIII). The effect sizes were calculated according to Cohen (Cohen, 1988; Cohen, 1994). All corrections were undertaken by Bonferroni correction.

Again, as a starting point for the analysis on the most important objective and subjective data, the means of the critical incidents of each condition were taken to check if a global effect existed.

6.4.1.1.1 Results regarding the critical situations

A differentiation between the critical incidents was not undertaken due to the complexity of the incidents in relation to their number and occurrence, but instead the incidents were separated into regular drive and turning tasks over all trials (see figure 33). The revision of the experiment protocols, however, shows that the critical incidents of the cooperative system variant mainly occurred during the turning process itself and not on the route sections in between because here the oncoming traffic had to be stringently implied as a factor for the incident.

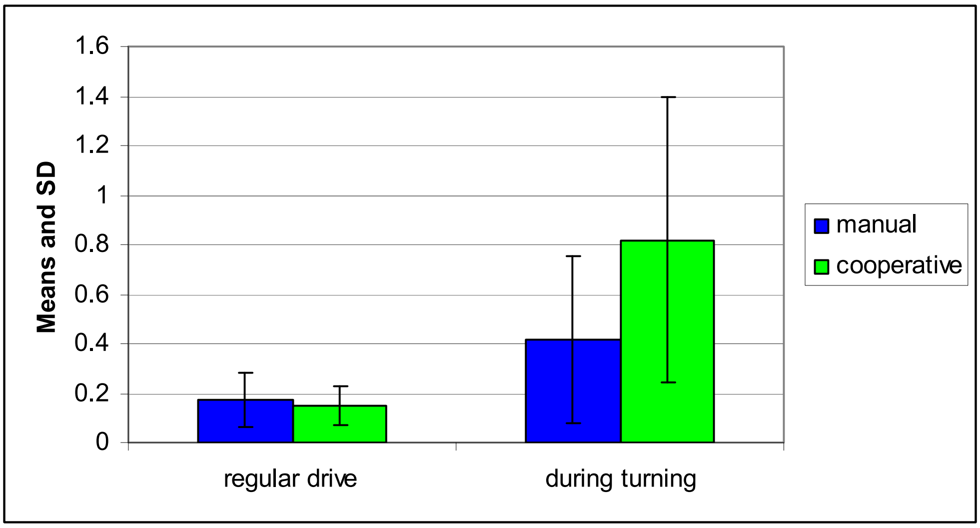

Figure 33: Means and standard deviation of critical incidents for all subjects of each condition over both trials separated into regular driving and turning tasks.

This is emphasized by the fact that the participants of the cooperative system variant experienced at most 4 critical incidents, while the participants of the manual variant only experienced 3 such incidents.

The T-test shows no significant differences between the conditions, which means that the initially assumed global effect seems not to exist.

However, these incidents also mirror the psychophysiological parameters and the driving mistakes, which will be discussed next to show whether one can find statistical effects at a lower data level. The hypotheses and subhypotheses are therefore as follows.

6.4.1.1.2 Results of the hypotheses

In the following the results relating to the hypotheses in section 3.2.2 are first descriptively displayed and then inferential statistically tested.

H1: On the level of the most important objective, which is observable performance characteristics, both test conditions should differ as follows: The cooperative system variant stands out based on its significantly better results with regard to the most important psychophysiological parameters as well as observable performance data.

Psychophysiological parameters

Workload – objective measures

In the following the results regarding the psychophysiological measuring at the lobulus (pulse) and skin (skin temperature) are presented (for baseline results see appendix XIII table A XIII-2 control variables).

As in the first experiment, it is assumed that the surveyed parameters are not subject to the circadian rhythm during the day; otherwise, measurement at different times of the day, as occurred in this experiment, would have led to distorted results. Furthermore, as in the first experiment, the values of all participants were first evaluated and compared throughout the complete course of the experiment in order to verify whether there was variance homogeneity. Following this, data regarding the relevant sections within which the turning processes took place were extracted. This procedure also became necessary because for this experiment, contrary to the first experiment, the car was required to halt (see task description in 6.2.1.3) at the stop line and thus for the same meter value several psychophysiological parameters existed.

Heart rate

Figure 34 shows the average values of heart rates for all participants under both conditions for the 20 tasks of turning left in high traffic density itemized by the turning type. It can be seen that the participants of the cooperative condition had on average 5 beats more per minute for each task than the participants of the manual condition. This increase can be attributed to the interaction with the system.

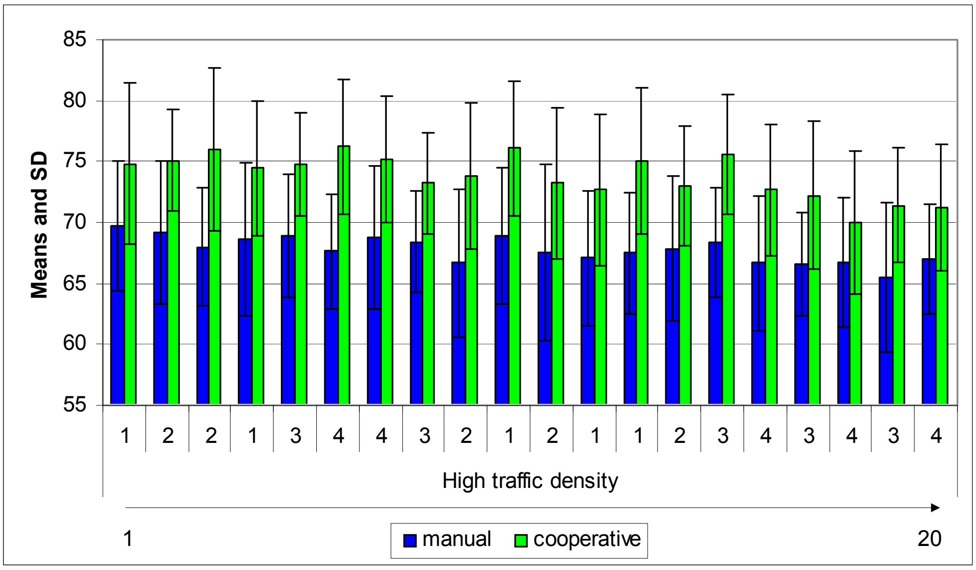

Figure 34: Means and standard deviation of heart rate for each condition in the high traffic density trial

(Task 1= full crossing inner city; Task 2= t-crossing inner city; Task 3= full crossing country road; Task 4= t-crossing country road).

Here, a systematic effect, caused, for example, by the crossing type or by buildings in crossing areas, is hardly noticeable. The highest heart rates for the cooperative condition were present in the inner city as well as country road crossings. In contrast, the values tend to decline at the end of the experimental period, which suggests a possible adaptation, at least in the high traffic density trial.

In figure 35 the heart rates for the 20 tasks for the low traffic density are depicted. Here also, all average heart rate values of the cooperative condition lie above those of the manual condition. A wavelike progress that tends to result in lower values at inner city crossings can be observed.

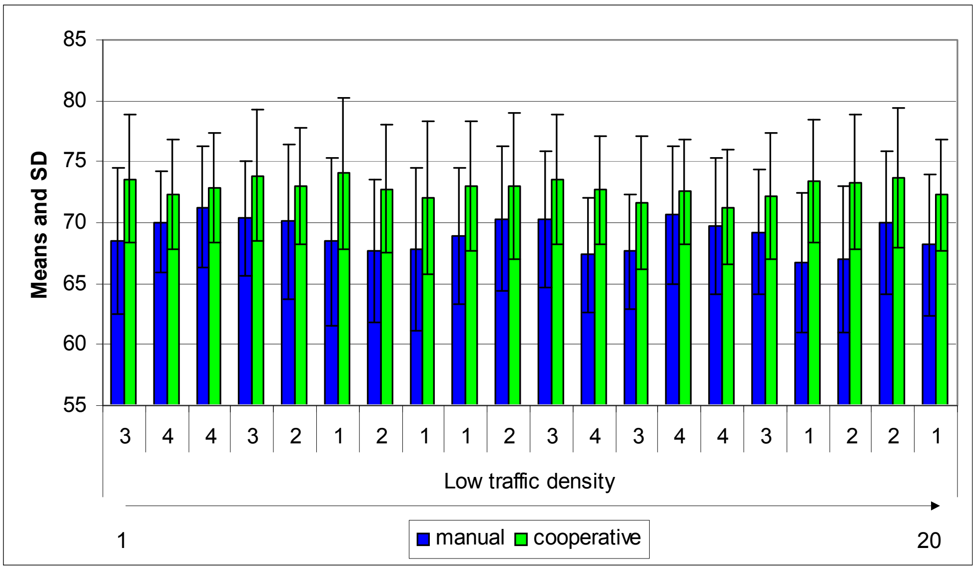

Figure 35: Means and standard deviation of heart rate for each condition in the low traffic density trial

(Task 1= full crossing inner city; Task 2= t-crossing inner city; Task 3= full crossing country road; Task 4= t-crossing country road).

In total, the average values of the manual condition with low traffic density are slightly higher than those with high density, and for the participants of the cooperative condition, the average values are slightly below those with high density. This result can be explained by the fact that the participants of the manual condition with less oncoming traffic turned earlier than those with high density and thus in this trial were more aroused. In the cooperative system variant, the participants turned earlier in general and thus were more aroused. This arousal, of course, was therefore lower with low traffic density. In addition, the differences between the conditions can be explained by the actual interactions. The remaining difference can be explained by the interaction with the cooperative system.

The ANOVA for the factor condition shows no main effect for the heart rate (F = 7.322; df = 1, 31; p = .221). Table 19 shows that these differences in heart rates were not significant for either trial.

Table 19: Means and ANOVA significance results for the comparison of the cooperative system with the manual system relating to the heart rate for each trial

	Mean C/M ; p-value C/M
Heart rate Trial HD	75.30/69.97 ; 0.252
Heart rate Trial LD	74.09/68.86 ; 0.178

(M=manual; C=cooperative; HD= high traffic density; LD=Low traffic density) (level of significance: ** = $p \leq 0.01$; * = $p \leq 0.05$), corrected by Bonferroni.

Skin temperature

When observing the skin temperature values of the fifth finger on the left hand a waveform becomes visible for the high traffic density trial in figure 36. For the two inner city crossing types, skin temperatures up to 0.8 degrees higher can be examined and a therefore accompanying lower arousal than for the country road crossings.

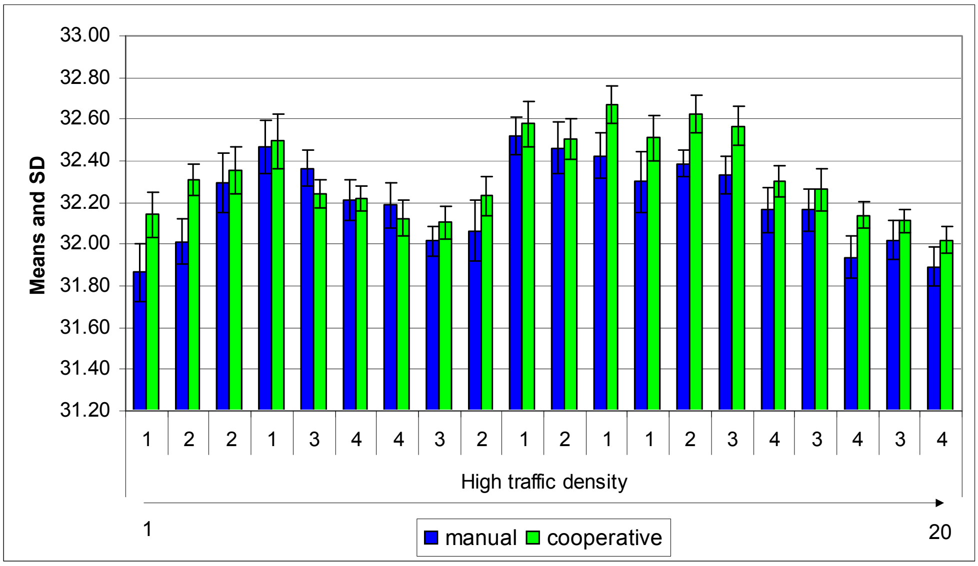

Figure 36: Means and standard deviation of the skin temperature (degree Celsius) at the fifth finger of the left hand for each condition and each turning task 1-20 in the high traffic density trial

(Task 1= full crossing inner city; Task 2= t-crossing inner city; Task 3= full crossing country road; Task 4= t-crossing country road).

At the same time, the participants of the cooperative condition showed slightly higher temperatures than those of the manual condition for every task but task 7.

For the second change from urban to rural areas, it requires a latency period of a full crossing before the values again start to decline noticeably.

Thus, it can be shown that thermoregulation of the human body is connected with visual impressions, in this case, by the buildings at crossings and the traffic density of the oncoming traffic. Although this relation seems to show that arousal is lower at inner city crossings than at country road crossings, this finding does not correspond to the results for heart rates, as no remarkable change was observed throughout the tasks and the cooperative participants were identified as being more aroused. Moreover, the results from Ladstätter (2006) lead to the assumption that all participants are more relaxed at country road crossings because less visual stimulus material is presented. In comparison to a drive with normal visibility Ladstätter measured an increase in finger temperature of up to 3 degrees (here only 0.8 degrees) when driving in fog (Ladstätter, 2006). In a further investigation of thermoregulation cognitive processes (Boucsein, 1988), changes initiated by different gap sizes and different speeds of the oncoming traffic would have to be examined. Comparable experiments for street lighting at crossings and for traffic density by using the electrodermal activity as the quantitative psychophysiological workload indicator were carried out in the early sixties (Cleveland, 1961; Michaels, 1960, 1962). Here also, supporting documents for the effects of road type, traffic density, driving speed, and street lighting could be provided. Additional, heterogeneous results can be referred to in Boucsein (1988). These studies, however, were carried out with small sample sizes (e.g. n=4) and included only a specific EDA parameter like the amplitude height (Boucsein, 1988).

In figure 37 the change in skin temperature as dependent on the factor route becomes apparent as well. Both the participants of the manual condition and those of the cooperative test condition show a finger temperature increased by up to one degree Celsius at inner city crossings.

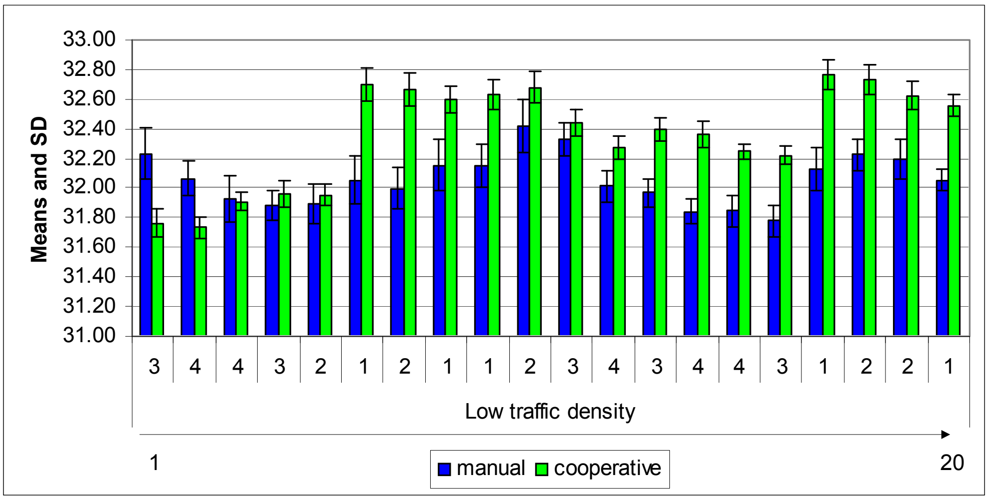

Figure 37: Means and standard deviation of the skin temperature (degree Celsius) at the fifth finger of the left hand for each condition and each turning task 1-20 in the low traffic density trial

(Task 1= full crossing inner city; Task 2= t-crossing inner city; Task 3= full crossing country road; Task 4= t-crossing country road).

Except for the first three country road crossings, the average values for the participants of the cooperative condition are clearly above those of the manual condition.

The ANOVA for the factor condition shows no main effect for the finger temperature (*F* = .522; *df = 1, 31*; *p* = .343). See also table 20.

Table 20: Means and ANOVA significance results for the comparison of the cooperative system with the manual system relating the finger temperature of each trial and all three mistake episode levels

	Mean C/M ; p-value C/M
Finger temperature Trial HD	32.46/32.08 ; 0.380
Finger temperature Trial LD	32.51/31.92 ;0.364

(M=manual; C=cooperative; HD= high traffic density; LD=Low traffic density) (level of significance: ** = $p \leq 0.01$; * = $p \leq 0.05$), corrected by Bonferroni.

The values for the heart rate and the finger temperature of the subjects from the cooperative condition are noticeably above those of the manual subjects. However, here the tendency varies. While an increased heart rate is considered as an arousal indicator, increased finger temperatures are to be considered as a relaxation indicator (see section 7 for a discussion of the psychophysiological parameters).

When comparing the driving parameters a highly different result becomes apparent.

Driving parameters

For the second experiment, the driving behavior was evaluated by selected elements from the method for evaluation of driver interaction systems (see appendix XVI) that was developed within the European project INVENT AP3100 (Böttcher et al., 2004) and that was validated and further developed in the AP3200 (Glaser et al., 2005). Here also, the critically categorized incidents can be found in the objective driving data and also, presumably, in the psychophysiological parameters. For the interpretation of the following results it is important to also keep in mind that the participants of the cooperative test condition required less time to complete the routes - 3.56 minutes on average with high traffic density and 2.43 minutes on average with low traffic density, as they turned more quickly at the crossings.

Exceeding the compulsory speed limit

The driving parameters show certain patterns in relation to the hypotheses. As an example, the results of the parameter *Exceeding compulsory speed limit* and *Unintended leaving the lane* shall be presented here (Result figures and tables for all other driving parameters can be found in appendix XIII in the section results of hypothesis 1).

The first purpose of this driving parameter is to show whether the subjects obeyed the instruction to maintain the speed limit. It is also, however, used to figure out how the participants acted during the drive, as it is supposed that an assistant system changes speed behavior (Koziol, 1999), which must be proven for this case. In figure 38 the means and standard deviations of the mistake levels 1 to 3 for the mistake exceeding the compulsory speed limit are presented (for calculation formula see appendix XVI, driving mistake 1).

The majority of these mistakes occurred when the participants had not reached 50 km/h upon entering the city, even though due to the knowledge of this phenomenon and the frequent speed changes, the start point of measuring the speeding and the hereby effected mistake episodes were situated 40 meters beyond each speed limit sign.

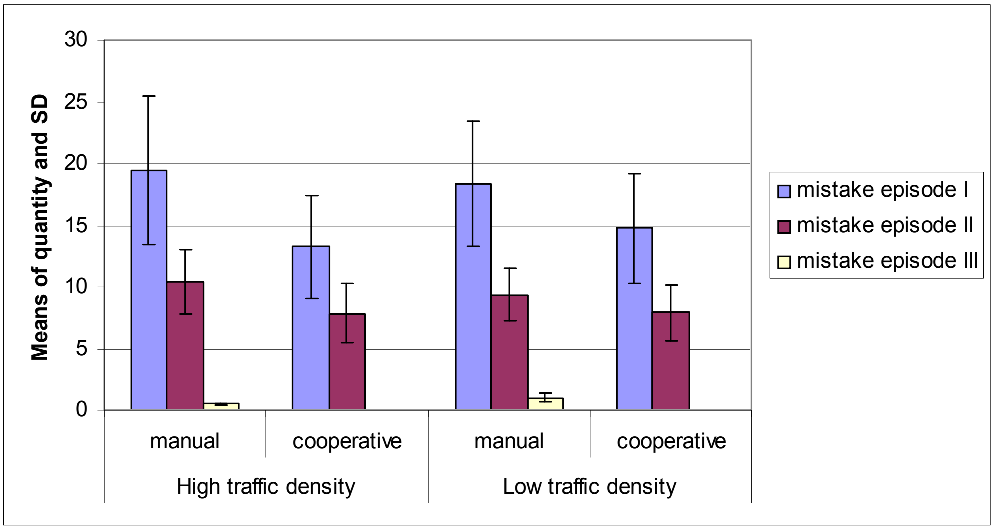

Figure 38: Means of quantity and standard deviation of mistake episodes 1-3 of the driving parameter *Exceeding the compulsory speed limit* per trial and each condition.

For both trials, the participants of the manual test condition committed approximately 30 percent more speeding offenses than the participants of the cooperative test condition, whereas no big difference between the trials is to be noticed.

The driving parameter speed shows in four of the six mistake levels a highly significant result and in one case a significant result in favor of the cooperative test condition (see table 21). Only on the third mistake level of the trial with low traffic density did both test groups make no mistakes at all.

Table 21: Means and ANOVA significance results for the comparison of the cooperative system with the manual system relating the finger temperature of each trial and all three mistake episode levels

	Mean C/M ; p-value C/M
Speed E1HD	14.39/19.91 ; <0.001**
Speed E2 HD	8.04/11.91 ; <0.001**
Speed E3 HD	0.00/0.45/ ; 0.023*
Speed E1 LD	15.88/18.78 ; 0.004**
Speed E2 LD	8.13/10.94 ; <0.001**
Speed E3 LD	0.00/0.00 ; -------

(M=manual; C=cooperative; HD= high traffic density; LD=Low traffic density) (level of significance: ** = $p \leq 0.01$; * = $p \leq 0.05$), corrected by Bonferroni.

Unsafe lane keeping

For this parameter the most mistakes occurred when decelerating before a crossing section. One reason for this was the unfamiliar steering in combination with the harder brake as in a real automobile. In contrast to the first experiment, the noticeable low number of mistakes can be explained by the lower difficulty degree when driving through bends and the lower speed.

The participants of the manual test condition committed more lane keeping mistakes than the participants of the cooperative test condition, whereas the former provoked only barely more mistakes in lower traffic density than the latter and the latter provoked more level-2-mistakes in the trial with low traffic density.

For the driving parameter *unsafe lane keeping* no significant differences occur.

Unintended leaving the lane

It becomes apparent that this driving mistake occurs even more scarcely than the mistake of unsafe lane keeping, although it can be seen as the next most serious mistake due to the definition of mistake levels.

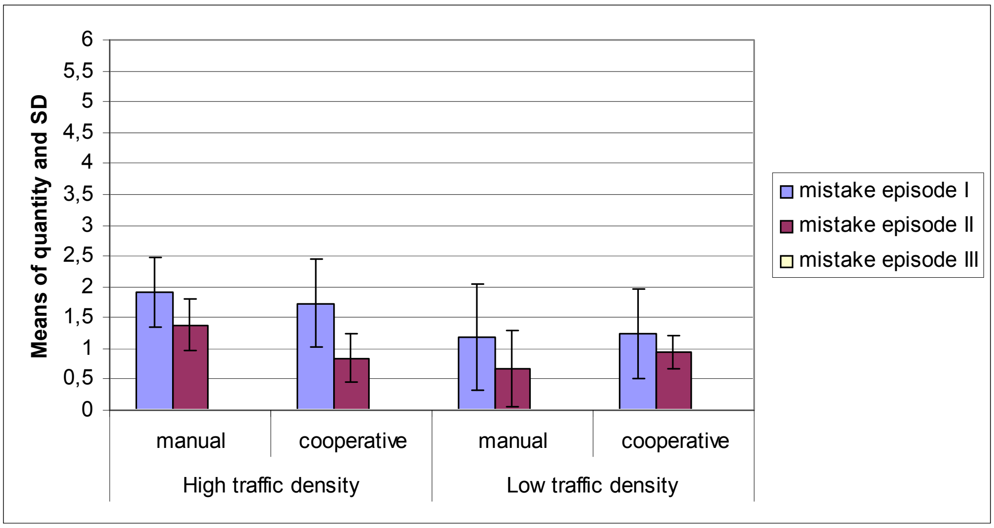

Figure 39: Means of quantity and standard deviation of mistake episodes 1-3 of the driving parameter *Unintended leaving the lane* per trial and for each condition.

Figure 39 shows that the participants of the manual condition this time made more lane-keeping mistakes than the participants of the cooperative test condition only in the trial with high traffic density. In the trial with low traffic density, both groups made fewer mistakes, whereas the participants of the manual condition made even fewer mistakes in levels 1 and 2 than the participants of the cooperative condition. Furthermore, not a single participant made a level-3 mistake, which signifies that none of the 32 participants unintentionally crossed the lane restriction for more than 50 cm.

For this parameter only a highly significant positive difference for the cooperative condition on the second mistake level in both trials can be found, whereas here both test groups again showed no mistakes on the third mistake level (see table 22).

Table 22: Means and ANOVA significance results for the comparison of the cooperative system with the manual system relating to the driving parameter *Unintended leaving the lane* for each trial and all three mistake episode levels

	Mean C/M ; p-value C/M
LL E1 HD	1.55/1.70 ; 0.122
LL E2 HD	0.76/1.61 ; <0.001**
LL E3 HD	0.00/0.00 ; -------
LL E1 LD	1.20/1.25 ; 0.595
LL E2 LD	0.58/0.97 ; <0.001**
LL E3 LD	0.00/0.00 ; -------

(M=manual; C=cooperative; HD= high traffic density; LD=Low traffic density) (level of significance: ** = $p \leq 0.01$; * = $p \leq 0.05$), corrected by Bonferroni.

Lateral interval too small

For this driving parameter the average values and standard deviations of the two test conditions for the respective trials do not differ very much, while at the same time the values for the high traffic density are above the ones for the low traffic density.

The driving parameter *Lateral interval too small* shows a highly significant result for each first mistake level, but a non-significant difference on the second level, and, due to a lack of mistakes under both conditions, no differences on the third level.

H2: On the level of the most important subjective, which is behavioral data, both test conditions should differ as follows:

In contrast to the subjects of the manual system variant, for which participants only had to imagine a cooperative system, the cooperative system variant stands out based on significantly better assessments by the subjects with regard to the most important subjective and behavioral data.

Cooperative interaction is a very complex form of human-machine interaction. As the necessary technical devices do not yet exist, it cannot be experienced in everyday life, but interactions with such a system shows already, after about an hour, significant differences in assessing the positive effects of such an interaction over just having to imagine it.

Subjective and behavioral data

Due to the multitude of items, a question as to reasonable presentation arises. In accordance with Ajzen (2002; 2004) and Arndt (2004), it is in the following assumed that all direct measurements can be summed up.

This approach can be rather problematic for indirect measurements, as no high internal consistency can be presumed in this particular case. This results because the items can be related to different reference groups, e.g. when asked about the social norms, there are various perceived behavior consequences (attitude) and various perceived obstacles (behavior control); these factors might be rated differently and thus important information could be lost when summing up. Furthermore, like in the first experiment, for the following illustration of the results it will be considered that the participants of the manual condition were imagining a cooperative system (according to the good experiences with this method by Beier et al. (Beier et al., 2002)) that was briefly described to them.

Acceptance

The results regarding acceptance are assembled from the questions on attractiveness and attitude towards acceptance.

Attractiveness

When evaluating the results of the attractiveness evaluation, it becomes apparent that the ratings within the respective conditions do not differ significantly between the two trials (high and low traffic density). For this reason, only the average mean values and standard deviations averaged over both trials and between the conditions shall be contemplated in the following.

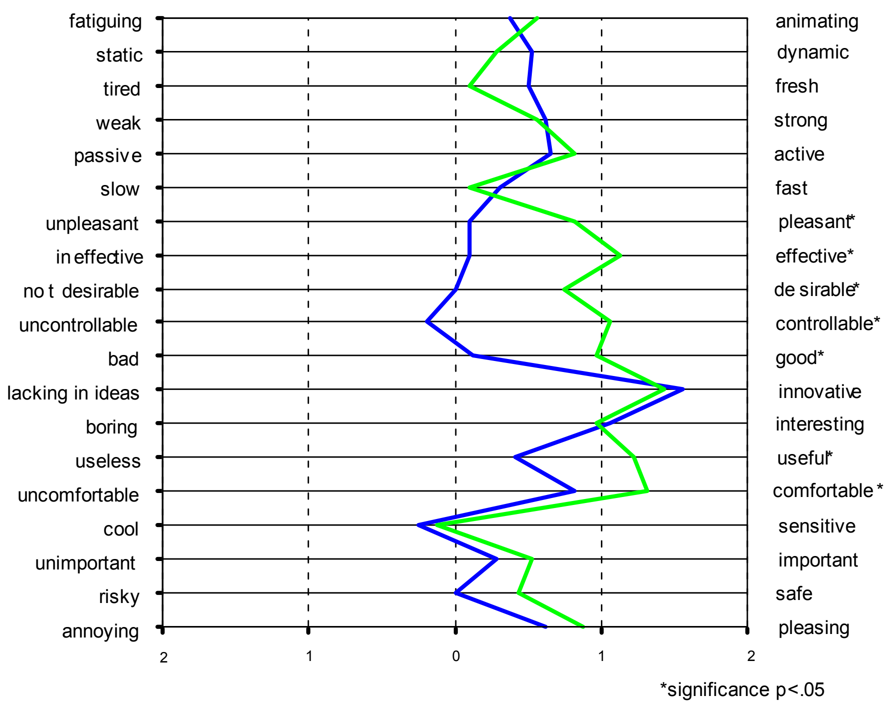

Figure 40: Semantic differential for all 19 attractiveness adjective pairs for both conditions

(blue line=manual; green line=cooperative) as mean values over both trials.

The semantic differential in figure 40 shows significant differences in 7 out of 19 adjective pairs, whereas here the cooperative system, analogous to the first experiment, is rated even more positively by those who really experienced it. In general, all adjectives are at least rated as so-so. Innovation, comfort, and usefulness are rated the highest. In addition, controllability and effectiveness are rated as good as by the participants of the cooperative condition. In contrast, these two characteristics could only be partly imagined by the participants of the manual condition.

The ANOVA for the factor condition shows no main effect for the index on attractiveness ($F = 2.405$; $df = 1, 31$; $p = .131$).

Attitude towards acceptance (part one)

In relation to the handling and utilization of the system (see figure 41), and the consequences resulting from these factors, differentiated results occur, although again the similar response behavior between the hypothetical imagination of the manual driver and the real experience of the "cooperative" driver stands out.

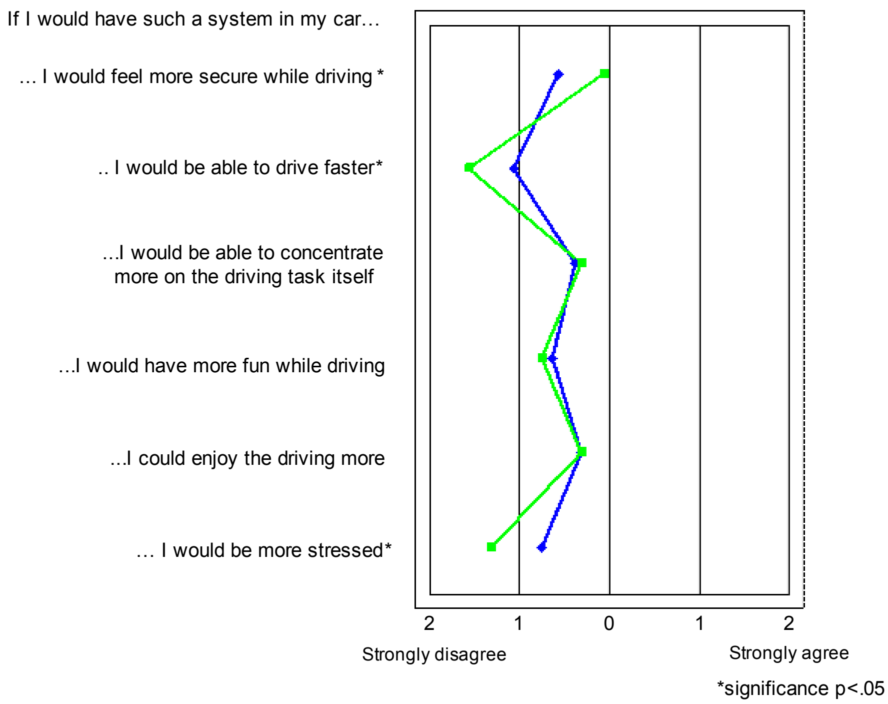

Figure 41: Semantical differential for the attitude toward acceptance answers of each condition

(blue line=manual; green line=cooperative).

According to the reported results, the participants would only be able to concentrate moderately on the actual driving task. They also would have only a bit more fun while driving and would not enjoy driving more when using the cooperative system.

Moreover they believe that they would feel only somewhat more secure and yet stated that they would also not feel more stressed and would not be able to drive faster as a result of the interaction. The latter, however, can be qualified on the basis of the results for the human-human interaction, in which a steadier speed was deemed to be a quality characteristic of cooperation (Neukum & Krüger, 2003). In the two first mentioned questions, the cooperative system is rated slightly better by those who experienced it themselves.

These results are in contrast to the other subjective ratings in which the cooperative system performed at a more satisfactory level.

Attitude towards acceptance (part two)

In figure 42 the attitude towards acceptance shows that the participants of the cooperative test conditions rate the system as good, pleasant, useful, and advantageous, and this to a significantly higher degree than the participants of the manual condition.

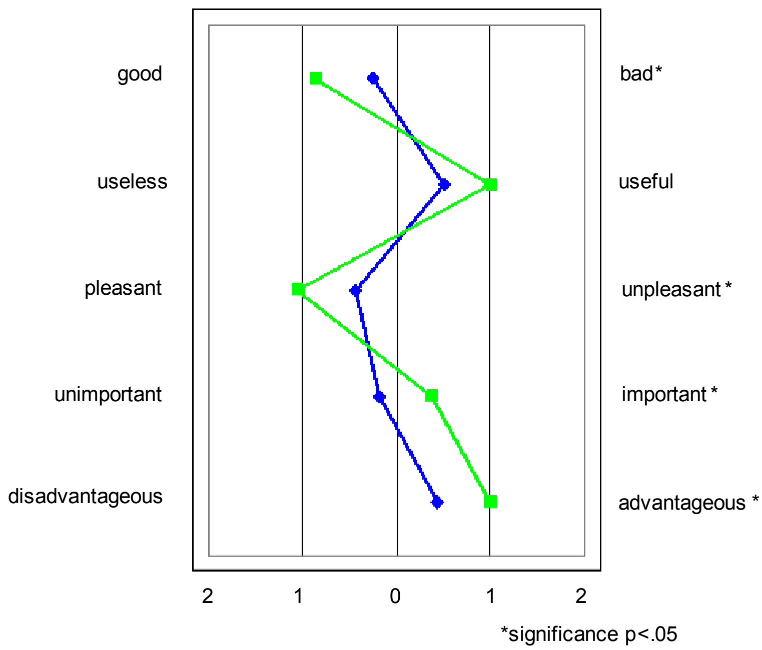

Figure 42: Semantical differential for the attitude toward acceptance answers of each condition

(blue line=manual; green line=cooperative).

Only for the adjective pair useless-useful do the answers for both test conditions not differ significantly, whereas the system here is rated as good.

The ANOVA for the factor condition shows no main effect for the attitude toward acceptance (*F* = .806; *df = 1, 31*; *p* = .771).

Subjective norm (the opinion of others)

The construct of the subjective norm was addressed based on the answers to several questions regarding what the participants thought that others would think about the system. The results are presented averaged over both experiment trials because both measurements showed almost identical values.

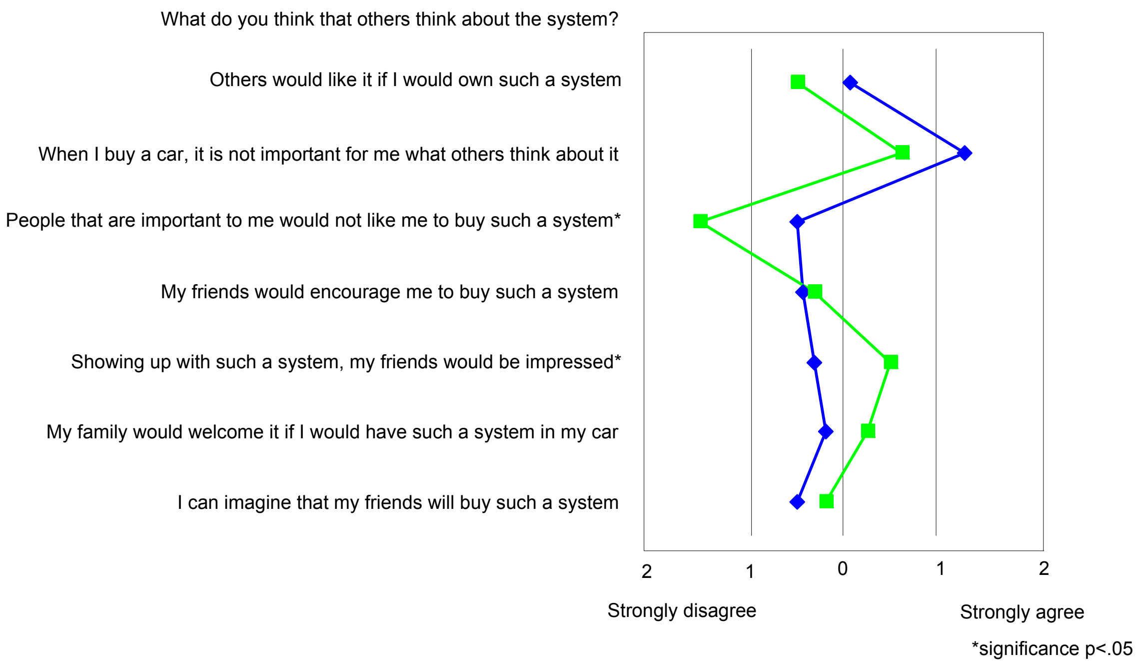

Figure 43: Semantical differential of the answers on the construct subjective norm

(blue line=manual; green line=cooperative).

Figure 43 shows for only two responses significantly better mean values for those who have actually experienced the system. These are the ratings of the questions regarding a positive impression that one could give to friends by such a system and the opinion that people who are considered important to oneself would not object if one would buy such a system. However, the majority of the mean values of the ratings from both test groups again were “so-so”. One explanation for the indifferent results here in comparison to the other results could be that the participants need more interaction time to make a positive statement regarding the opinions of others.

Behavior control

As the rating of the system regarding behavior control shows similar values for the two conditions, the results are presented averaged over both experiment trials (see figure 44).

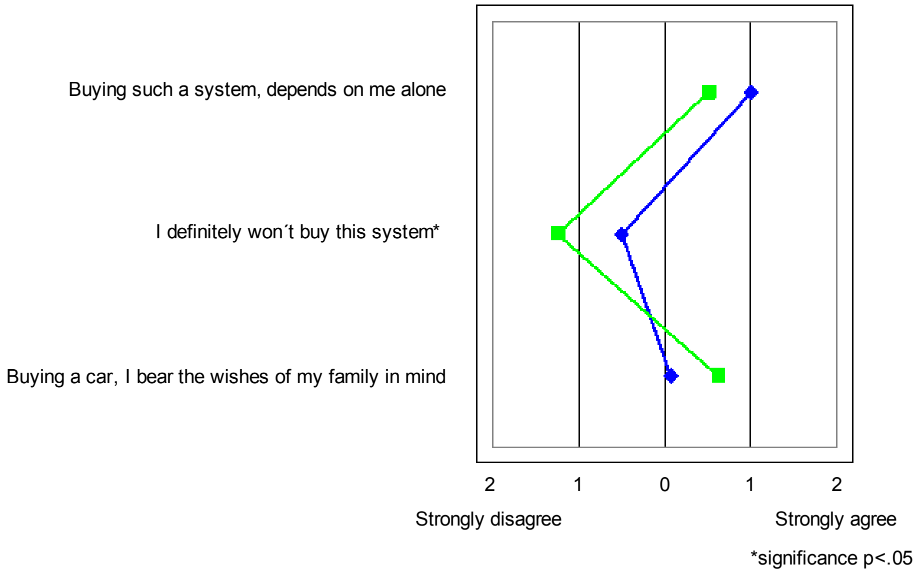

Figure 44: Means for the three answers on behavior control for each condition

(blue line=manual; green line=cooperative).

That they would not buy such a cooperative system was significantly more negated by participants who experienced this system than by those of the manual test condition. Both test groups responded that the actual purchase would depend more on their own wishes, but that they would bear the wishes of their families in mind.

Behavior intention

When assessing the results of the behavior intention adaptation index, an almost constant picture throughout both measurement times also becomes apparent (see figure 45). Here the effects of traffic density are also not noticeable.

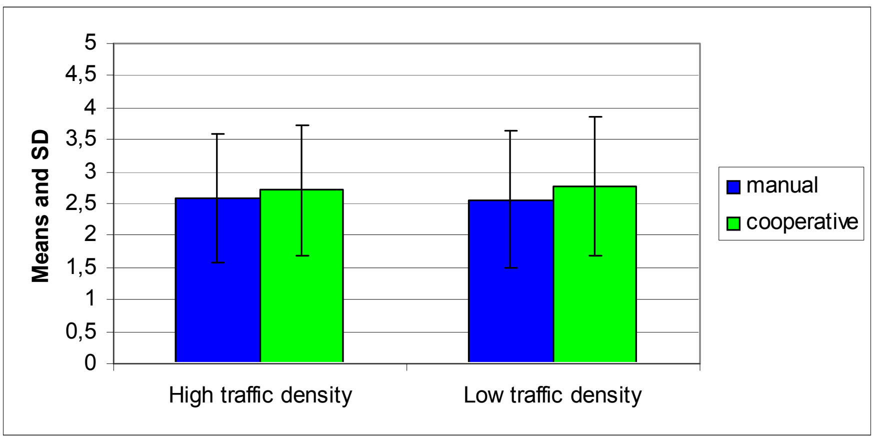

Figure 45: Means and standard deviation of the intention index for each condition and trial.

The cooperative system variant is consistently rated as above-average attractive, whereas only a small difference in relation to the manual subjects existed.

The ANOVA for the factor condition shows no main effect for the index on behavioral intention (F = .030; df = 1, 31; p = .864).

Results for the perceived characteristics of the system

In this section, the results regarding the perceived characteristics of the system are described. With the ratings for the system it becomes clear that the participants of the cooperative condition rate all items only slightly better than those who have not experienced the system. In six out of 16 questions, however, the participants of the cooperative condition rate the system significantly better (see figure 46).

The system is rated as modern and easy to operate both hypothetically by the manual subjects and actually by the cooperative subjects. Furthermore, the participants attribute a traffic safety-promoting and stress-reducing effect to the system.

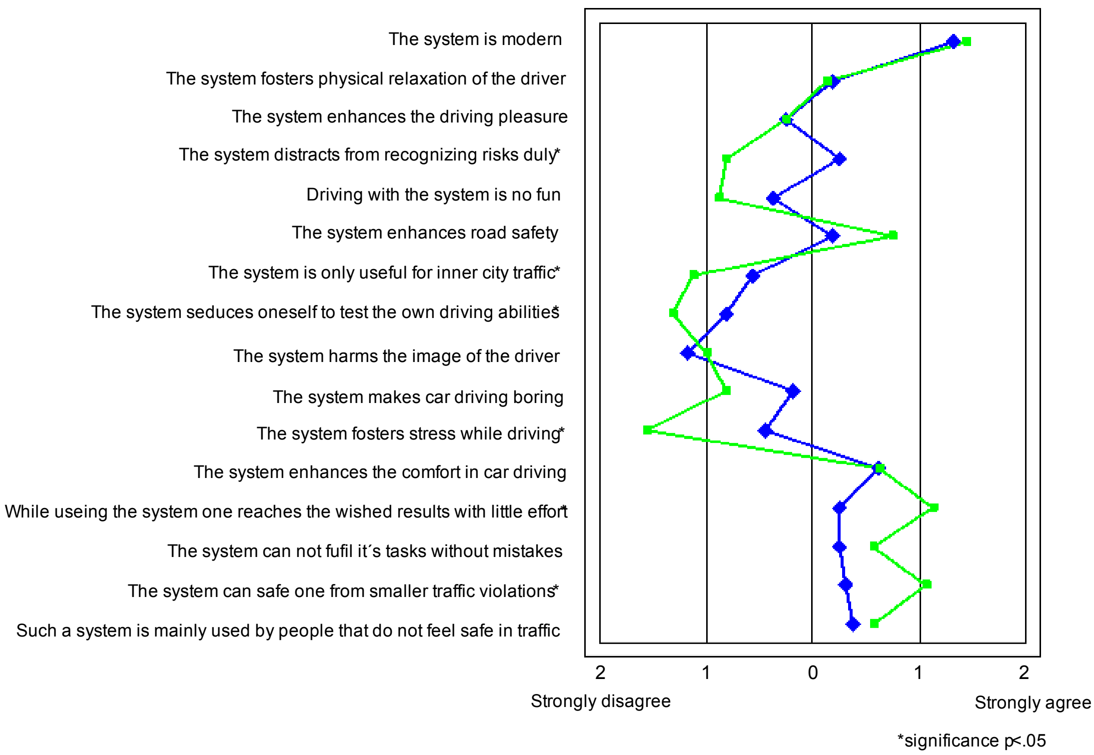

Figure 46: Semantical differential of perceived attributes of the system for each condition (blue line=manual; green line=cooperative).

Additionally, the system is reported to protect against smaller traffic violations and to enhance driving comfort, although it is also reported to not fulfill its tasks without mistakes. At this point, however, it must be kept in mind that for the overall evaluation of the system these questions did not differentiate whether this was only hypothetically or subjectively experienced in the experiment. Furthermore it was indicated in the theory section that users of assistance systems allow the interaction to produce a certain number of mistakes and conflicts.

Trust

The illustration of the results for accumulating the trust index for the three trust items in figure 47 shows that the participants of the cooperative system variant certify the system on average the highest trust throughout the two times of measurement.

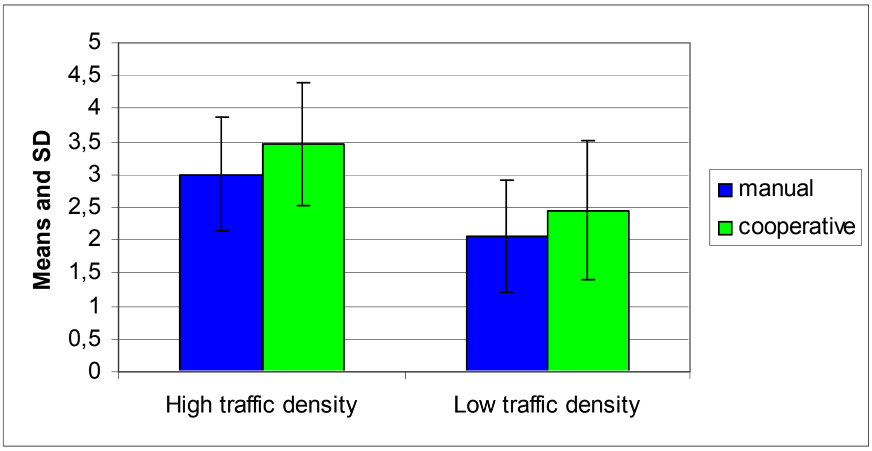

Figure 47: Means and standard deviation of the trust index for each condition and trial.

The values rise for both conditions after the drive with oncoming high traffic density.

The ANOVA for the factor condition shows no main effect for the index on trust (F = .982; df = *1, 31*; p = .330).

Workload – subjective measures

When reflecting the four subscales of the BLV for the three times of measurement of the two conditions, an almost constant picture becomes apparent.

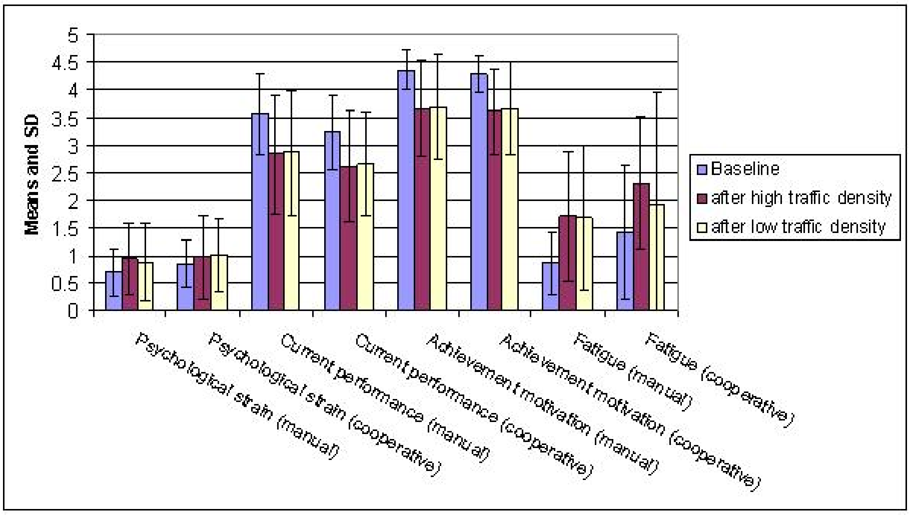

Figure 48: Means and standard deviation for each condition of the four subscales of the BLV at the three measuring times.

Figure 48 shows that for both conditions the subjective current performance and achievement motivation decline in the next trial driven in relation to the baseline and then remains almost steady, though consistently staying above average. The psychological strain and fatigue, however, for both conditions after the high and low traffic density drive show slightly higher values in comparison to the baseline, whereas all values are placed in the below average range here. This result indicates that the participants through interaction did not experience higher subjective workloads. This finding corresponds to the psychophysiological values of the finger temperature parameter which, however, is in contradiction with the higher heart rates.

To specify this discrepancy, the BLV-results and the psychological parameters of the individual participants were z-transformed separately for each group and subsequently became subject to a 2-related sample test for the individual condition and parameter combinations (for a graphical illustration see appendix XIII figure XIII-6 and 7).

If a trend cluster is built for the three times of measuring and the six objective and subjective parameters together, then the heart rate for the cooperative system variant builds one cluster with psychological strain and fatigue, while the finger temperature together with the current performance and the achievement motivation builds the second cluster.

A different trend cluster occurs for the manual condition. Here, the heart rate also shows the same trend as fatigue, analogous to the cooperative variant, but also the same trend as the current performance. The finger temperature, contrary to the cooperative system variant, shows for this test condition the same trend as the psychological strain. The achievement motivation here presents a third trend "cluster.”

The 2-related sample test shows no significant differences for all combinations (see appendix XIII table 11 and 12).

Results for the individual system variants

As in the first experiment, two test conditions were applied, but only for one could a system be experienced that would lead to the development of question blocks which came into effect for each of the two conditions. The difference for the participants of the manual condition was, as in the preceding section, that they were required to imagine a cooperative system.

The corresponding results shall be presented in the following.

Results for the expected change in abilities and skills

Manual condition

As expected, participants who only imagined the cooperative system named only up to three potential advantages with regard to their own abilities. The most frequent nominations were like in the scenario-based interviews (see section 4.3), including oncoming traffic detection, blind spot detection, and driver speed management.

As the expected disadvantages with regard to abilities, the phenomenon of the driver out-of-the-loop in connection with a presumed error sensitivity of the system was most frequently named.

According to the participants, advantages related to driver skills would appear for the functions of lane keeping and braking as well as for monotonous stop-and-go drives.

As a disadvantage for skill development, all functions related to the experiment were named. As the cause for these disadvantages, the phenomenon of the driver out-of-the-loop and the effects that can be subsumed under the construct "learned carelessness" (see section 2.4.1.1.4) were assumed.

Cooperative system variant

As expected, advantages from a longer cooperation with the experienced system with regard to driver abilities led the participants of the cooperative test condition to name only up to two points at a time. Among the most frequent nominations were surveillance tasks in general, e.g. blind spot detection and driver speed management. Oncoming traffic detection was not mentioned here.

As expected, disadvantages with respect to abilities in connection with presumed interpretation difficulties of system information and the consequences resulting from this, as well as a faint declining sense of responsibility, were named most frequently, whereas 9 out of 16 subjects stated that they expected no disadvantages at all.

According to the participants, advantages related to driving skills would appear for the functions of lane keeping and braking. Some participants did not only imagine a cooperation for the actual situations but assumed that the system compensates for aging effects occurring over time. However, here also 10 participants stated that they would not expect any advantages.

All 16 subjects of the cooperative condition stated that they did not expect any disadvantages for skill development in terms of system handling.

Results regarding communication behavior

For the communication behavior of the cooperative system, again 11 adjective pairs and 3 alternative questions were asked. Figure 49 shows the answers from all 16 participants of the cooperative test condition for the 11 answer pairs as a semantic differential.

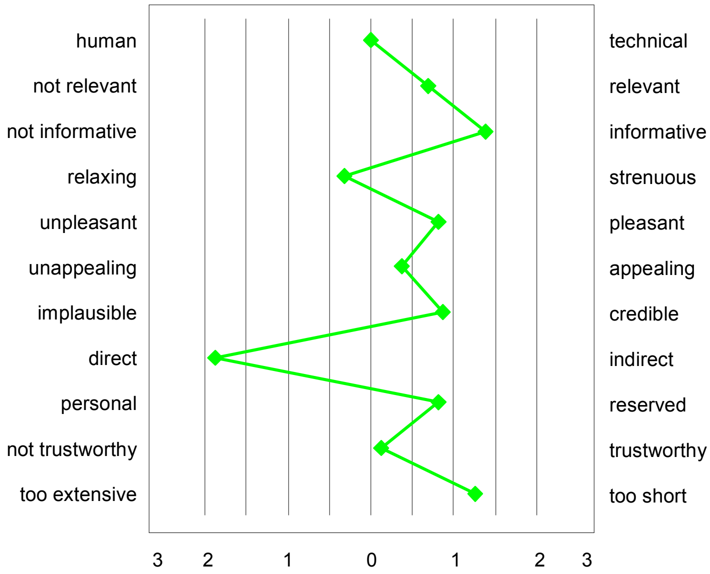

Figure 49: Semantic differential for the judgment of the communicative behavior of all 16 subjects experiencing the cooperative system

(green line=cooperative).

It becomes apparent that the system is only rated as moderately trustworthy and thus lower by this measure than by the questions regarding trust itself. Furthermore, it is considered humanlike and only slightly relaxing. Additionally, all 16 participants rated the system as rather too short and very direct but nonetheless informative in its communication style.

The alternative questions showed that 62.5 percent of all interviewees would rather hold a dialog in colloquial language; 31.2 percent preferred the imperative language; the remaining participants were indecisive.

Voice and articulation of the system were mainly rated as "rather good" up to "good." Furthermore, all participants felt "rather not" or "not at all" distracted by the communication with the system.

Results for the cooperative system variant

The results for the effects of the interplay with the system are presented in figure 50. It can be seen that all questions were exceptionally positively answered.

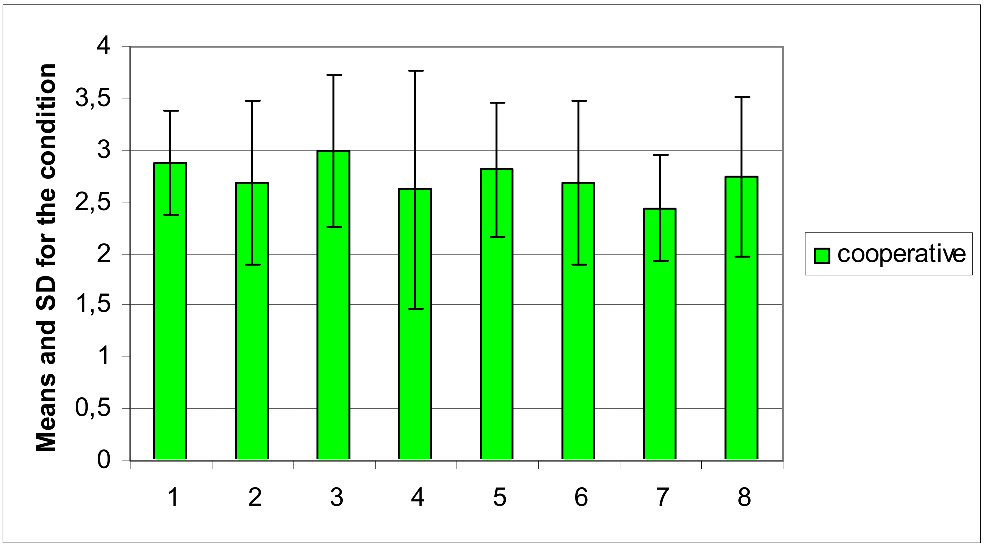

Figure 50: Means and standard deviation for the cooperative condition

(1=situational awareness; 2=motivation for task execution; 3=ability for decision making regarding driving tasks; 4=surveillance and control of driving situation; 5=information integration for decision making; 6=coordination of partial actions; 7=mutual processing feedback of action results; 8=quality of action execution).

A particularly positively subjective change showed the ability for decision making with regard to the driving requirements. From the 8 related questions, the one regarding the change of the mutual feedback of action results from the cooperation was rated the lowest.

Halden human-automation-cooperation questionnaire

The Halden Human-Automation Cooperation Questionnaire shows an acceptable inter-item reliability in this experiment, as the Cronbach Alpha coefficient is 0.62.

Table 23: Means and standard deviations for the six items of the Halden Co-operation Scale

Question:	Mean	Standard deviation
1. To what extent did the system provide relevant information about its activities?	**2.94**	**1.063**
2. To what extent did you receive relevant information from the system on time to benefit from it?	**3.06**	**0.574**
3. To what extent did you immediately understand the information that the system provided?	**3.37**	**0.719**
4. To what extent did the automatic system perform the activities you requested of it (e.g. answer questions)?	**2.75**	**0.931**
5. To what extent did the system perform the activities you expected it to do?	**3.13**	**0.619**
6. Overall, how would you characterize the cooperation between you and the system?	**3.00**	**0.730**
Total Mean	**3.04**	**0.773**

(N= 16 ; 0 = not relevant; 4 = relevant).

The results in table 23 show for all items a tendency toward good acceptance of the dialog concept. On the other hand, there was no extreme positive feedback from the subjects. The lack of multimodality and the sparse functional range of the cooperative system could be seen as the main reasons for not having achieved even higher scores.

6.5 Interpretation of the results and conclusions

In the following, analogous to the first experiment, analysis of the descriptive and the inferential statistical results regarding the individual hypotheses of the preceding sections shall be carried out in order to deduce the following interpretations and conclusions for the second experiment in relation to the formulated questions mentioned in section 3.1.

A second structuring characteristic of this interpretation shall be the premises formulated in section 1.2 regarding the rating of an enhanced concept of interaction and the indicators formulated in section 2.4.1 for the benefit of cooperative interaction.

1. Does cooperation as a form of automation take place in the driving situation “Turning Left on Urban and Country Roads with Oncoming Traffic”?

The answering of this question is divided into two parts. First, the question of the ability to realize cooperation in this environment at all shall be discussed.

Only the comprehensive analysis carried out beforehand made it possible to create a prototype on the basis of the described limitations. Additionally, it can be assumed that only the combination of the Wizard of Oz-method and real technical solutions made the cooperative “prototype” possible.

The answering of the question as to whether cooperation can be experienced at all by drivers constitutes the second part of the discussion.

In order to prove the criterion of the development of practical knowledge, the questions regarding changes in abilities and skills were asked. Here, the participants of the cooperative condition compared to the manual condition stated more advantages such as an expected anticipatory driving style, improved speed management, and improved handling of surveillance tasks, for instance, blind spot detection by the driver. Furthermore, the participants of the cooperative test condition expected from such a system positive influences in terms of age-related effects. Here again, of high interest are the responses of the participants from the manual condition, who could imagine an increase in the multitasking potential for the interaction with a cooperative system.

The results of the Halden Human-Automation-Cooperation-Questionnaire, which were consistently above average, can be regarded as an indicator for a statement regarding the support and improvement of the communication. This is first underlined by the result that 96 percent of the cooperative participants stated that they were not distracted by the communication with the system. In addition, the evaluation of the experiment protocols showed very few communicative misunderstandings.

Finally, for answering this question it would have been helpful to be able to analyze in more depth the communication between the cooperative prototype and the driver as well as certain specific tasks like the indicating behavior with its trading patterns.

If all results are taken into consideration for answering the question – keeping the mentioned restrictions on the previous system complexity in mind – for the experiment scenario "Overtaking on Highways", in principle a realization and the chance of practical experience of a cooperative system by the driver can be assumed. This is supported by the variant-related analysis in which the participants of the cooperative system variant described the system with distinct cooperative attributes. These findings include an understanding that a single system was successfully implemented as an "interaction partner" just as demanded for the interaction with the driver in section 1.1. As a result, subsystems received less attention.

2. Is it possible to show for the driving situation "Turning Left on Urban and Country Roads with Oncoming Traffic" that "cooperation" in this form of an experimental prototype generates a benefit from a subjective point of view?

The response to this question is the main objective of this paper. The instantiation of the concept of “cooperative interaction in automobiles” has not yet been studied or even verified. It is therefore important to discuss whether a subjective benefit from this form of interaction can be achieved.

In addition, for the second experiment, this question shall be answered by means of the premises formulated in section 1.2 regarding the rating of an enhanced concept of interaction and the indicators formulated in section 2.4.1 for the benefit of cooperative interaction.

A potential optimization of the exchange processes between human and automobile can be justified by the results for the action levels. These results show that the structuring of the interaction based on the cooperative dialog concept leads throughout all eight levels to a positive rating of above average for this new system. This result also can be interpreted as an increase in the interaction quality.

As has already been commented upon, the promotion of situation awareness was not examined in this second experiment. However, due to the recorded dialogs between the cooperative system and participants, a low visual and cognitive distraction and thus a high situation awareness, can be assumed.

From a subjective point of view, the optimization of the subjective workload can be regarded as proven with restrictions. The ratings of both test groups are almost identical; however, for the values from the participants of the cooperative system variant this very interaction with the system must be taken into account. This in particular affects the actual turning process, as the participants, due to the cooperative interaction, chose gaps sooner than the participants of the manual condition.

It can therefore be concluded that the higher objective workload due to the earlier turning is compensated for by the cooperative system, and this to such an extent that values equally as high as those for the participants of the manual condition occurred.

The cooperative system was consistently well-accepted, and the attractiveness was even rated above this. The trust in the system in the high traffic density trial was very good, and most interesting, in the trial with low traffic density significantly lower. With regard to this result, the other indices and the objective data give no explanation. This result means, however, that for the situation characteristic traffic density, a shift in the interaction intensity depending on the traffic density is necessary so as not to lose the driver's trust.

With regard to the inferential statistical results for hypothesis 2 regarding the most important subjective and behavior data, the comparison of the ratings from the participants of the cooperative system variant with the appraisals and conceptions of the participants from the manual test condition shows no significant difference. This signifies that the participants of the manual condition could well imagine a cooperative system and that the ratings for this imagined system are not significantly worse than those for the real experience.

If all results are taken into consideration for answering the question, here also - with the mentioned restrictions on the previous system complexity - in principle, a realization and the potential of practical experience itself of a cooperative system by the driver can be assumed for the experimental scenario "Turning Left on Urban and Country Roads with Oncoming Traffic."

3. Is it possible to show for the driving situation "Turning Left on Urban and Country Roads with Oncoming Traffic" that "cooperation" in this form of an experimental prototype generates a benefit from an objective point of view?

It is essential to identify and judge the similarities and dissimilarities of different situations in which the technical realization of a cooperative interaction is possible, and to determine whether its implementation regarding fulfillment of the driving task is both desirable and reasonable.

In order to answer this question here, the results for the most important psychophysiological parameters as well as the driving performance data from hypotheses H1b of the second experiment shall be discussed.

When comparing both participant groups with respect to the most important psychophysiological parameters and driving performance data, it becomes evident that the hypothesis can only be completely confirmed for the driving parameter *Speed*. This finding matches with the statements made by the participants regarding the development of skills and abilities through interactions with the system. For the driving parameter *Unintended lane leaving* and *Lateral interval too small*, this applies only for certain mistake levels. For all other driving parameters no significant benefit from the cooperative system variant can be noted.

In addition, no significant differences between the conditions can be detected for the psychophysiological parameters. If one, however, further differentiates the crossing types of the respective trial, it becomes apparent that related to the condition, the heart rates do not significantly differ from each other. The finger temperature instead shows significantly higher values for the inner city crossings; that is, the subjects are more relaxed than at the country road crossings.

Also, it is important to keep in mind that the cooperative participants in both trials arrived at the destination earlier than those under the manual condition, which is to be attributed to the interaction with the system.

The lack of multimodality in this experiment also can be regarded as a possible reason for the heterogeneous results. Therefore, in future experiments it will be important to bear in mind that the driver should be provided with even more functionality in order to make the effects of the system even more experienceable.

Here also, if all results to the questions are taken into consideration - with the mentioned restrictions also with regard to the previous system complexity for the results for the experiment scenario "Turning Left on Urban and Country Roads with Oncoming Traffic" - "cooperation" in this form of an experimental prototype then can only to a limited extent be regarded as an objective benefit.

4. Which effects have situational characteristics with regard to the objective parameters and the subjective rating of a cooperative system in the automobile for the driving situation "Turning Left on Urban and Country Roads with Oncoming Traffic"?

This question focuses on situations in traffic that come with different potentials for workload that can be described by the degree of difficulty of the roadway or the traffic density. Also, such environmental factors as the weather and its associated effects on the driver’s line-of-sight obstruction must be analyzed in relation to their effects on the cooperative interaction.

The crossing type and thus the associated density of oncoming traffic as well as the buildings in the crossing area show no noticeable influence on the driving performance data.

The results of the psychophysiological parameters in relation to the three mentioned characteristics show a heterogeneous picture. While finger temperature in this driving situation can be regarded as a good indicator of situation characteristics, this is not the case for heart rate. To which part which of the situation characteristics play a role in the results for the psychophysiological parameters is not clear due to the simultaneous appearance of the combination of these characteristics in this experiment.

The situation characteristics appeared to have no influence on the subjective ratings. This, however, can only be deductively concluded, as the subjective ratings show no differences between the two traffic density situations, except for trust. In further research, experimental designs would have to be developed to allow retrospective questions (after each trial) that could show a correspondence between individual characteristics and the objective data. The only exception is the low trust values in the trial with low traffic density. These could have been caused by situation characteristics, which have to be examined by future experiments.

Due to the heterogeneous results within and between the subjective and objective data, experimental designs should be applied in upcoming experiments that could clarify the influences of individual characteristics.

This question focuses on situations in traffic that come with different potential for workload and that can be described by the degree of difficulty of the roadway or the traffic density. Also, such environmental factors as the weather and its associated effects on the driver’s line-of-sight obstruction must be analyzed in relation to their effects on cooperative interaction.

7 Interpretation and potential analysis of the results from both experiments

In this section the results from both experiments shall be related to each other with regard to the potentials for a cooperative interaction in the contexts of driver.

First, for both experiments it can be seen that the respective preliminary tests for the theme development were necessary and meaningful. Also, the selected driving situations due to the therein-gained experiences and results are suitable in order to effectively verify the concept of cooperative automation in the automobile.

When pre-drawing the results regarding the supposed potential fields for the driver as an interpretation basis, it can be stated that in both experiments no noteworthy influence on the dependent variables can be assumed for the three control variables, TO-value, KUT, and age, other than a few negligible exceptions. The present driving situation enables the interpretation of a potential uniformly designed cooperative system for this target group. In further experiments, however, it would need to be clarified how the objective dependent and control variables change, for example, with women, less or more control convinced persons, younger or older participants, and less team-oriented drivers.

Results regarding the supposed potential fields for the driver

The premises and indicators from the theory section shall be referred to for the following effectuations. The optimization of the exchange processes between driver and automobile are considered to be the most important indicator for a potential appraisal for the driver.

On the one hand, the results from the Halden Human-Automation-Cooperation Questionnaire serve as a statement on the increase in interaction quality and the support and improvement of communication and thus the cooperation maxims according to Grice. In all cases, these results were positive for both experiments.

On the other hand, the matching of the structure characteristics to the action levels and their implementation by means of the dialog concept were rated as well-managed for both experiments.

The observations by the investigator regarding trading between driver and automobile while signaling can be considered as a good starting point for further experiments on the effects of structure characteristics in the interaction. These must be operationalized in experiments in order to gain proved findings that later can be assigned to other sub-actions in the driver-automobile cooperation.

These and the displayed results of both experiments for communication behavior as well as for ergonomic design signify that there are interaction characteristics that can only be initially traded in the respective dyad, as the individual desires are at the same time heterogeneous and situational (e.g. communication style and role understanding).

As a further indicator of the increase in interaction quality, the promotion of situation awareness has only explicitly been discussed with regard to the first experiment. Here, only for the first two trials was significantly higher situation awareness for the cooperative condition compared to the other conditions apparent.

For the second experiment, the dialogs between driver and automobile led to the assumption of high situation awareness due to the low level of visual and cognitive distractions.

Here, for both experiments it can be stated that with the mentioned methodological restrictions for situation awareness acquisition, the situation awareness is better than for other types of interactions.

Furthermore, an optimization of the driver's workload had to be achieved. Between the objective and subjective measures of workload results, a heterogeneous pattern becomes obvious, and not only because of the experimental methods.

In both experiments, the workload of the participants from the cooperative interaction was subjectively low. For the objective parameters in the first experiment, the heart rate as well as the skin conductivity showed an adaptation to the overall situation over time. Since the process of this adaptation individually varies in speed and intensity and thus exerts immanent influences on the interaction, here also the benefit of a cooperative system is to be recognized, as it can react to these differences.

In the second experiment, the two physiological indicators of heart rate and finger temperature showed different results. While the heart rate indicated a slightly increased workload, the finger temperature showed relaxation.

With respect to the driving parameter, it became apparent that the cooperative interaction affects the various driving situations and driving maneuvers very differently. The more even speed management observed in both experiments confirms the results of Neukum and Krüger (2003) regarding the human-human interaction.

In conclusion, a heterogeneous pattern for the various psychophysiological parameters and measurements was observed; here the search for distinct parameters for subjective and objective measuring of workload must be pursued further.

Competence preservation and development of practical knowledge

For the experienced interaction in both driving situations, an improved competence preservation was confirmed from the participants of the cooperative system variant in both experiments.

With a long-term interaction in mind, the participants of both experiments expected positive effects of such a system in terms of age-related effects, surveillance tasks, and speed management, whereas these effects can also be beneficially utilized for the other two contexts, automobile and environment, in manifold types.

Competence preservation can therefore be regarded as proven. For any further experiments, it is essential to also explicitly include the learning methods mentioned in section 2.4.1.2 in the concept in order to examine a feasible expansion of competence.

Increase of acceptance and trust

For both driving situations the cooperative system variant received good trust and acceptance values.

The results regarding trust confirm the findings of Weinberger (2001) for the course of trust development during the first 4 weeks using the example of an ACC, whereby in the driving situations and function scales presented herein, good values were attained as early as within 2 hours of the start of the experiment.

The results regarding acceptance confirm the findings in real vehicle tests as well as driving simulator experiments (Ishida, 2003; Koziol, 1999).

Finally, for the potential analysis it should be noted that with regard to the driver, none of the participants doubted the cooperative interaction as such, which in turn signifies that the design should continue to be developed.

8 Potentials for the establishment and embedding of driver-automobile cooperation into the overarching context

After seeing that the results of the preliminary experiments and experiments from chapter 4 to 6 show a positive rating and, thus an effect or benefit, respectively, it is clear that the most important next step is to establish the correct procedure for embedding the concept of driver-automobile cooperation into the overarching context. Two different means of achieving this goal are suggested herein.

A general discussion of the concept of cooperation in the human-machine interaction is to be led in which all parties sensitize to the topic. These discussions should include, in particular, the decision-makers from the manufacturers and suppliers of the relevant technology.

Furthermore, as shown above, the development or pre-development performances in this context are only individually established. Therefore, the advantages of the cooperation in the human-machine interaction context must be backed by further empirical data; the existing approaches, for instance, regarding the adaptive function allocation and the automation must be linked as well in order to integrate already existing system solutions into the concept (e.g. by means of the examples presented below).

In terms of the complete embedding of the concept, further approaches and concepts for the theoretical integrative model should be considered which could not be included herein, or could only tangentially be referred to. As an example, the theory of complemation (Jürgensohn & Timpe, 2001; Schutte, 2000) or selected language and interaction concepts focused on adding additional sense modalities like the haptic sense modality are of interest (Salmen, 2002; Sarter, 2002; Wagner, 2002).

In addition, the establishment and extension of relations to other socio-technical systems like traffic telematics (here in particular the visions of self-organizing traffic and the utilization of floating car data), themes like robotics and socionics with their related questions, or even the work in the sector of computer-supported cooperative work (CSCW) is to be investigated, as these offer multilayered sources for design indications.

For the embedding, such an integrative relation shall be exemplarily established by a socionic approach. Figure 51 shows the scale of the system levels in the overall context of humans and technology (Rammert, 2002b). The specific quality of this socionic perspective in the driver-automobile interaction lies in the maintenance of heterogeneity of the technical instruments and human actions and, within these so-called hybrid systems, the search for patterns of distributed activities and elements of interactivity between driver, automobile, and environment.

The blue marking shows the part with which the thesis originally dealt and therefore the integration ability of the cooperative concept into the overall socio-technical context.

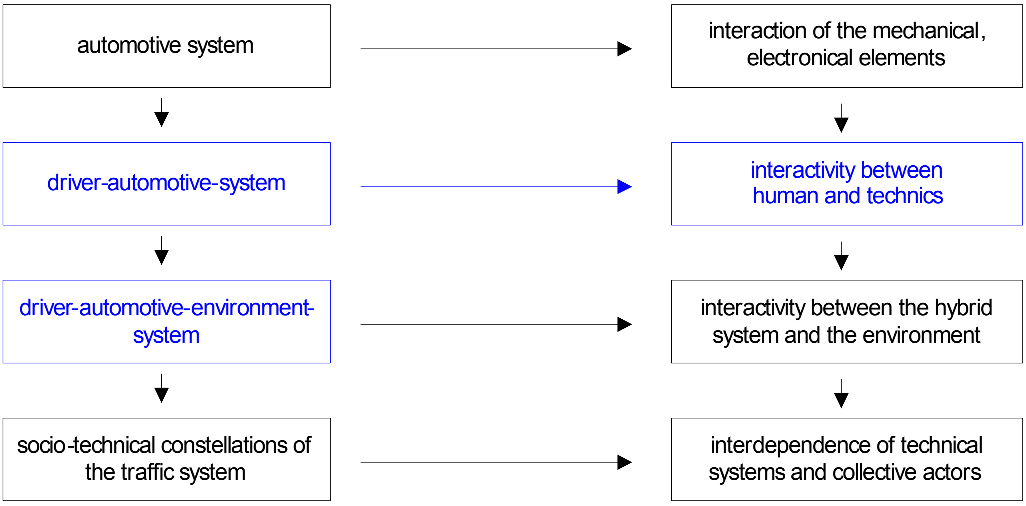

Figure 51: Scaling of system levels according to Rammert (Rammert, 2002).

This socionic perspective additionally shows the necessity of the conceptual design of a completely intelligent mobility system (Rammert & Schulz-Schaeffer, 2002) by switching the focus of the current questioning to the interactivity between driver, automobile, and environment.

This is why for the cooperative driver-automobile interaction, in terms of the intelligent mobility, city and traffic planners as well as the manufacturers of alternative mobility technologies and telecommunication providers (e.g. for car-to-car-communications) must consider the structures of their respective products in order to clearly design the interfaces and to use the synergistic effects.

By transferring such an interaction concept into further sections of the human-technology interaction, such as intelligent home technology, and particularly home entertainment, a congruency between these sections can be established which in terms of the premises, can be beneficially applied.

9 Conclusion and future perspectives for the human-automobile interaction

The cooperative layout of interaction in the automobile represents an opportunity for research and development. For instance, some of the current problems in the automotive, aviation, and aerospace sector, which from today's point of view arise from the function and task allocation approaches, can likely be overcome. This mainly refers to inadequate system feedbacks as well as autonomous system behavior and the perceived complexity of overall systems (Billings, 1997).

Moreover, the concept introduced herein has a high integration ability for both traffic and non-traffic environments, particularly for many innovative systems in the automobile of the future and in the next step by means of gathering more socionic aspects.

A cooperatively designed interaction can become relevant in marketing situations, especially in relation to accumulated problems due to hardware and software mistakes (source: ADAC-technical-breakdown-statistics, 2005) or due to maloperations. Thus, the aim must be to increase the affinity and the trust of the consumers towards new technology and systems.

Accompanying the theoretical discussion on the interaction design in the automobile, differentiated research must be carried out. In particular, not only in connection with the concept introduced herein and the deduced prototype, data must be obtained that will show whether and under which circumstances drivers are motivated to interact with their car. The next step should be the step that is usually carried out as the first step. Experimental designs must be developed to evaluate the components of the integrative model in its parts.

As discussed in the theoretical part of this thesis, a cooperative interpretation represents a new quality of the driver-automobile interaction. Consequently, it is essential to analyze whether the increased degree of interaction is an additional source of workload for the driver that could be caused by communicative misunderstandings and would lead to frustration and non-acceptance of the system.

Additionally, the evaluation concept presented herein is to be further developed, namely in the direction of a more realistic environment as well as in the direction of more realistic sensors, actors, and algorithms for the prototype. Only in this way can it be determined which approaches and concepts are capable of supplying the best-designed solution for the problems that occur with interactions in the automobile.

10. References

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11.Index

11.1 List of abbreviations

ACC	=	Adaptive Cruise Control
BLV-test	=	Belastungsverlaufs-Test
BSD	=	Blind Spot Detection
CMS	=	Collision Mitigation Brake System
CSCL	=	Computer Supported Cooperative Learning
CSCW	=	Computer Supported Cooperative Work
ECG	=	Electrocardiogram
KUT	=	Kontrollüberzeugung und Technik (Control belief and technology)
LDW	=	Lane Departure Warning
LKAS	=	Lane Keeping Assistance System
LKS	=	Lane Keeping Support
μS	=	Microsiemens (measure for skin conductivity)
SAGAT	=	Situation Awareness Global Assessment Technique
SKT	=	Skin conductivity
TCAS	=	Traffic alert and Collision Avoidance System
TO-value	=	Team orientation value

11.2 List of figures

11.3 List of tables

12. Appendix

Table of Contents

Appendix I: Stage models of action

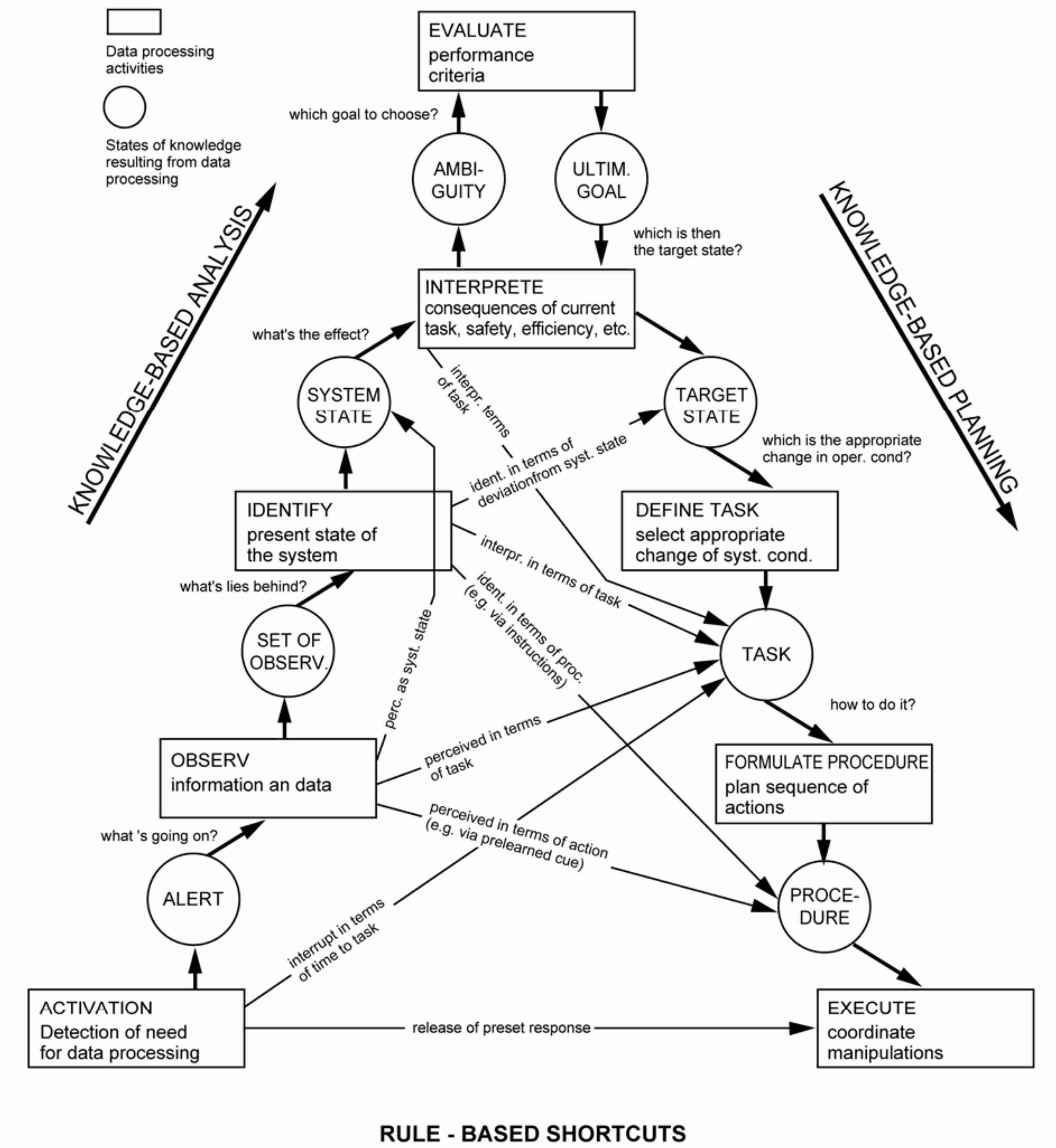


Figure A I - 1: Decision-Ladder by Rasmussen (Rasmussen, 1986)

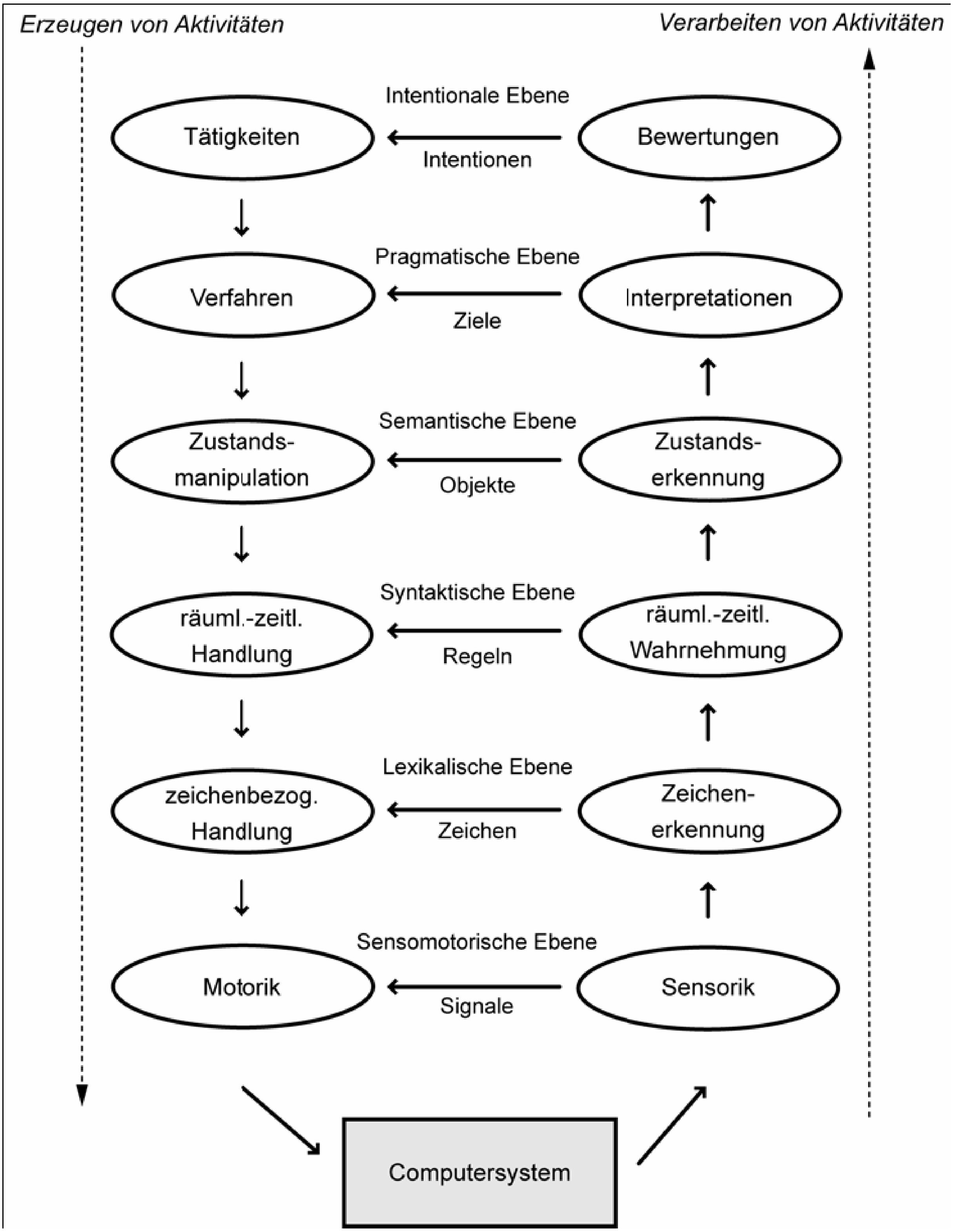


Figure A I - 2: Model of the driver regarding Herczeg (2004)

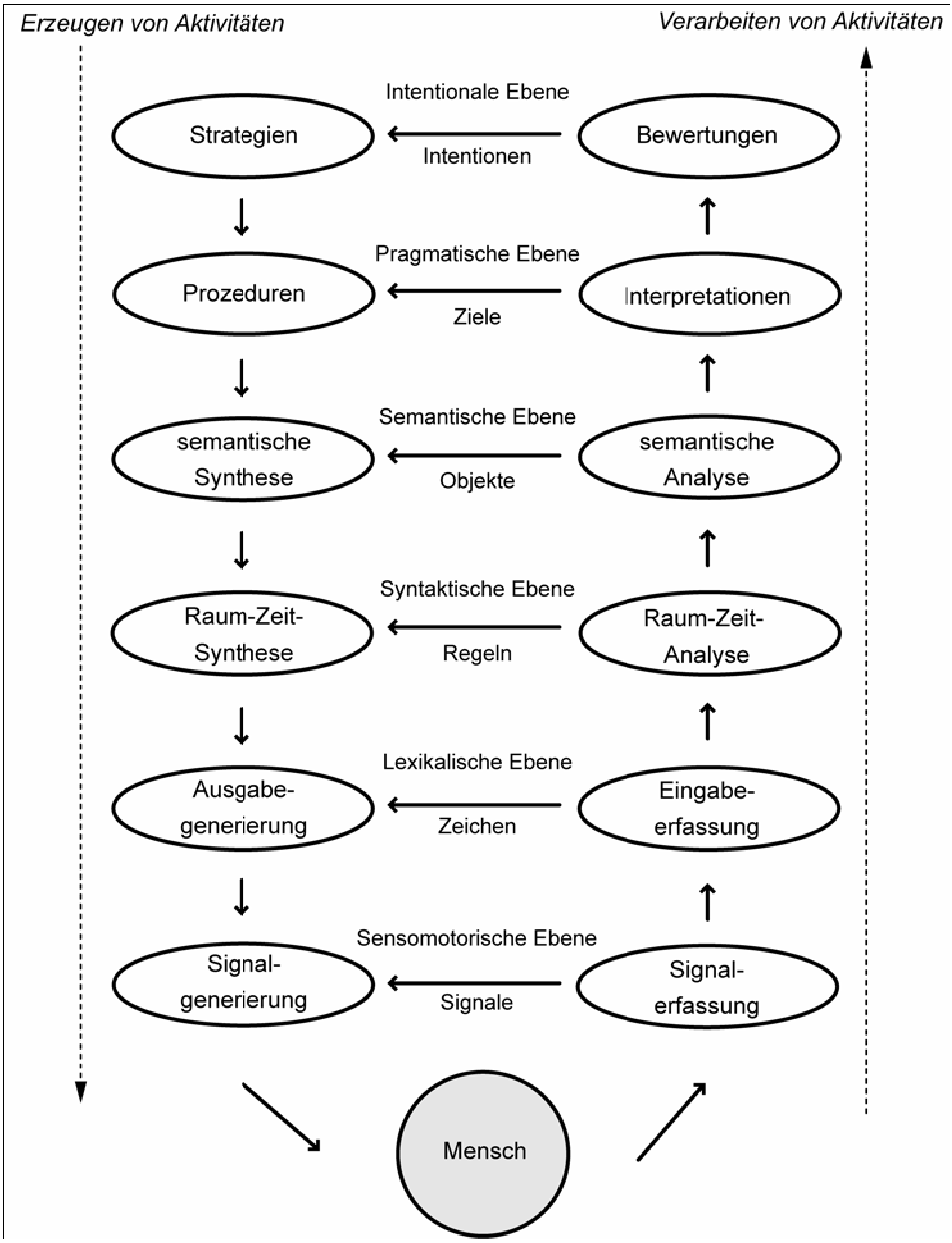


Figure A I - 3: Model of an interactive process system regarding Herczeg (2004)

Appendix II: A conceptual model of the dynamic process that governs trust and its effect on reliance

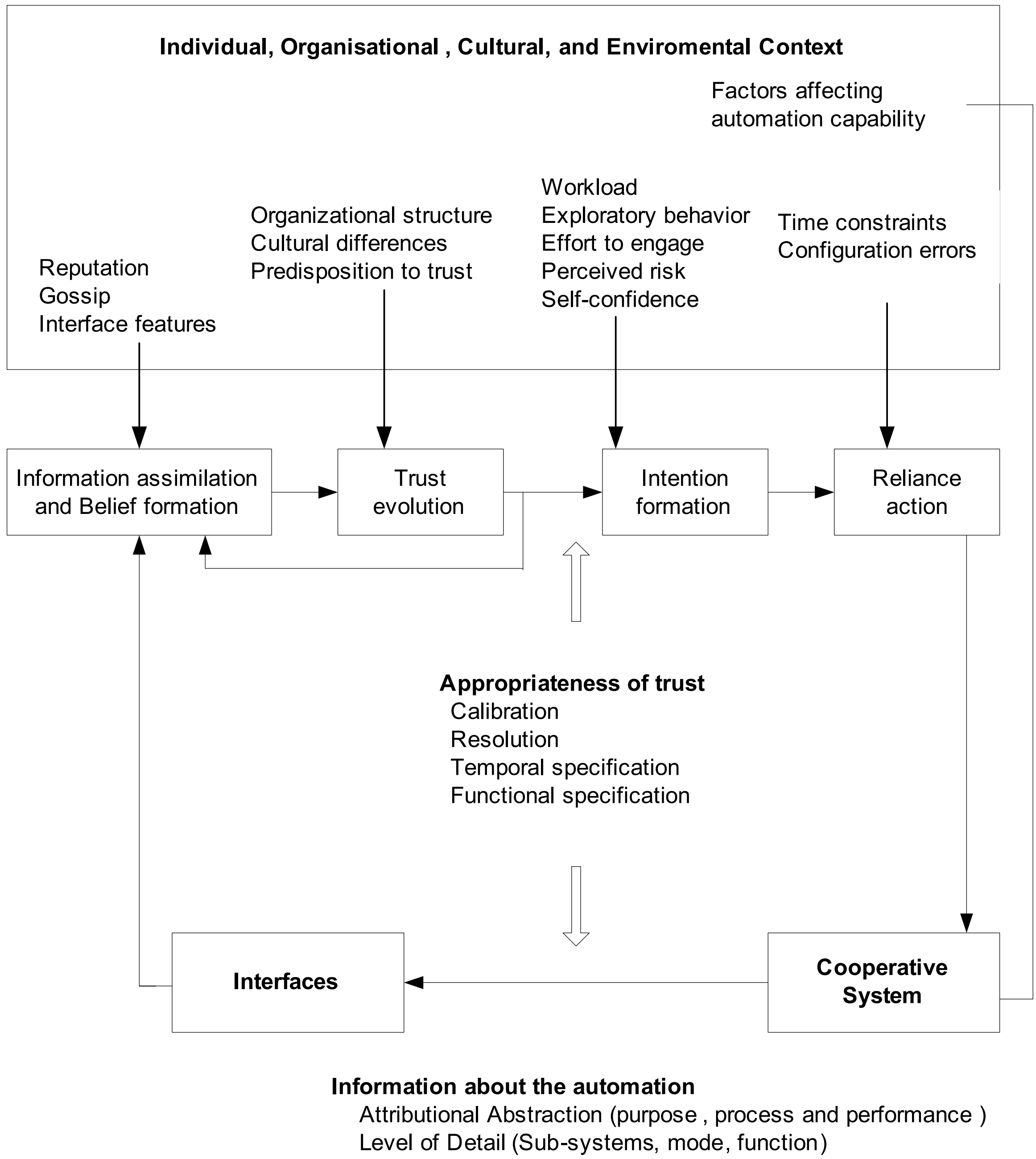


Figure A II - 1: A conceptual model of the dynamic process that governs trust and its effect on reliance (Lee & See, 2003a)

Appendix III: Results of the Online-Questionnaire

Table A III - 1: Means of the desired function allocation of 66 functions in cars (values in parentheses do have a standard deviation > 2).

Means 1-2	Means 2-3	Means 3-4
1. Accelerating (1.73) 2. Overtaking (1.92) 3. Changing lanes (1.93) 4. Right turns (1.98)	1. U-Turn (2.06) 2. Left turns (2.11) 3. Steering (2.17) 4. Getting into the lane (2.37) 5. Selecting a radio channel (2.48) 6. Opening/Closing of the Sliding roof (2.55) 7. Opening/closing of the windows (2.60) 8. Reversing (2.99) 9. (Selecting a title from a CD) (2.81)	1. Regulating the seat heating (3.06) 2. Braking (3.22) 3. Selecting optimal speed (3.30) (e.g. traffic jam prevention, saving gas) 4. Lane keeping (3.32) 5. Pulling out (3.45) 6. Adjusting the mirrors (3.49) 7. Regulating the volume of radio/CD (3.49) 8. Adjusting the ventilators position (3.69) 9. Speed control (3.72) 10. Setting of acoustics and (3.79) sound 11. Administer incoming calls/mailbox (3.80) 12. Setting the seat position (3.84) 13. Object recognition (Cyclists, pedestrians etc.) (3.92) 14. Recognition of other vehicles (3.93) 15. Beginning of the trip (Route Planning regarding the traffic situation) (3.98) 16. Adjusting the nozzles of the(3.99) air condition 17. (Indicating) (3.08) 18. (Entering the destination) (3.12) 19. (Parking) (3.86) 20. (Changing gear) (3.87) 21. (Regulation of the interior lights) (3.99)

Means 4-5	**Means 5-6**	**Means 6-7**
1. Selecting route options (4.00) or type (e.g. only highways) 2. Regulating volume of the Hands free speaking system (4.09) 3. Emergency braking (4.09) 4. Space keeping to the sides (4.11) 5. Space keeping to the front (4.15) 6. Entering a telephone number (4.24) 7. Cleaning of the windshields front (4.49) 8. Space keeping to the back (4.71) 9. Holding the speed (4.73) (cruise control) 10. Regulation of the airflow (4.75) 11. Compiling information (4.78) regarding the destination 12. Recognition of road condition (e.g. grip or ice) (4.98) 13. Checking traffic messages (4.98) 14. (Writing of SMS) (4.07) 15. (Regulating the desired temperature) (4.07) 16. (Maintenance of the telephone book) (4.11) 17. (Insert/Change of a CD) (4.59) 18. (Receiving of SMS) (4.80)	1. Searching for radio channels (5.02) 2. Regulation of the headlights (5.07) (e.g. Night vision) 3. Cleaning of the windshields back (5.14) 4. Redialing of telephone numbers (5.21) 5. Specification of detours (5.30) (e.g. because of traffic jams) 6. Saving of destinations (5.32) 7. Heating the rear window (5.51) 8. Dialing of telephone numbers (5.63) 9. Compiling position information (5.71) 10. (Selecting of telephone net) (5.00)	1. Searching for a telephone number inthe telephone book (6.02) 2. Surveillance tasks (6.03) (e.g. checking of fuel consumption gauge, tyre pressure) 3. Defrost windscreen (6.07) 4. ESP/ABS (6.26)

Appendix IV: Analysis of an overtaking trial

Überholvorgängen in Anlehnung an Fastenmeier (Fastenmeier, Hinderer, Lehnig, & Gstalter, 2001):

1. Normales Fahren im Verkehrsfluss auf einer Spur der Autobahn
    1.1. Geschwindigkeit vom /Abstand zum Vordermann beobachten
    1.2. Geschwindigkeit vom /Abstand zum Hintermann beobachten
    1.3. Beobachtung des Freiraums auf der Nachbarspuren
2. Entscheidungsprozess für einen Spurwechsel
    2.1. Überlegung zum Spurwechsel (langsamer fahrendes Fahrzeug)
    2.2. Prüfung der Legalität des beabsichtigten Spurwechsels
    2.3. Prüfung der Durchführbarkeit des beabsichtigten Spurwechsels
        2.3.1. Kontrolle der Fahrzeugumgebung
            2.3.1.1. Kontrolle der hinterherfahrenden Fahrzeuge
            2.3.1.2. Sichernder Blick für toten Winkel
            2.3.1.3. Prüfung anderer Fahrstreifen
3. Vorbereitung des Spurwechsels
    3.1. Signalisieren der Absicht, die Spur zu wechseln
    3.2. Herstellung der erforderlichen Geschwindigkeit
4. Durchführung des Spurwechsels
    4.1. Zweites Sichern nach setzen des Blinkers
    4.2. Lenkbewegung zum Wechsel der Fahrspur
    4.3. Erneute Kontrolle und eventuelle Anpassung der Geschwindigkeit
5. Abschluss des Spurwechsels
    5.1. Positionierung des Fahrzeugs in die Mitte der Zielspur
    5.2. Beendigung des Signals für die Spurwechselabsicht
    5.3. Eventuelle Anpassung der Geschwindigkeit an den Verkehrsfluss auf dem neuen Fahrstreifen
6. Evaluation des letzten Spurwechsels
    6.1. Diskussion was am gesamten letzten Überholvorgang besser hätte gemacht werden können (auf beiden Seiten)

Appendix V: Experimental design of experiment 1

	Trial 1		Trial 2		Trial 3		Trial 4	
	High traffic density		Low traffic density		High traffic density		Low traffic density	
	Visibility more then 450 meters (low fog)		Visibility under 200 meters (high fog)		Visibility under 200 meters (high fog)		Visibility more then 450 meters (low fog)	
All cells Men between 25-40; Average mileage per year 10000-20000 Km	2 easy left / 2 easy right curves	2 sharp left/ 2 sharp right curves	2 easy left / 2 easy right curves	2 sharp left/ 2 sharp right curves	2 easy left / 2 easy right curves	2 sharp left/ 2 sharp right curves	2 easy left / 2 easy right curves	2 sharp left/ 2 sharp right curves
Condition Manual								
Condition Cooperative								
Condition Half automatic								
Condition Fully automatic								

- Between 24-30 subjects per Condition (the benchmark was a minimum of 6 subjects per trial/condition)
- 4 trials a 29 Kilometers
- Duration ca. 15 minutes per trial
- Avoidance of sequence effects (traffic density, curves, fog)

Appendix VI: Questionnaire before both experiments

Guten Tag! Vielen Dank für Ihre Mitarbeit im Rahmen eines Versuchs am Fahrsimulator der Robert Bosch GmbH Stuttgart. Das Ausfüllen des Ihnen vorliegenden Fragebogens dauert ca. 10 Minuten. Bitte beantworten Sie alle Fragen in dem dafür vorgesehenen Kästchen. Bei vielen Fragen können Sie zwischen unterschiedlichen Antwortalternativen wählen. Markieren Sie bitte in einem solchen Fall die für Sie zutreffende Antwort bzw. Aussage mit einem > x <.

Ihre Angaben werden gemäss den Datenschutzrichtlinien streng vertraulich behandelt.

Vielen Dank für Ihre Mitarbeit!

1. Persönliche Angaben

1.1	Wie heissen Sie?		Name	Vorname
1.2	Wann sind Sie geboren (MM.JJJJ)?			
1.3	Ihr Geschlecht?		Männlich	Weiblich
1.4	Was ist Ihre Muttersprache?			
1.5	Ihre derzeitige Tätigkeit?	Student	Berufstätig	Andere, welche?
1.6	Welche Art von Tätigkeit bzw. Fach (z.B. Abteilungsleiter oder Biologie)?			
1.7	Sind Sie Mitarbeiter der Bosch-Gruppe?		Ja	Nein
1.8	In welchem Alter haben Sie Ihren Führerschein gemacht?			
1.9	Haben sie schon einmal an einem Fahrsimulatorexperiment teilgenommen?		Ja	Nein
1.10	Bitte geben Sie Telefonnummern an, unter denen wir Sie zwecks Terminabsprache erreichen können.	Tagsüber	Abends	Handy
1.11	Bitte geben Sie Ihre Email-Adresse an, unter der wir Sie am besten erreichen können.			

2. Angaben zu Gewohnheiten und gesundheitlichen Einschränkungen

In dem folgenden Abschnitt möchten wir Sie um Angaben zu Ihren Gewohnheiten sowie gesundheitlichen Einschränkungen bitten. Diese Informationen dienen der Vergleichbarkeit der durch die Untersuchung gewonnenen Informationen. Bitte markieren Sie die für Sie zutreffende Antwort mit einem < x >.

2.1	Sind Sie Links- oder Rechtshänder?	Linkshänder	Rechtshänder		Beidhänder		
2.2	Benötigen Sie beim Fahren eine Sehhilfe?	Nein	Ja, Brille		Ja, Kontaktlinsen		Kontaktlinsen oder Brille
2.3	Leiden Sie unter einer Farbsehschwäche?	Nein	Rot/Grün		Blau/Gelb		Andere
2.4	Leiden Sie unter Hörschäden?		Ja		Nein		
2.5	Sind Sie Raucher oder Nichtraucher?		Nichtraucher		Raucher		
2.6	Nehmen Sie Medikamente ein, die Sie in Ihrer Fahrtauglichkeit einschränken können?		Ja		Nein		Weiss nicht
2.7	Leiden Sie unter Schlafstörungen?		Ja		Nein		
2.8	Wie ist Ihr Arbeitsrythmus?		Geregelt tagsüber		2-Schicht		3-Schicht
2.9	Halten Sie zur Zeit regelmäßig Mittagsschlaf?	Ja	Nein		Nein, würde aber gerne		
2.10	Wie häufig leiden Sie unter Schwindelgefühlen?		> 1 Mal/Woche		< 1 Mal/Monat		Nie
2.11	Leiden Sie als Mitfahrer unter Übelkeit bzw. Reiseübelkeit aufgrund der Fahrbewegung?		Nie	Selten	Manchmal	Oft	Immer
2.12	Wird Ihnen schwindelig bzw. übel, wenn Sie als Mitfahrer während der Autofahrt lesen o.ä.?		Ja		Nein		

3. Angaben rund ums Fahrzeug

Im folgenden Abschnitt möchten wir Ihnen ein paar Fragen zu Ihren bisherigen Erfahrungen mit Kraftfahrzeugen stellen.

3.1.1	Was für einen PKW fahren Sie hauptsächlich?	
3.1.2	Welches Baujahr hat dieser PKW?	
3.2	Seit wieviel Jahren fahren Sie Ihren jetzigen PKW?	

		< 10.000 km	<10.000 km und > 20.000 km	> 20.000 km
3.3	Wieviele Kilometer fahren Sie durchschnittlich im Jahr? Bitte markieren Sie mit einem > x <.			

3.4 Bitte markieren Sie mit einem > x < welche technischen Systeme sie aktuell in Ihrem PKW haben und wie oft Sie diese nutzen.

		System vorhanden?		Falls vorhanden, wie häufig nutzen Sie diese Technik?				
		ja	nein	sehr selten	selten	teils/teils	häufig	sehr häufig
3.4.1	Navigationssystem							
3.4.2	Tempomat							
3.4.3	Automatische Abstandsregelung (z.B. ACC)							
3.4.4	Parkpilot (Einparkhilfe)							
3.4.5	Telefon							
3.4.6	Radio							
3.4.7	CD und/oder CD-Wechsler							
3.4.8	Klimaanlage							
3.4.9	Bordcomputer							
3.4.10	Multifunktionslenkrad							
3.4.11	Sprachbedienung							
3.4.12	Elektronisches Stabilitätsprogramm							
3.4.13	Automatikgetriebe							
3.4.14	Antiblockiersystem (ABS)							

		Sehr schlecht	Schlecht	Teils teils	Gut	Sehr gut
3.5	Wie sind Ihre bisherigen Erfahrungen mit denen von Ihnen genannten Systemen?					

		Sehr niedrig	Niedrig	Teils teils	Hoch	Sehr hoch
3.6	Wie hoch würden Sie Ihre Neigung zu neuen Technologien im Auto einschätzen?					

4. Angaben zu technischen Problemen

Im Folgenden Abschnitt interessiert uns Ihre Meinung zu Problemen im Umgang mit technischen Geräten. Es gibt keine richtigen oder falschen Antworten, allein Ihre persönliche Meinung zählt! Mit „technischen Problemen“ sind im Folgenden Schwierigkeiten im Umgang mit den verschiedensten Geräten aus Alltag und Beruf gemeint, z.B. bei der Programmierung eines Videorecorders, der Arbeit mit dem Computer, der Bedienung einer Mikrowelle, dem Aufstellen von Selbstmontagemöbeln, der Bedienung von Wasserhähnen in öffentlichen Toiletten, dem Lösen von Fahrkarten am Automaten usw. Bitte Markieren Sie den für Sie zutreffenden Fall mit einem > x <.

		Gar nicht	Meist nicht	Weder noch	Zumeist	Absolut
4.1	Ich kann ziemlich viele der technischen Probleme, mit denen ich konfrontiert bin, allein lösen.					
4.2	Technische Geräte sind oft undurchschaubar und schwer zu beherrschen.					
4.3	Es macht mir richtig Spaß, ein technisches Problem zu knacken.					
4.4	Weil ich mit bisherigen technischen Problemen gut zurecht gekommen bin, blicke ich auch künftigen optimistisch entgegen.					
4.5	Ich fühle mich technischen Geräten gegenüber so hilflos, dass ich lieber die Finger von ihnen lasse.					
4.6	Auch wenn Widerstände auftreten, bearbeite ich ein technisches Problem weiter.					
4.7	Wenn ich ein technisches Problem löse, so geschieht das meistens durch Glück.					
4.8	Die meisten technischen Probleme sind so kompliziert, dass es wenig Sinn hat, sich mit ihnen auseinander zusetzen.					

5. Verhaltensweisen und Gewohnheiten im Berufsleben

Die folgenden Aussagen beziehen sich auf das Berufsleben. Bitte markieren Sie den Grad, indem die formulierte Aussage auf Sie zutrifft mit einem > x <. Denken Sie nicht zu lange über eine Aussage nach, sondern treffen Sie Ihre Wahl möglichst spontan. Es ist wichtig, dass Sie keine Aussage auslassen. Es gibt keine richtigen oder falschen Antworten!

		Trifft voll zu	Trifft meistens zu	Trifft eher zu	Trifft eher nicht zu	Trifft meistens nicht zu	Trifft überhaupt nicht zu
5.1	Meine Arbeit stellt mich vor allem dann zufrieden, wenn ich nicht auf die Unterstützung anderer angewiesen bin.						
5.2	Ich erziele die besten Arbeitsergebnisse, wenn ich alleine arbeite.						
5.3	Mir ist es wichtig, dass ich mich bei meiner Tätigkeit nicht ständig mit anderen abstimmen muss.						
5.4	Ich ziehe es vor, allein zu arbeiten.						
5.5	Ich bin davon überzeugt, dass nahezu alle aktuellen Probleme nur im Team zu bewältigen sind.						
5.6	Wenn man eine Aufgabe optimal erledigen will, sollte man sie allein angehen.						
5.7	Bei nahezu allen Aufgaben nimmt die Bearbeitung in Gruppen mehr Zeit als nötig in Anspruch.						
5.8	Meine Kollegen (Kommilitonen) meinen, ich sei ein Einzelkämpfer.						
5.9	Ich kann meine Fähigkeiten vor allem in der Zusammenarbeit mit anderen voll entfalten.						
5.10	Bei der Bearbeitung einer Aufgabe möchte ich so lange wie möglich ohne Hilfe anderer auskommen.						
5.11	Wenn ich etwas plane, überlege ich zunächst, wer noch bei dem Projekt mitarbeiten könnte.						
5.12	Es widerstrebt meinem Arbeitsstil, ständig alles mit anderen diskutieren zu müssen.						
5.13	Wenn ich die Wahl habe, bearbeite ich Aufgaben lieber gemeinsam mit anderen.						

6. Schluss

Vielen Dank für Ihre Mitarbeit!

Bei eventuellen Fragen oder Problemen wenden Sie sich bitte per Email an Tobias.Keil@de.bosch.com.

	Ja	Nein
Haben Sie Interesse auch an anderen Versuchen teilzunehmen?		

Falls sie später einmal Ihre Daten aus der Datenbank löschen möchten, so schicken Sie uns bitte eine Email mit dem Betreff "Eintrag löschen".

	Ja	Nein
Ich wurde über die Möglichkeit informiert, meine Einträge in der Datenbank jederzeit wieder löschen zu können und stimme der Speicherung der oben gemachten Angaben zu:		

Appendix VII: Instructions and interaction concept for the cooperative system variant

1. Instructions for the cooperative system variant

Herzlich Willkommen bei einem Bereich der Bosch Forschung. Wir freuen uns, dass Sie am Fahrversuch teilnehmen.

<u>Vorbereitende Bemerkungen:</u>

- Stellen Sie sich bitte zunächst den Sitz auf die für Sie optimale Position ein.
- Sie finden im Cockpit mehrere Bedienelemente, die Sie im Rahmen der Simulation benutzen sollen:
  - Lenkrad
  - Gaspedal und Bremse
  - Blinkhebel (Dieser muss immer manuell aktiviert oder deaktiviert werden)

  → Alle anderen Bedienelemente im Simulator dürfen nicht verwendet werden!
- Bitte stützen Sie sich beim Ein- und Aussteigen aus dem Fahrzeug nicht am Lenkrad ab.
- Sie werden während der Fahrt per Video überwacht. Sollten Sie sich unwohl fühlen, so können Sie dies jederzeit der Sie betreuenden Person durch entsprechende Zeichengabe signalisieren. Bitte versuchen Sie nicht, alleine aufzustehen!
- Bitte betätigen Sie bis zum Start der Simulation durch den Versuchsleiter keine Bedienteile und bringen Sie das Lenkrad in Mittelstellung.
- Nach dem Ende der Fahrt möchten wir Sie bitten ruhig sitzen zu bleiben. Der Versuchsleiter wird dann umgehend zu Ihnen kommen.

Zur Simulation im engeren Sinne

- Im folgenden Versuch geht es darum, dass Sie auf der Autobahn eine Strecke von 120 Kilometern zurücklegen.
- Während der Fahrt sind die Verkehrsregeln einzuhalten, insbesondere die Geschwindigkeitsbegrenzung von 120 km/h.
- Bitte denken Sie an das Rechtsfahrgebot!
- Während der Fahrt steht Ihnen als Prototyp ein neues <u>**kooperatives**</u> System zur Verfügung. Dieses System ist sprachbasiert.

- Wir möchten Sie bitten mit diesem System beim Überholen zusammenzuarbeiten.
- Das System namens „VIRA“ weist das folgende funktionale Verhalten auf:
  - Es hilft beim Geschwindigkeitsmanagement
  - Es detektiert Fahrzeuge im „Toten Winkel“ und erkennt Gefahren.

- Es hilft bei der Planung und Entscheidung wann Überholen sinnvoll und möglich ist.
- Es errechnet Lückengrößen zwischen Fahrzeugen.
- Es erkennt die Abstände, Geschwindigkeiten im Verhältnis zu und das Bremsverhalten von anderen Fahrzeugen während eines Überholvorganges.
- Das System kann Blinken.

- Es gelten folgende Kommunikationsregeln mit **„VIRA“**:

  - Sie können dem System jederzeit Fragen bezüglich der Fahrsituation und Fahraufgabe stellen und es bitten Aufgaben zu übernehmen oder wieder abzugeben.
  - Das System kann Ihnen Fragen zur Informationsgewinnung stellen.
  - **„VIRA“** kann von sich aus Unterstützung anbieten.
  - Das System wird Ihnen Antworten geben, die für die Fahrsituation relevant sind. Falls Sie eine Systemausgabe nicht verstanden haben, können Sie es bitten die Ausgabe zu wiederholen.
  - Für Fragen jenseits des Systemumfangs erhalten Sie die Rückmeldung **„Hierzu liegen mir keine Informationen vor“!**

Gute Fahrt!

2. Interaction concept for the cooperative system variant

Initial und während normaler Fahrt:

1. Ich unterscheide nicht zwischen Motorrad und Auto
2. Bei Wetteränderungen oder Stau auf unserer Strecke melde ich mich
3. Hallo ich bin das System "VIRA", ich werde Sie auf der Autobahnfahrt begleiten!
4. Die Verkehrsnachrichten melden Nebel mit Sicht bei 450 Meter für diesen Streckenabschnitt
5. Die Verkehrsnachrichten melden Nebel mit Sicht unter 250 Meter für diesen Streckenabschnitt
6. Soll ich den Abstand zum Vordermann beobachten?
7. Soll ich die Geschwindigkeit vom Vordermann beobachten?
8. Kann ich Ihnen beim Geschwindigkeitsmanagement behilflich sein?
9. Ja, kann ich übernehmen
10. Ich helfe Ihnen bei der Herstellung der erforderlichen Geschwindigkeit!
11. Wir sind momentan noch circa 20 Km/h langsamer als die anderen Autos
12. Wir sind momentan noch circa 10 Km/h langsamer als die anderen Autos
13. Wir sind momentan gleich schnell wie die anderen Autos
14. Wir sind momentan schneller als 130 Km/h

15. Wir sind momentan etwas zu schnell!
16. Auf dieser Strecke gilt eine Geschwindigkeitsbegrenzung auf 120 Km/h
17. Der Vordermann fährt 90 Kilometer pro Stunde
18. Der Vordermann fährt 135 Kilometer pro Stunde
19. Der Vordermann fährt langsamer als Sie!
20. Der Vordermann fährt schneller als Sie!
21. Der Abstand zum Vordermann ist jetzt unter 300 Meter
22. Der Abstand zum Vordermann ist zu klein.
23. Der Abstand zum Vordermann ist jetzt unter 200 Meter
24. Der Abstand zum Vordermann ist jetzt unter 100 Meter
25. Der Abstand zum Vordermann ist kleiner als 50 Meter
26. Sie können ruhig näher heranfahren!
27. Sie müssen mehr Abstand halten, um sinnvoll überholen zu können
28. Soll ich den Abstand zum Hintermann beobachten?
29. Soll ich die Geschwindigkeit vom Hintermann beobachten?
30. Ja, kann ich übernehmen
31. Der Hintermann auf der linken Spur fährt 135 Km/h
32. Der Hintermann fährt 140 Km/h
33. Der Hintermann hat von sich aus den Abstand vergrößert
34. Der Hintermann auf der rechten Spur fährt 90 Km/h
35. Der Abstand zum Hintermann ist kleiner als 50 Meter
36. Der Abstand zum Hintermann ist größer als 50 Meter
37. Der Hintermann fährt langsamer als Sie
38. Der Hintermann fährt schneller als Sie

Entscheidung für Spurwechsel:

39. Möchten Sie den langsamer fahrenden LKW überholen?
40. Ich schaue mal, wann ein Spurwechsel sinnvoll ist
41. Kann ich beim Überholen behilflich sein?
42. Der Abstand zum Hintermann ist zu klein
43. Kann ich bei der Überwachung der hinterherfahrenden Fahrzeuge behilflich sein?
44. Soll ich nach den Lücken auf dem linken Fahrstreifen schauen?
45. Da kommt eine Kolonne mit mehreren Fahrzeugen auf der linken Spur.

46. Es ist genug Platz
47. Ich achte auf die hinterherfahrenden Autos und sage Bescheid, wenn sich etwas Relevantes tut
48. Die Lücke reicht noch nicht aus
49. Die Lücken sind unterschiedlich groß!
50. Wir können wieder rechts fahren
51. Nach sechs Autos ist eine Lücke für einen Spurwechsel
52. Nach fünf Autos ist eine Lücke für einen Spurwechsel
53. Nach vier Autos ist eine Lücke für einen Spurwechsel
54. Nach drei Autos ist eine Lücke für einen Spurwechsel
55. Nach zwei Autos ist eine Lücke für einen Spurwechsel
56. Nach dem nächsten Auto ist eine gute Lücke für einen Spurwechsel
57. Soll ich den linken Fahrstreifen auf Sicherheit überprüfen?
58. Soll ich beim Spurwechsel den Blick in den toten Winkel übernehmen?
59. Ja, kann ich machen!
60. Momentan befindet sich kein Auto im Toten Winkel!
61. Haben Sie das Auto eben selbst gesehen?
62. Im toten Winkel befindet sich ein anderes Fahrzeug.
63. Haben Sie das Auto im toten Winkel gesehen?
64. Der Vordermann fährt 90 Kilometer pro Stunde
65. Momentan ist hinter Ihnen alles frei!
66. Überholen wäre jetzt sinnvoll
67. Die Lücke ist unter 80 Meter groß
68. Die Lücke die wir genommen haben, war eigentlich zu klein
69. Die Lücke entsprach nicht den rechtlich notwendigen Sicherheitsabständen
70. Soll ich den Blinker setzen?
71. Ich werde immer den Blinker setzen, wenn Sie es nicht machen!
72. Soll ich immer den Blinker setzen, wenn Sie es nicht machen?

Durchführung des Spurwechsels:

73. Kann ich Ihnen bei der Durchführung des Spurwechsels behilflich sein?
74. Da ist doch noch ein schnelleres Auto!
75. Jetzt ist frei
76. Im Moment ist alles in Ordnung

77. Wir sollten etwas schneller fahren
78. Wir können ruhig etwas langsamer fahren
79. Wir fahren zu dicht auf
80. Wir fahren zu weit links!
81. Wir fahren zu weit rechts!
82. Wir schlingern!
83. Soll ich den Blinker zurücksetzen?
84. Soll ich den Blinker ab jetzt immer zurücksetzen?
85. Soll ich beim erneuten Anpassen der Geschwindigkeit behilflich sein?
86. Sie fahren aktuell noch etwas langsamer als die anderen Fahrzeuge!

Evaluation:

87. Bei was soll ich Sie beim nächsten Überholen mehr unterstützen?
88. Über was wünschen Sie beim nächsten Mal mehr Informationen?
89. Ja, kann ich machen!

Appendix VIII: Questionnaire of experiment 1

A - Fragen zum letzten Fahrabschnitt

A1. Wie schnell war der LKW, den Sie als letztes überholt haben? (Kreisen Sie bitte ihre Antwort ein)

A. 70 Km/h B. 75 Km/h C. 80 Km/h D. 85 Km/h E. 90 Km/h
F. 95 Km/h G. 100 Km/h H. 105 Km/h I. 110 Km/h

A2. Was für eine Farbe hatte der LKW, den Sie als letztes überholt haben? (Kreisen Sie bitte ihre Antwort ein)

A. Blau B. Gelb C. Grün D. Rot E. Keine

A3. Reisten Sie gerade? (Kreisen Sie bitte ihre Antwort ein)

A....schneller als die Geschwindigkeitsbegrenzung

B....genauso schnell wie die Geschwindigkeitsbegrenzung

C….langsamer als die Geschwindigkeitsbegrenzung

A4. Wie sieht der Straßenverlauf vor Ihnen in den nächsten 300 Metern aus? (Kreisen Sie bitte ihre Antwort ein)

A. Geradeaus B. Leichte Linkskurve C. Leichte Rechtskurve
D. Scharfe Linkskurve E. Scharfe Rechtskurve

A5. Was für ein Fahrzeugtyp war das letzte Auto, das Sie überholt hat? (Kreisen Sie bitte ihre Antwort ein)

A. Sport Utility Vehicle B. Sportwagen C. Limousine
D. Kleinwagen E. Motorrad F. Anderer Fahrzeugtyp

A6. Was für eine Farbe hatte das letzte Auto, das Sie gerade überholt hat? (Kreisen Sie bitte ihre Antwort ein)

A. Rot B. Schwarz C. Blau D. Weiß E. Silber F. Andere

A7. Geben Sie bitte an, welche relativen Bedeutungen die sechs Beanspruchungsdimensionen bei den während der Fahrt durchgeführten Aufgaben für Ihre empfundene Gesamtbeanspruchung hatten.

Lesen Sie dazu bitte zunächst die folgenden Erläuterungen:

Geistige Anforderungen	Wie viel geistige Anstrengung war bei der Informationsaufnahme und bei der Informationsverarbeitung erforderlich (z.B. Denken, Entscheiden, Rechnen, Erinnern, Hinsehen, Suchen o.ä.)? War die Aufgabe leicht oder anspruchsvoll, einfach oder komplex, erfordert sie hohe Genauigkeit oder ist sie fehlertolerant?
Körperliche Anforderungen	Wie viel körperliche Aktivität war erforderlich (z.B. ziehen, drücken, drehen, steuern, aktivieren o.ä.)? War die Aufgabe leicht oder schwer, einfach oder anstrengend, erholsam oder mühselig?
Zeitliche Anforderungen	Wie viel Zeitdruck empfanden Sie hinsichtlich der Häufigkeit oder dem Takt mit dem Aufgaben oder Aufgabenelemente auftraten? War die Abfolge langsam und geruhsam oder schnell und hektisch?
Ausführung der Aufgaben	Wie erfolgreich haben Sie ihrer Meinung nach die vom Versuchsleiter (oder Ihnen selbst) gesetzten Ziele erreicht? Wie zufrieden waren Sie mit Ihrer Leistung bei der Verfolgung dieser Ziele?
Anstrengung	Wie hart mussten Sie arbeiten, um Ihren Grad an Aufgabenerfüllung zu erreichen?
Frustration	Wie unsicher, entmutigt, irritiert, gestresst und verärgert (versus sicher, bestätigt, zufrieden, entspannt und zufrieden mit sich selbst) fühlten Sie sich während der Aufgabe?

Im Folgenden werden jeweils zwei der sechs Beanspruchungsdimensionen in verschiedenen Kombinationen (Paaren) gegenübergestellt. Geben Sie bitte an, welche Beanspruchungsdimension für die empfundene Gesamtbeanspruchung bedeutsamer war. Entscheidend ist nicht, wie hoch die Beanspruchung in den einzelnen Dimensionen war, sondern welche Dimension wichtiger für das Gesamtempfinden war!

Beispiel: Wenn für Sie die *geistigen Anforderungen* durch die Aufgaben bedeutsamer für das Beanspruchungserleben waren, als die *Anstrengung*, die Sie aufbringen mussten, um die Aufgabe durchzuführen, kreuzen Sie bitte wie folgt an:

Paar 1	Anstrengung	☐		X☐	Geistige Anforderungen

Alles klar? Dann zum vollständigen Paarvergleich:

Paar 1	Körperliche Anforderungen	☐		☐	Zeitliche Anforderungen
Paar 2	Anstrengung	☐		☐	Geistige Anforderungen
Paar 3	Frustration	☐		☐	Körperliche Anforderungen
Paar 4	Anstrengung	☐		☐	Frustration
Paar 5	Geistige Anforderungen	☐		☐	Zeitliche Anforderungen
Paar 6	Körperliche Anforderungen	☐		☐	Anstrengung
Paar 7	Zeitliche Anforderungen	☐		☐	Ausführung der Aufgaben
Paar 8	Frustration	☐		☐	Geistige Anforderungen
Paar 9	Zeitliche Anforderungen	☐		☐	Frustration
Paar 10	Ausführung der Aufgaben	☐		☐	Anstrengung
Paar 11	Geistige Anforderungen	☐		☐	Körperliche Anforderungen

Paar 12	Frustration	□		□	Ausführung der Aufgaben
Paar 13	Ausführung der Aufgaben	□		□	Körperliche Anforderungen
Paar 14	Geistige Anforderungen	□		□	Ausführung der Aufgaben
Paar 15	Anstrengung	□		□	Zeitliche Anforderungen

B - Fragen zur Simulation

Jetzt haben wir ein paar Fragen an Sie, wie Sie die Simulation erlebt haben.

Wie haben Sie sich während der Simulation gefühlt?

		Stimmt völlig...Stimmt gar nicht				
SS.1	Ich fühlte mich normal.	❍	❍	❍	❍	❍
SS.2	Ich war irritiert.	❍	❍	❍	❍	❍
SS.3	Mir war schwindelig.	❍	❍	❍	❍	❍
SS.4	Mir war übel.	❍	❍	❍	❍	❍
SS.5	Ich fühlte mich nicht gut.	❍	❍	❍	❍	❍
SS.6	Ich hatte Kopfschmerzen.	❍	❍	❍	❍	❍
SS.7	Ich hatte Schwierigkeiten Objekte zu fokussieren.	❍	❍	❍	❍	❍
SS.8	Ich fühlte mich müde.	❍	❍	❍	❍	❍
SS.9	Meine Augen wurden überanstrengt.	❍	❍	❍	❍	❍
SS.10	Ich hatte Schwierigkeiten mich zu konzentrieren.	❍	❍	❍	❍	❍
SS.11	Ich empfand generelles Unbehagen.	❍	❍	❍	❍	❍
SS.12	....	❍	❍	❍	❍	❍

B1. Fühlten Sie sich während der Simulatorfahrt durch irgendetwas abgelenkt?

B2. Hatten Sie Probleme mit dem System? Wenn ja, welche konkret?

C - Generelle Fragen zum System

Sie haben während der Fahrt das System näher kennen gelernt. Uns interessiert nun, wie Sie es aus Ihrer persönlichen Sicht einschätzen.

Im Folgenden werden Ihnen einige Aussagen vorgegeben, denen Sie mehr oder weniger zustimmen bzw. die Sie ablehnen können. Bitte kreuzen Sie die Antwortmöglichkeit an, die Sie spontan für die beste halten und die am ehesten auf Sie zutrifft. Bitte beantworten Sie jede Frage!

Wie würden Sie das System aus Ihrer persönlichen Sicht bewerten?

		Stimmt gar nicht	Stimmt kaum	Stimmt Teilweise	Stimmt über-wiegend	Stimmt völlig
C1.1	Dieses System ist sinnvoll.	❍	❍	❍	❍	❍
C1.2	Mit diesem System würde ich mich wohl fühlen.	❍	❍	❍	❍	❍
C1.3	Dieses System ist nichts für mich.	❍	❍	❍	❍	❍
C1.4	Ich finde, dieses System ist sehr nützlich.	❍	❍	❍	❍	❍
C1.5	Ich bin von diesem System begeistert.	❍	❍	❍	❍	❍
C1.6	Diese Technologie im Auto zu besitzen ist für mich ein absolutes Muss.	❍	❍	❍	❍	❍
C1.7	Ich denke, dieses System ist unsicher.	❍	❍	❍	❍	❍
C1.8	Dieses System passt zu mir.	❍	❍	❍	❍	❍
C1.9	Dieses System gefällt mir überhaupt nicht.	❍	❍	❍	❍	❍
C1.10	Dieses System ist eine wertvolle Unterstützung.	❍	❍	❍	❍	❍
C1.11	Dieses System sagt mir spontan zu.	❍	❍	❍	❍	❍

Wie würden Sie das System aus Ihrer persönlichen Sicht bewerten?

		Stimmt gar nicht	Stimmt Kaum	Stimmt teilweise	Stimmt über-wiegend	Stimmt völlig
C2.1	Die Nutzung dieses Systems fördert die Verkehrssicherheit.	❍	❍	❍	❍	❍
C2.2	Die Nutzung dieses Systems empfinde ich als sicher.	❍	❍	❍	❍	❍
C2.3	Dieses System ist vertrauenswürdig.	❍	❍	❍	❍	❍
C2.4	Dieses System wird mich nicht enttäuschen.	❍	❍	❍	❍	❍

C2.5	Dieses System wirkt glaubwürdig.	❍	❍	❍	❍	❍
C2.6	Dieses System wirkt verlässlich.	❍	❍	❍	❍	❍
C2.7	Ich vertraue darauf, dass dieses System in meinem Interesse handelt.	❍	❍	❍	❍	❍
C2.8	Die Nutzung dieses Systems ist zu risikoreich.	❍	❍	❍	❍	❍
C2.9	Dieses System möchte das Beste für mich.	❍	❍	❍	❍	❍
C2.10	Dieses System empfinde ich als angenehm.	❍	❍	❍	❍	❍
C2.11	Dieses System arbeitet effektiv.	❍	❍	❍	❍	❍
C2.12	Dieses System ist hilfreich.	❍	❍	❍	❍	❍
C2.13	Wenn ich dieses System im Auto hätte, würde ich es regelmäßig nutzen.	❍	❍	❍	❍	❍

Stellen Sie sich nun bitte noch einmal die Situationen vor, die Sie während der Fahrt erlebt haben.

C3. An welchen Stellen würden Sie aufgrund des von Ihnen erlebten Systems mit Vorteilen im Hinblick auf ihre Fähigkeiten (def. als das gegenwärtige Potential etwas zu tun) rechnen?

C4. An welchen Stellen würden Sie aufgrund des von Ihnen erlebten Systems mit Nachteilen im Hinblick auf ihre Fähigkeiten (def. als das gegenwärtige Potential etwas zu tun) rechnen?

C5. An welchen Stellen würden Sie aufgrund des von Ihnen erlebten Systems mit Vorteilen im Hinblick auf ihre Fertigkeiten (def. als die gelernte Integration gut ausgeführter Leistungen, die durch Übung verbessert werden können; z.B. Steuern des PKW, Abwehr von Schlingern etc.) rechnen?

C6. An welchen Stellen würden Sie aufgrund des von Ihnen erlebten Systems mit Nachteilen im Hinblick auf ihre Fertigkeiten (def. als die gelernte Integration gut ausgeführter Leistungen, die durch Übung verbessert werden können; z.B. Steuern des PKW, Abwehr von Schlingern etc.) rechnen?

C7. Hat das System ihr Interesse an einer Kooperation/Zusammenarbeit mit technischen Systemen gesteigert oder gesenkt?

D - Ergonomische Gestaltung des Systems

		Stimmt gar nicht	Stimmt Kaum	Stimmt teilweise	Stimmt über-wiegend	Stimmt völlig
D1.1	Das System war mir unmittelbar verständlich	❍	❍	❍	❍	❍
D1.2	Das System gab mir ausreichend Rückmeldung	❍	❍	❍	❍	❍
D1.3	Die Abläufe des Systems waren für mich transparent	❍	❍	❍	❍	❍

D2. Hätten Sie sich gewünscht, dass es die Möglichkeit gegeben hätte zwischen mehreren Varianten des Systems zu wechseln?

OA – Optische und akustische Signale

Im Laufe Ihrer Fahrt, wurde auf dem Display in der Fahrzeugmitte ein Icon mit einem *optischen* Zeichen angezeigt. Zudem waren in manchen Situationen *akustische* Signale zu hören.

OA1. Beschreiben Sie bitte - in Ihren eigenen Worten - das auf dem Display dargestellte optische Zeichen.

OA2. Wie und in welchen Situationen hat sich das optische Zeichen verändert?

OA3. Beschreiben Sie bitte - in Ihren eigenen Worten - die über Lautsprecher ausgegebenen akustischen Signale.

OA4. In welcher Situation wurden die akustischen Signale wiedergegeben?

OA5. Wo haben Sie ähnliche akustische Signale (im Umgang mit Technik) schon einmal gehört?

!!! Bitte wenden Sie sich jetzt an den Versuchsleiter !!!

Rechts sehen Sie das optische Zeichen.

Wenn Sie mit der Maus auf den Bildschirm vor Ihnen klicken, können Sie sich auch die akustischen Zeichen erneut anhören.

OA6. Was bedeutete das dargestellte Zeichen für Sie?

OA7. Was haben Sie auf dieses Zeichen hin getan?

OA8. Wann haben Sie das getan?

sofort	etwas später	später	viel später	irgendwann	gar nicht
❍	❍	❍	❍	❍	❍

Das erste dargebotene akustische Signal waren zwei Töne: Zuerst ein tiefer und dann ein hoher Ton. Das Signal ist einem Tusch nachempfunden.

OA9. Was bedeutete das akustische Signal für Sie?

OA10. Was haben Sie auf dieses Signal hin getan?

OA11. Wann haben Sie das getan?

sofort	etwas später	später	viel später	irgendwann	gar nicht
❍	❍	❍	❍	❍	❍

Das zweite akustische Signal waren vier schnell hintereinander gespielte Töne, die in der Tonhöhe abnahmen. Es ist einer Melodie nachempfunden, die Windows beim Schließen von Prozessen verwendet.

OA12. Was bedeutete dieses Signal für Sie?

OA13. Was haben Sie auf dieses Signal hin getan?

OA14. Wann haben Sie das getan?

sofort	etwas später	später	viel später	irgendwann	gar nicht
❍	❍	❍	❍	❍	❍

Das optische Zeichen wurde Ihnen oben noch einmal dargeboten.

OA15. Ist das optische Zeichen geeignet, um die Bedeutung "automatischer Überholassistent" auszudrücken?

nicht geeignet	wenig geeignet	mittelmäßig geeignet	annähernd geeignet	sehr geeignet
❍	❍	❍	❍	❍

OA16. Wirkt das optische Zeichen auf Sie ansprechend?

nicht ansprechend	wenig ansprechend	mittelmäßig ansprechend	annähernd ansprechend	sehr ansprechend
❍	❍	❍	❍	❍

OA17. Was ist positiv an diesem optischen Zeichen?

OA18. Was ist negativ an diesem optischen Zeichen?

Noch einmal zu den akustischen Signalen.

OA19. Ist der Tusch geeignet, um die Bedeutung "automatischer Überholassistent aktiviert!" auszudrücken?

nicht geeignet	wenig geeignet	mittelmäßig geeignet	ziemlich geeignet	sehr geeignet
❍	❍	❍	❍	❍

OA20. Wirkt der Tusch auf Sie ansprechend?

nicht ansprechend	wenig ansprechend	mittelmäßig ansprechend	Ziemlich ansprechend	sehr ansprechend
❍	❍	❍	❍	❍

OA21. Was ist positiv am Tusch?

OA22. Was ist negativ am Tusch?

OA23. Ist die tiefer werdende Tonfolge geeignet, um die Bedeutung "automatischer Überholassistent schaltet ab! Bitte übernehmen Sie wieder das Fahrzeug!" auszudrücken?

nicht geeignet	wenig geeignet	mittelmäßig geeignet	ziemlich geeignet	sehr geeignet
❍	❍	❍	❍	❍

OA24. Wirkt die Tonfolge auf Sie ansprechend?

nicht ansprechend	wenig ansprechend	mittelmäßig ansprechend	ziemlich ansprechend	sehr ansprechend
❍	❍	❍	❍	❍

Was ist positiv an der Tonfolge?

Was ist negativ an der Tonfolge?

E - Fragen zur Kommunikation mit dem System im Fahrzeug

Nun haben wir ein paar Fragen zum Kommunikationsverhalten des Systems an Sie.

Wie beurteilen Sie das Kommunikationsverhalten des Systems?

Mit Kommunikationsverhalten ist der Prozess der Übermittlung von Bedeutungen oder Sinngehalten durch das System in Form von Sprache, bildlichen Darstellungen, optischen und akustischen Signalen gemeint.

		links trifft zu.........................						...rechts trifft zu	
		3	2	1	0	1	2	3	
E1.1	zu kurz	❍	❍	❍	❍	❍	❍	❍	zu ausführlich
E1.2	vertrauenswürdig	❍	❍	❍	❍	❍	❍	❍	nicht vertrauenswürdig
E1.3	distanziert	❍	❍	❍	❍	❍	❍	❍	persönlich
E1.4	indirekt	❍	❍	❍	❍	❍	❍	❍	direkt
E1.5	glaubwürdig	❍	❍	❍	❍	❍	❍	❍	unglaubwürdig
E1.6	sympathisch	❍	❍	❍	❍	❍	❍	❍	unsympathisch
E1.7	angenehm	❍	❍	❍	❍	❍	❍	❍	unangenehm
E1.8	anstrengend	❍	❍	❍	❍	❍	❍	❍	entspannend
E1.9	informativ	❍	❍	❍	❍	❍	❍	❍	disinformativ
E1.10	relevant	❍	❍	❍	❍	❍	❍	❍	unrelevant
E1.11	technisch	❍	❍	❍	❍	❍	❍	❍	menschlich

		nicht abgelenkt	eher abgelenkt	überwiegend abgelenkt	abgelenkt	sehr abgelenkt
E1.13	Fühlten Sie sich durch die Kommunikation mit dem System abgelenkt?	❍	❍	❍	❍	❍
		Sprache	eher	weder	eher	Touchscreen

			Sprache	noch	Touchscreen	
E1.14	Welchen Modus der Interaktion würden Sie bevorzugen?	❍	❍	❍	❍	❍
		Command-sprache	eher Command-sprache	Weder noch	eher normale Alltagssprache	normale Alltags-sprache
E1.15	Welche Art des Dialogs würden Sie bevorzugen?	❍	❍	❍	❍	❍

Abschließend möchten wir Sie bitten einzuschätzen wie sich das Zusammenspiel mit dem System für Sie ausgewirkt hat.

		positiv......................................negativ				
E2.1	Durch die Kooperation mit dem System veränderte sich meine Wahrnehmung der Gesamtsituation...	❍	❍	❍	❍	❍
E2.2	Durch die Kooperation mit dem System veränderte sich meine Motivation zur Aufgabenerfüllung…	❍	❍	❍	❍	❍
E2.3	Durch die Kooperation mit dem System veränderte sich meine Entscheidungsfähigkeit im Hinblick auf die Fahranforderungen...	❍	❍	❍	❍	❍
E2.4	Durch die Kooperation mit dem System veränderte sich meine Überwachung und Kontrolle der Fahrsituation…	❍	❍	❍	❍	❍
E2.5	Durch die Kooperation mit dem System veränderten sich meine Möglichkeiten zur Integration von Informationen in die notwendigen Entscheidungsprozesse...	❍	❍	❍	❍	❍
E2.6	Durch die Kooperation mit dem System veränderten sich die Koordination meiner Teilhandlungen...	❍	❍	❍	❍	❍
E2.7	Durch die Kooperation mit dem System veränderte sich die gegenseitige Rückmeldung über Ergebnisse von Handlungen...	❍	❍	❍	❍	❍
E2.8	Durch die Kooperation mit dem System veränderte sich die Ausführungsqualität der Aufgabe…	❍	❍	❍	❍	❍

Fragen nur für Teilnehmer der kooperativen Systemvariante

		Nicht relevant………..…………..Relevant				
H1	In welchem Ausmaß bot Ihnen das System <u>relevante</u> Informationen bezüglich seiner Aktivitäten an?	❍	❍	❍	❍	❍
		Nie…………………….……………..Imme r				
H2	In welchem Ausmaß erhielten Sie relevante Informationen vom System rechtzeitig genug, um davon zu profitieren?	❍	❍	❍	❍	❍
		Nie…………………………………...Imme				

		r				
H3	In welchem Ausmaß verstanden Sie die Informationen, die das automatische System Ihnen anbot, sofort bzw. unmittelbar?	❍	❍	❍	❍	❍
		Nie…………………………………...Imme r				
H4	In welchem Ausmaß vollzog das automatische System die von Ihnen gewünschten Aktivitäten (z.B. Fragen beantworten)?	❍	❍	❍	❍	❍
		Nie…………………………………...Imme r				
H5	In welchem Ausmaß vollzog das automatische System die Aktivitäten, die Sie erwarteten?	❍	❍	❍	❍	❍
		Sehr schlecht………..……..…...Sehr gut				
H6	Wie würden Sie die Kooperation zwischen Ihnen und dem System insgesamt charakterisieren?	❍	❍	❍	❍	❍

!! Vielen Dank für ihre Mitarbeit !!

2. Psychological construct assignment within the first questionnaire

Construct	Questions in for Experiment	Item in SPSS
Affective attitude	Mit diesem System würde ich mich wohl fühlen.	Akp2
Affective attitude	Ich bin von diesem System begeistert.	Akp5
Affective attitude	Dieses System gefällt mir überhaupt nicht.	Akp9
Affective attitude	Das System sagt mir spontan zu.	Akp11
Affective attitude	Das System ist hilfreich.	Trs12
Acceptance	Das System empfinde ich als angenehm.	Trs10
Acceptance	Wenn ich das System im Auto hätte, würde ich es regelmäßig nutzen.	Trs13
Cognitive attitude	Dieses System finde ich sinnvoll.	Akp1
Cognitive attitude	Ich finde, das System ist sehr nützlich.	Akp4
Cognitive attitude	Ich denke, dieses System ist unsicher.	Akp7
Cognitive attitude	Dieses System ist eine wertvolle Unterstützung.	Akp10
Cognitive attitude	Die Nutzung dieses Systems empfinde ich als sicher.	Trs2
Cognitive attitude	Das System arbeitet effektiv.	Trs11
Personal norm	Dieses System ist nichts für mich.	Akp3
Personal norm	Diese Technik zu besitzen, ist für mich ein absolutes Muss.	Akp6
Personal norm	Das System passt zu mir.	Akp7
Risk awareness	Die Nutzung dieses Systems fördert die Verkehrssicherheit.	Trs1
Risk awareness	Die Nutzung des Systems ist zu risikoreich.	Trs8
Trust	Dieses System ist vertrauenswürdig.	Trs3
Trust	Dieses System wird mich nicht enttäuschen.	Trs4
Trust	Dieses System wirkt glaubwürdig.	Trs5
Trust	Dieses System wirkt verlässlich.	Trs6
Trust	Ich vertraue darauf, dass dieses System in meinem Interesse handelt.	Trs7
Trust	Das System möchte das Beste für mich.	Trs9

Appendix IX: Results of experiment 1

1. Auxiliary equipment in the automobile of the participants

Table A IX - 1: Results of the auxiliary equipment in the automobile of the participants in percent

	Non existent	existent
Navigation system	88.4	11.6
Cruise control	79.5	20.5
Multifunctional steering wheel	84.8	15.2
Adaptive criuse control (ACC)	76.8	23.2
Parking assistant	94.6	5.4
Phone	81.3	18.8
Car radio	1.8	98.2
CD-Changer	33.0	65.0
Air condition	45.5	54.5
On-board computer	75.0	25.0
Electronic stabilization program (ESP)	76.8	23.2
Automatic	91.9	8.1
Anti-lock brake system	31.3	68.8
Speech control	98.2	0.8

2. Results of the control variables

Results for the control belief and technology

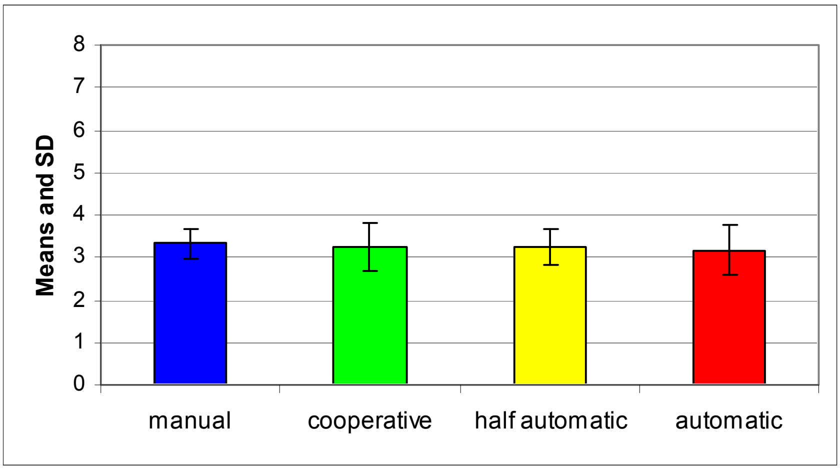


Figure A IX - 1: Means and standard deviation of the KUT index for each condition taken in the pre-questioning.

Table A IX - 2: Baseline measurement results for the psychopsychological data for each condition

	Manual	Cooperative	Half automatic	Automatic
Heart rate	75.46	74.58	74.79	75.21
SKT	0.11	0.1	0.09	0.1

Manipulation check for hypotheses 1a and b:

Effects of personality characteristics (i.e. KUT, TO-value of the BIP, age) as control variables on the most important psychophysiological parameters as well as observable performance data can be ruled out for all four test conditions.

The personality characteristic KUT[42] shows no influence on the psychophysiological parameter neither for the manual, cooperative and half automatic nor for the automatic condition (see table 6). However, there is a significant influence on the SKT in three out of four trials of the cooperative variant (*F* = 4.550; *df* = 3; *p* = 0.010 and *F* = 2.976; *df* = 3; *p* = 0.049).

Table A IX - 3: ANOVA significance results for the psychopsychological data for each condition and trial (M=manual; C=cooperative; HA=half automatic; A=automatic) (level of significance: ** = $p \leq 0.01$; * = $p \leq 0.05$).

		Heart rate Trial 1 (td+/v+)	Heart rate Trial 2 (td-/v-)	Heart rate Trial 3 (td+/v-)	Heart rate Trial 4 (td-/v+)	SKT Trial 1 (td+/v+)	SKT Trial 2 (td-/v-)	SKT Trial 3 (td+/v-)	SKT Trial 4 (td-/v+)
KUT	M	0,538	0,812	0,778	0,702	0,738	0,640	0,155	0,966
	C	0,524	0,632	0,704	0,606	0.010**	0,177	0.049*	0.010**
	HA	0,055	0,209	0,229	0,262	0,741	0,334	0,167	0,112
	A	0,899	0,948	0,918	0,919	0,790	0,823	0,666	0,387
TO-value	M	0,584	0,981	0,571	0,712	0,237	0,814	0,642	0,829
	C	0,451	0,728	0,703	0,575	0,378	0,962	0,267	0,598
	HA	0,936	0,695	0,868	0,851	0,158	0,603	0,548	0,512
	A	0,298	0,380	0,423	0,568	0,198	0,965	0,831	0,838
Age	M	0,813	0,742	0,768	0,783	0,820	0,963	0,916	0,939
	C	0,479	0,219	0,271	0,177	0,481	0,979	0,892	0,853
	HA	0.010**	0.025*	0.021*	0.007**	0,073	0,933	0,663	0,954
	A	0,348	0,364	0,235	0,218	0,589	0,147	0,468	0,132

[42] Attempts to norm the KUT have been proven to be little successful. It became obvious that for experiments on human-technology-interaction the setting applies a considerable influence on the distribution of the test values. For this reason, the KUT values here were categorized into 4 levels for further calculations. As the BIP with its scale for team orientation is only normed for different use cases like the present experiment here also a 4 level categorization for further calculations was applied.

For the driving performance data no influences from the control belief for the manual, cooperative and automatic variant were observed whereas for the automatic condition this aspect is equally presented for all three attributes and justified in the programming. Only for the half automatic variant this was noticed for the *speed* in trial 4 on the third mistake level (F = 4.139; df = 3; p = 0.017) as well as for the parameter *longitudinal distance too small for difference speed* in trial 1 episode 2 (F = 3.338; df = 3; p = 0.036) and for the parameter *unintended lane leaving* in trial 1 episode 1 (F = 4.381; df = 3; p = 0.014) and 3 (F = 3.350; df = 3; p = 0.036) as shown in table 7.

Table A IX - 4: ANOVA significance results for the driving parameter unintended lane leaving for each condition and trial on all three mistake episode levels

		LL E1 Trial 1 (td+/v+)	LL E2 Trial 1	LL E3 Trial 1	LL E1 Trial 2 (td-/v-)	LL E2 Trial 2	LL E3 Trial 2	LL E1 Trial 3 (td+/v-)	LL E2 Trial 3	LL E3 Trial 3	LL E1 Trial 4 (td-/v+)	LL E2 Trial 4	LL E3 Trial 4
KUT	M	0,472	0,524	0,567	0,632	0,524	0,608	0,581	0,524	0,768	0,879	0,459	0,923
	C	0,980	0,977	0,969	0,969	0,979	0,765	0,978	0,969	0,910	0,993	------	------
	HA	0.014*	0,148	0.036*	0,087	0,062	0,189	0,994	0,727	0,090	0,413	0,388	0,835
	A	------	------	------	------	------	------	------	------	------	------	------	------
TO-value	M	0,316	0,543	0,125	0,268	0,543	0,125	0,160	0,543	0,268	0,672	0,421	0,447
	C	0,383	0,245	0,280	0,224	0,292	------	0,369	0,239	0,280	0,315	0,243	------
	HA	0,730	0,629	0,949	0,765	0,892	0,645	0,699	0,527	0,620	0,408	0,498	0,795
	A	------	------	------	------	------	------	------	------	------	------	------	------
Age	M	0,202	0,337	0,470	0,240	0,337	0,477	0,227	0,337	0,078	0,339	0,059	0,146
	C	0,222	0,343	0,473	0,664	0,512		0,268	0,504	0,473	0,452	0,618	------
	HA	0,839	0,963	0,444	0.044*	0,091	0,593	0,280	0,189	0,410	0,566	0,275	0,828
	A	------	------	------	------	------	------	------	------	------	------	------	------

(M=manual; C=cooperative; HA=half automatic; A=automatic) (level of significance: ** = $p \leq 0.01$; * = $p \leq 0.05$).

The TO-value as a measure for the team orientation of the subjects shows for all four conditions no influence neither on the psychophysiological parameters nor on the driving performance data.

The age shows no influence on the psychophysiological parameters of the manual, cooperative and automatic test conditions. On the other hand there is a significant influence of the age on the subjects of the half automatic variant in the first three trials (F = 4.758; df = 3; p = 0.010 and F = 3.735; df = 3; p = 0.025 and F = 3.927; df = 3; p = 0.021) which becomes highly significant in trial 4 with low traffic density and good visibility (F = 5.046; df = 3; p = 0.007).

The age shows in most cases of all conditions no influence on the driving performance data. Exceptions here are only the half automatic variant for the parameter *unintended lane leaving* on mistake level 2 in trial 2 (F = 3.141; df = 3; p = 0.044) and for the manual condition and the parameters *longitudinal distance too small in relation to own speed* in the third trial on mistake level 2 (F = 3.123; df = 3; p = 0.046) and the *longitudinal distance too small for difference speed*, also in the third trial on mistake level 2 (F = 3.122; df = 3; p = 0.046), as well as for the *speeding* in trial 1 on the highest mistake level (F = 3.026; df = 3; p = 0.050).

Table A IX - 5: ANOVA significance results for the driving parameter exceeding the compulsory speed limit for each condition and trial on all three mistake episode levels (M=manual; C=cooperative; HA=half automatic; A=automatic) (level of significance: ** = p≤0.01; * = p≤0.05)

		Speed E1 Trial 1 (td+/v+)	Speed E2 Trial 1	Speed E3 Trial 1	Speed E1 Trial 2 (td-/v-)	Speed E2 Trial 2	Speed E3 Trial 2	Speed E1 Trial 3 (td+/v-)	Speed E2 Trial 3	Speed E3 Trial 3	Speed E1 Trial 4 (td-/v+)	Speed E2 Trial 4	Speed E3 Trial 4
KUT	M	0.296	0.299	0.546	0.333	0.442	0.443	0.297	0.529	0.443	0.298	0.185	0.422
	C	0.694	0.804	0.665	0.730	0.596	0.857	0.734	0.788	0.665	0.694	0.788	0.665
	HA	0.630	0.530	0.178	0.436	0.478	0.062	0.447	0.333	0.336	0.415	0.189	0.017*
	A	------	------	------	------	------	------	------	------	------	------	------	------
TO-value	M	0.240	0.239	0.127	0.179	0.173	0.160	0.202	0.039	0.160	0.252	0.192	0.213
	C	0.285	0.273	0.311	0.264	0.375	0.380	0.279	0.280	0.311	0.285	0.280	0.311
	HA	0.637	0.554	0.802	0.708	0.528	0.901	0.709	0.742	0.410	0.641	0.684	0.885
	A	------	------	------	------	------	------	------	------	------	------	------	------
Age	M	0.163	0.298	0.050*	0.173	0.146	0.081	0.121	0.091	0.081	0.181	0.208	0.085
	C	0.524	0.460	0.406	0.497	0.455	0.318	0.563	0.513	0.406	0.524	0.513	0.406
	HA	0.332	0.344	0.866	0.499	0.330	0.624	0.520	0.634	0.392	0.348	0.455	0.765
	A	------	------	------	------	------	------	------	------	------	------	------	------

Table A IX - 6: ANOVA significance results for the driving parameter distance to small in relation to own speed for each condition and trial on all three mistake episode levels (M=manual; C=cooperative; HA=half automatic; A=automatic) (level of significance: ** = *p*≤0.01; * = *p*≤0.05)

		LongDist1 E1 Trial 1 (td+/v+)	LongDist1 E2 Trial 1	LongDist1 E3 Trial 1	LongDist1 E1 Trial 2 (td-/v-)	LongDist1 E2 Trial 2	LongDist1 E3 Trial 2	LongDist1 E1 Trial 3 (td+/v-)	LongDist1 E2 Trial 3	LongDist1 E3 Trial 3	LongDist1 E1 Trial 4 (td-/v+)	LongDist1 E2 Trial 4	LongDist1 E3 Trial 4
KUT	M	0.701	0.688	0.699	0.555	0.739	0.918	0.508	0.479	0.749	0.427	0.375	0.589
	C	0.853	0.665	------	0.612	0.992	------	0.535	0.424	------	0.875	0.934	0.951
	HA	0.264	0.329	0.261	0.410	0.120	0.049*	0.249	0.169	0.116	0.369	0.109	0.155
	A	------	------	------	------	------	------	------	------	------	------	------	------
TO_value	M	0.065	0.217	0.076	0.102	0.212	0.181	0.101	0.445	0.089	0.075	0.065	0.379
	C	0.212	0.311		0.222	0.196		0.319	0.390	------	0.322	0.282	0.348
	HA	0.905	0.549	0.342	0.529	0.962	0.916	0.978	0.917	0.553	0.480	0.719	0.989
	A	------	------	------	------	------	------	------	------	------	------	------	------
Age	M	0.075	0.097	0.695	0.053	0.220	0.136	0.046*	0.211	0.524	0.100	0.139	0.423
	C	0.580	0.406	------	0.601	0.500	------	0.566	0.323	------	0.520	0.352	0.361
	HA	0.368	0.298	0.263	0.293	0.642	0.748	0.741	0.709	0.339	0.310	0.479	0.777
	A	------	------	------	------	------	------	------	------	------	------	------	------

Table A IX - 7: ANOVA significance results for the driving parameter longitudinal distance to small for difference speed for each condition and trial on all three mistake episode levels (M=manual; C=cooperative; HA=half automatic; A=automatic) (level of significance: ** = *p*≤0.01; * = *p*≤0.05)

		LongDist2 E1 Trial 1 (td+/v+)	LongDist2 E2 Trial 1	LongDist2 E3 Trial 1	LongDist2 E1 Trial 2 (td-/v-)	LongDist2 E2 Trial 2	LongDist2 E3 Trial 2	LongDist2 E1 Trial 3 (td+/v-)	LongDist2 E2 Trial 3	LongDist2 E3 Trial 3	LongDist2 E1 Trial 4 (td-/v+)	LongDist2 E2 Trial 4	LongDist2 E3 Trial 4
KUT	M	0.388	0.450	0.699	0.745	0.595	0.918	0.545	0.543	0.908	0.401	0.267	0.941
	C	0.418	0.992	------	0.612	0.996	------	0.700	0.665	------	0.693	0.992	------
	HA	0.067	0.036*	0.013	0.205	0.228	0.281	0.238	0.621	0.248	0.345	0.801	0.053
	A	------	------	------	------	------	------	------	------	------	------	------	------
TO-value	M	0.220	0.833	0.076	0.151	0.380	0.181	0.123	0.196	0.127	0.181	0.360	0.396
	C	0.382	0.196	------	0.222	0.227	------	0.260	0.311	------	0.266	0.177	------
	HA	0.722	0.751	0.940	0.628	0.811	0.960	0.739	0.682	0.931	0.493	0.500	0.475
	A	------	------	------	------	------	------	------	------	------	------	------	------
Age	M	0.080	0.629	0.695	0.080	0.296	0.136	0.059	0.046*	0.174	0.059	0.145	0.152
	C	0.356	0.500	------	0.601	0.488	------	0.504	0.406	------	0.452	0.410	------
	HA	0.627	0.506	0.564	0.951	0.896	0.932	0.855	0.969	0.718	0.285	0.270	0.903
	A	------	------	------	------	------	------	------	------	------	------	------	------

Table A IX - 8: ANOVA significance results for the driving parameter unsafe lane keeping for each condition and trial on all three mistake episode levels (M=manual; C=cooperative; HA=half automatic; A=automatic) (level of significance: ** = *p*≤0.01; * = *p*≤0.05)

		UnsafeLK E1 Trial 1 (td+/v+)	UnsafeLK E2 Trial 1	UnsafeLK E3 Trial 1	UnsafeLK E1 Trial 2 (td-/v-)	UnsafeLK E2 Trial 2	UnsafeLK E3 Trial 2	UnsafeLK E1 Trial 3 (td+/v-)	UnsafeLK E2 Trial 3	UnsafeLK E3 Trial 3	UnsafeLK E1 Trial 4 (td-/v+)	UnsafeLK E2 Trial 4	UnsafeLK E3 Trial 4
KUT	M	0.337	0.635	0.908	0.473	0.654	0.853	0.308	0.335	0.828	0.482	0.793	0.997
	C	0.441	0.484	0.969	0.612	0.993	------	0.417	0.969	0.969	0.896	0.951	------
	HA	0.281	0.168	0.051	0.410	0.251	0.024	0.653	0.172	0.041	0.881	0.432	0.181
	A	------	------	------	------	------	------	------	------	------	------	------	------
TO-value	M	0.251	0.120	0.127	0.185	0.129	0.396	0.400	0.352	0.153	0.128	0.430	0.467
	C	0.382	0.217	0.280	0.222	0.243	------	0.387	0.284	0.280	0.329	0.231	------
	HA	0.797	0.973	0.374	0.989	0.779	0.715	0.868	0.449	0.918	0.521	0.631	0.056
	A	------	------	------	------	------	------	------	------	------	------	------	------
Age	M	0.212	0.143	0.174	0.150	0.056	0.074	0.349	0.215	0.159	0.119	0.472	0.220
	C	0.404	0.491	0.473	0.601	0.618	------	0.270	0.322	0.473	0.414	0.314	------
	HA	0.978	0.758	0.826	0.782	0.566	0.604	0.921	0.389	0.559	0.211	0.451	0.455
	A	------	------	------	------	------	------	------	------	------	------	------	------

Manipulation check for hypothesis 2:

Effects of personality characteristics (i.e. KUT, TO-value of the BIP, age) on the most important subjective that is behavioral data can be ruled out for all four test conditions.

The personality characteristic KUT shows for all four conditions no influence on the inquired subjective and behavior data.

Also the TO-value as a measure for the team orientation of the subjects shows for all four conditions no influence on the subjective parameter (see table A IX – 9).

Table A IX - 9: ANOVA significance results for the subjective data indices for each condition (M=manual; C=cooperative; HA=half automatic; A=automatic) (level of significance: ** = p≤0.01; * = p≤0.05).

		Index acceptance	Index trust	Index risk awareness	Index personal norm	Index interaction quality	Index cognitive attitude	Index affective attitude
KUT	M	0,841	0,874	0,223	0,796	Data not collected	0,479	0,911
	C	0,487	0,955	0,254	0,529	0,975	0,797	0,716
	HA	0,207	0,633	0,587	0,319	0,405	0,345	0,329
	A	0,940	0,492	0,714	0,905	0,438	0,812	0,824
TO-value	M	0,136	0,219	0,594	0,338	Data not collected	0,638	0,204
	C	0,605	0,615	0,433	0,935	0,445	0,438	0,809
	HA	0,198	0,905	0,062	0,213	0,280	0,280	0,547
	A	0,111	0,123	0,193	0,319	0,404	0,104	0,091
Age	M	0,472	0,253	0,019*	0,765	Data not collected	0,583	0,790
	C	0,089	0,158	0,360	0,191	0,766	0,381	0,058
	HA	0,273	0,403	0,452	0,604	0,160	0,756	0,726
	A	0,903	0,879	0,589	0,872	0,505	0,886	0,885

The age also shows no significant influence on the subjective data with one exception. Only for the manual variant a significant connection (F = 3.919; df = 3; p = 0.019) was noticed between the age and the index of the risk awareness.

3. Results of the hypothesis 1

Results of hypothesis 1a:

Psychophysiological parameters

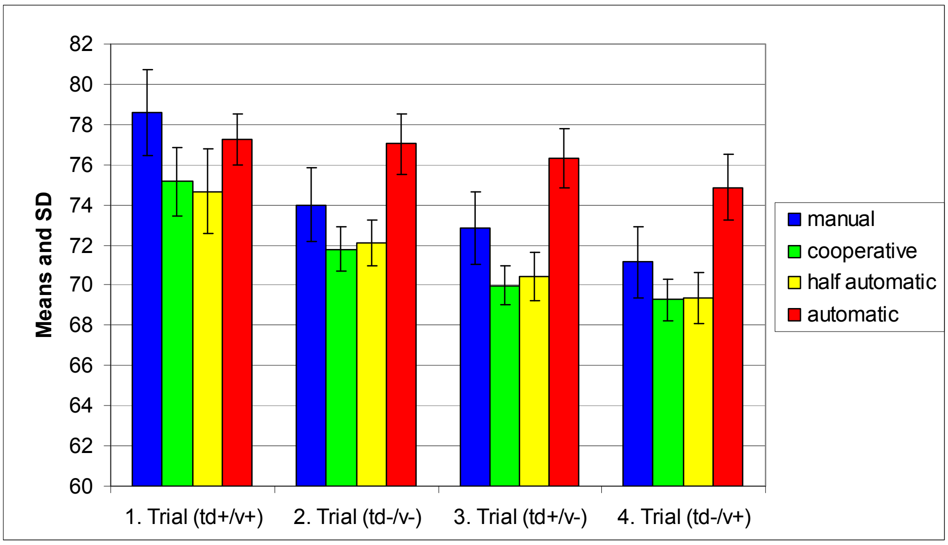


Figure A IX - 2: Means and standard deviation of the heart rate for all subjects of each condition and each trial (traffic density high/low (td+/td-) and visibility more than 450 meters/lower than 250 meters (v+/v-)).

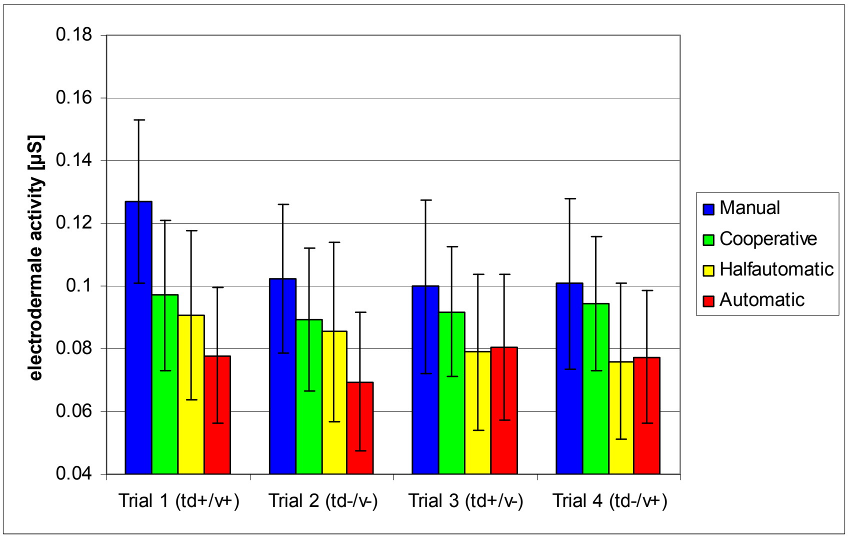


Figure A IX - 3: Means and standard deviation of the skin conductivity for each trial (traffic density high/low (td+/td-) and visibility more than 450 meters/lower than 250 meters (v+/v-)).

Driving parameters

Small longitudinal distance in relation to difference speed (Time to collision)

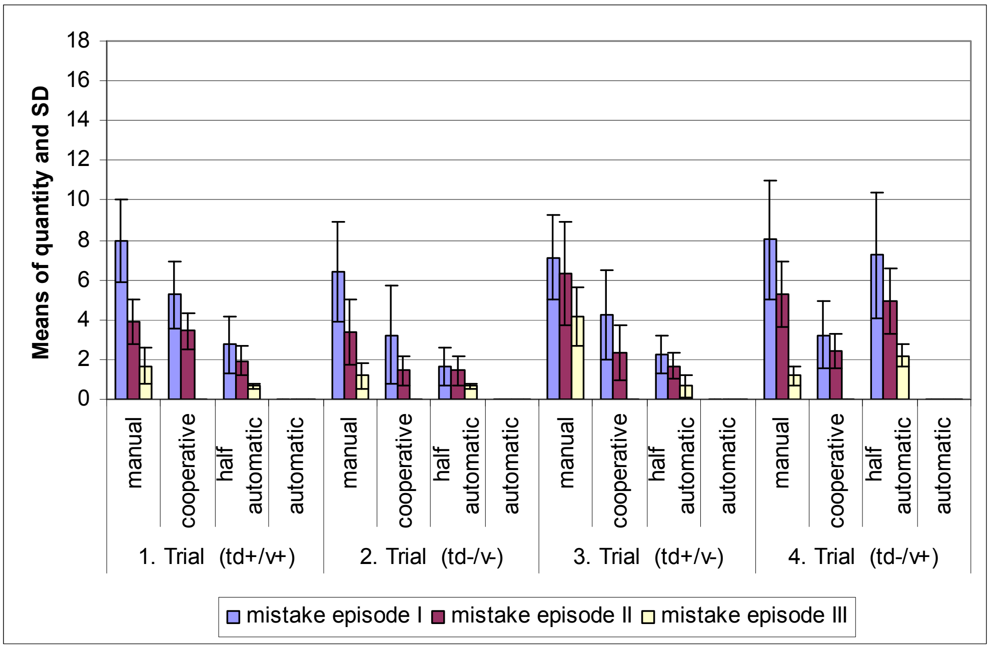


Figure A IX - 4: Means of quantity and standard deviation of mistake episode 1-3 of the driving parameter longitudinal distance to small for difference speed per trial and condition (Time to Collision, TTC) (traffic density high/low (td+/td-) and visibility more than 450 meters/lower than 250 meters (v+/v-)).

Table A IX - 10: Means and ANOVA significance results for the comparison of the manual condition with the two other conditions relating the driving parameter longitudinal distance to small for difference speed of each trial and all three mistake episode levels (M=manual; C=cooperative; HA=half automatic) (level of significance: ** = p≤0.01; * = p≤0.05)

	Mean M/C ; p-value M/C	Mean M/HA ; p-value M/HA
LongDist2 E1 Trial 1 (td+/v+)	8.03/5.58 ; <0.001**	8.03/3.86 ; <0.001**
LongDist2 E2 Trial 1	3.89/3.52 ; 0.811	3.89/3.45 ; 0.999
LongDist2 E3 Trial 1	1.70/0.00 ; <0.001**	1.70/1.43 ; 0.979
LongDist2 E1 Trial 2 (td-/v-)	6.31/3.55 ; <0.001**	6.31/1.54 ; <0.001**
LongDist2 E2 Trial 2	3.23/1.48 ; <0.001**	3.23/1.04 ; <0.001**
LongDist2 E3 Trial 2	1.15/0.00 ; <0.001**	1.15/0.57 ; 0.024*
LongDist2 E1 Trial 3 (td+/v-)	7.07/4.46 ; <0.001**	7.07/1.23 ; <0.001**
LongDist2 E2 Trial 3	6.22/2.27 ; <0.001**	6.22/1.07 ; <0.001**
LongDist2 E3 Trial 3	4.19/0.00 ; <0.001**	4.19/0.68 ; <0.001**
LongDist2 E1 Trial 4 (td-/v+)	8.04/3.45 ; <0.001**	8.04/8.36 ; <1.000
LongDist2 E2 Trial 4	5.26/2.53 ; <0.001**	5.26/4.29 ; 0.480
LongDist2 E3 Trial 4	1.18/0.00 ; <0.001**	1.18/2.43 ; <0.001**

Unsafe lane keeping

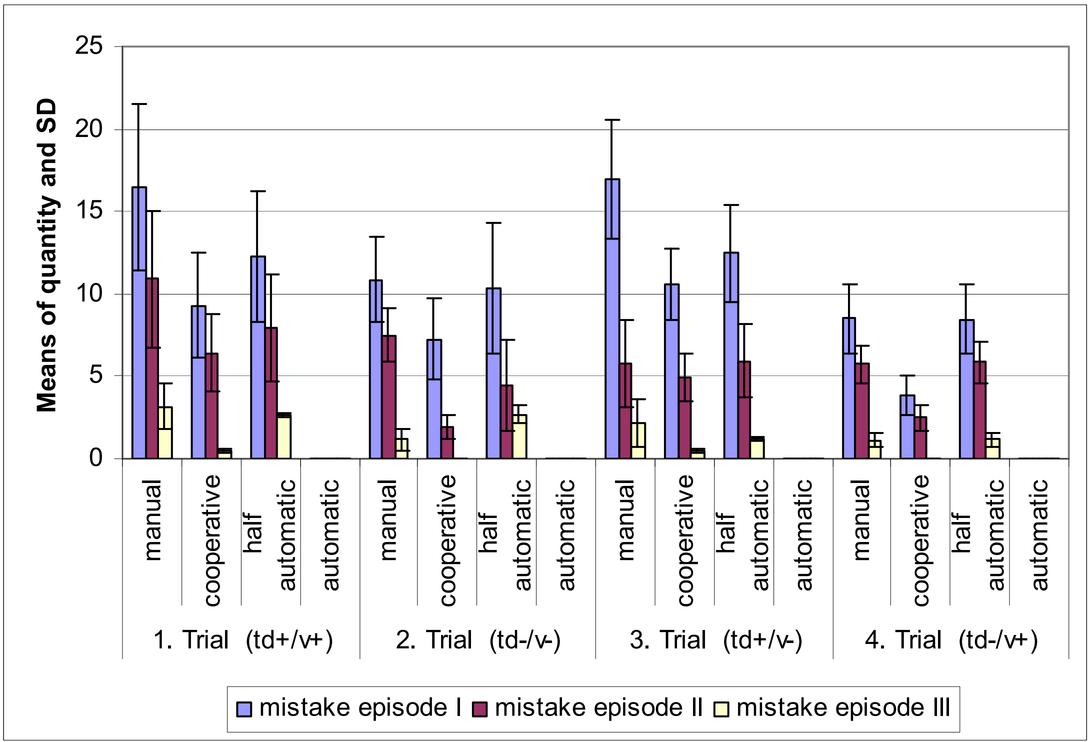


Figure A IX - 5: Means of quantity and standard deviation of mistake episode 1-3 of the driving parameter unsafe lane keeping per trial and condition (traffic density high/low (td+/td-) and visibility more than 450 meters/lower than 250 meters (v+/v-)).

Table A IX - 11: Means and ANOVA significance results for the comparison of the manual condition with the two other conditions relating the driving parameter unsafe lane keeping of each trial and all three mistake episode levels (M=manual; C=cooperative; HA=half automatic) (level of significance: ** = *p*≤0.01; * = *p*≤0.05)

	Mean M/C ; p-value M/C	Mean M/HA ; p-value M/HA
UnsafeLK E1 Trial 1 (td+/v+)	16.44/9.58 ; <0.001**	16.44/11.18 ; <0.001**
UnsafeLK E2 Trial 1	10.89/6.65 ; <0.001**	10.89/7.46 ; <0.001**
UnsafeLK E3 Trial 1	3.19/0.61 ; <0.001**	3.19/2.64 ; 0.492
UnsafeLK E1 Trial 2 (td-/v-)	10.75/7.52 ; <0.001**	10.75/9.39 ; 0.395
UnsafeLK E2 Trial 2	7.41/2.06 ; <0.001**	7.41/5.11 ; <0.001**
UnsafeLK E3 Trial 2	1.19/0.00 ; <0.001**	1.19/2.17 ; <0.001**
UnsafeLK E1 Trial 3 (td+/v-)	17.02/10.81 ; <0.001**	17.02/11.32 ; <0.001**
UnsafeLK E2 Trial 3	5.93/5.13 ; 0.249	5.93/6.89 ; 0.379
UnsafeLK E3 Trial 3	2.22/0.61 ; <0.001**	2.22/1.14 ; 0.001**
UnsafeLK E1 Trial 4 (td-/v+)	8.59/4.03 ; <0.001**	8.59/7.46 ; 0.264
UnsafeLK E2 Trial 4	5.85/2.58 ; <0.001**	5.85/5.32 ; 0.753
UnsafeLK E3 Trial 4	1.26/0.00 ; <0.001**	1.26/1.28 ; 0.995

Unintended lane leaving

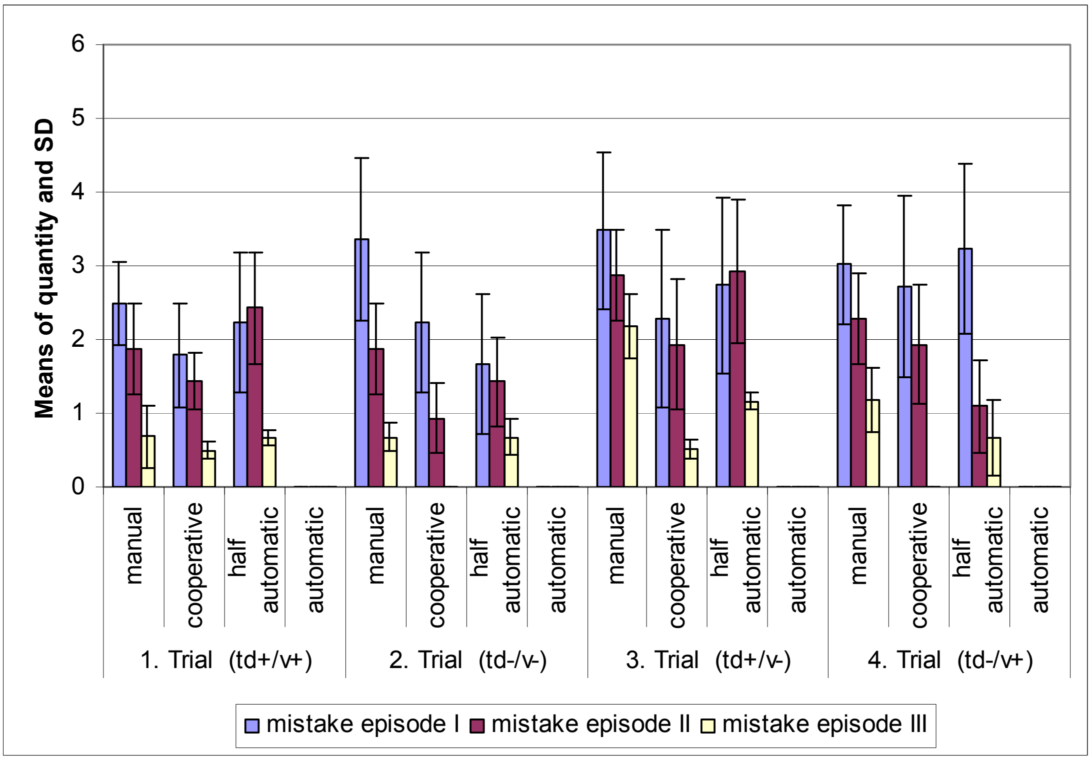


Figure A IX - 6: Means of quantity and standard deviation of mistake episode 1-3 of the driving parameter unintended leaving the lane per trial and condition (traffic density high/low (td+/td-) and visibility more than 450 meters/lower than 250 meters (v+/v-)).

Table A IX - 12: Means and ANOVA significance results for the comparison of the manual condition with the two other conditions relating the driving parameter unintended lane leaving of each trial and all three mistake episode levels (M=manual; C=cooperative; HA=half automatic; A=automatic) (level of significance: ** = *p*≤0.01; * = *p*≤0.05)

	Mean M/C ; p-value M/C	Mean M/HA ; p-value M/HA
LL E1 Trial 1 (td+/v+)	2.44/1.81 ; 0.181	2.44/1.93 ; 0.457
LL E2 Trial 1	1.78/1.42 ; 0.780	1.78/1.39 ; 0.603
LL E3 Trial 1	0.63/0.51 ; <1.000	0.63/0.86 ; 0.950
LL E1 Trial 2 (td-/v-)	3.30/2.39 ; 0.018*	3.30/1.29 ; <0.001**
LL E2 Trial 2	1.49/1.07 ; 0.056	1.49/0.97 ; <0.001**
LL E3 Trial 2	0.81/0.00 ; <0.001**	0.81/0.68 ; <1.000
LL E1 Trial 3 (td+/v-)	3.52/2.28 ; 0.020*	3.52/2.32 ; <0.001**
LL E2 Trial 3	2.76/2.03 ; 0.084	2.76/1.89 ; 0.006*
LL E3 Trial 3	2.26/0.63 ; <0.001**	2.26/1.04 ; <0.001**
LL E1 Trial 4 (td-/v+)	3.07/2.87 ; 0.999	3.07/2.21 ; 0.065
LL E2 Trial 4	2.33/2.06 ; 0.924	2.33/1.29 ; 0.006**
LL E3 Trial 4	1.22/0.00 ; <0.001**	1.22/0.57 . 0.012*

Results of hypothesis 1b:

Table A IX - 13: Means and ANOVA significance results for the comparison of the cooperative system with the half automatic system relating the driving parameter exceeding the compulsory speed limit of each trial and all three mistake episode levels (M=manual; C=cooperative; HA=half automatic) (level of significance: ** = *p*≤0.01; * = *p*≤0.05)

	Mean C/HA ; p-value C/HA
Speed E1 Trial 1 (td+/v+)	17.06/19.82 ; 0.262
Speed E2 Trial 1	16.23/17.54 ; 0.785
Speed E3 Trial 1	3.48/1.86 ; 0.003**
Speed E1 Trial 2 (td-/v-)	15.03/25.32 ; <0.001**
Speed E2 Trial 2	13.14/22.46 ; <0.001**
Speed E3 Trial 2	2.42/5.04 ; 0.006**
Speed E1 Trial 3 (td+/v-)	16.19/17.31 ; 0.852
Speed E2 Trial 3	15.42/18.01 ; 0.209
Speed E3 Trial 3	3.31/6.12 ; 0.084
Speed E1 Trial 4 (td-/v+)	15.06/20.54 ; 0.002**
Speed E2 Trial 4	14.72/20.14 ; <0.001**
Speed E3 Trial 4	3.98/4.21 ; 0.766

Table A IX - 14: Means and ANOVA significance results for the comparison of the cooperative system with the half automatic system relating the driving parameter longitudinal distance to small for difference speed of each trial and all three mistake episode levels (M=manual; C=cooperative; HA=half automatic) (level of significance: ** = *p*≤0.01; * = *p*≤0.05)

	Mean C/HA ; p-value C/HA
LongDist2 E1 Trial 1 (td+/v+)	5.58/3.86 ; 0.055
LongDist2 E2 Trial 1	3.52/3.45 ; <1.000
LongDist2 E3 Trial 1	0.00/1.43 ; <0.001**
LongDist2 E1 Trial 2 (td-/v-)	3.55/1.54 ; <0.001**
LongDist2 E2 Trial 2	1.48/1.04 ; 0.473
LongDist2 E3 Trial 2	0.00/0.57 ; <0.001**
LongDist2 E1 Trial 3 (td+/v-)	4.46/1.23 ; <0.001**
LongDist2 E2 Trial 3	4.46/1.07 ; <0.001**
LongDist2 E3 Trial 3	0.00/0.68 ; <0.001**
LongDist2 E1 Trial 4 (td-/v+)	3.45/8.36 ; <0.001**
LongDist2 E2 Trial 4	2.53/4.29 ; <0.007**
LongDist2 E3 Trial 4	0.00/2.43 ; <0.001**

Table A IX - 15: Means and ANOVA significance results for the comparison of the cooperative system with the half automatic system relating the driving parameter unsafe lane keeping of each trial and all three mistake episode levels (M=manual; C=cooperative; HA=half automatic) (level of significance: ** = *p*≤0.01; * = *p*≤0.05)

	Mean C/HA ; p-value C/HA
UnsafeLK E1 Trial 1 (td+/v+)	9.58/11.18 ; 0.156
UnsafeLK E2 Trial 1	6.65/7.46 ; 0.654
UnsafeLK E3 Trial 1	0.61/2.64 ; <0.001**
UnsafeLK E1 Trial 2 (td-/v-)	7.52/9.39 ; 0.059
UnsafeLK E2 Trial 2	2.06/5.11 ; <0.001**
UnsafeLK E3 Trial 2	0.00/2.17 ; <0.001**
UnsafeLK E1 Trial 3 (td+/v-)	10.81/11.32 ; 0.868
UnsafeLK E2 Trial 3	5.13/6.89 ; 0.010**
UnsafeLK E3 Trial 3	0.61/1.14 ; 0.294
UnsafeLK E1 Trial 4 (td-/v+)	4.03/7.46 ; <0.001**
UnsafeLK E2 Trial 4	2.58/5.32 ; <0.001**
UnsafeLK E3 Trial 4	0.00/1.28 ; <0.001**

Table A IX - 16: Means and ANOVA significance results for the comparison of the cooperative system with the half automatic relating the driving parameter unintended lane leaving of each trial and all three mistake episode levels (M=manual; C=cooperative; HA=half automatic) (level of significance: ** = *p*≤0.01; * = *p*≤0.05)

	Mean C/HA ; p-value C/HA
LL E1 Trial 1 (td+/v+)	1.81/1.93 ; 0.983
LL E2 Trial 1	1.42/1.39 ; <1.000
LL E3 Trial 1	0.51/0.86 ; 0.854
LL E1 Trial 2 (td-/v-)	2.39/1.29 ; 0.004**
LL E2 Trial 2	1.07/0.97 ; 0.999
LL E3 Trial 2	0.00/0.68 ; <0.001**
LL E1 Trial 3 (td+/v-)	2.28/2.32 ; 0.997
LL E2 Trial 3	2.03/1.89 ; 0.967
LL E3 Trial 3	0.63/1.04 ; 0.522
LL E1 Trial 4 (td-/v+)	2.87/2.21 ; 0.301
LL E2 Trial 4	2.06/1.29 ; 0.116
LL E3 Trial 4	0.00/0.57 ; 0.002**

Mirror looks

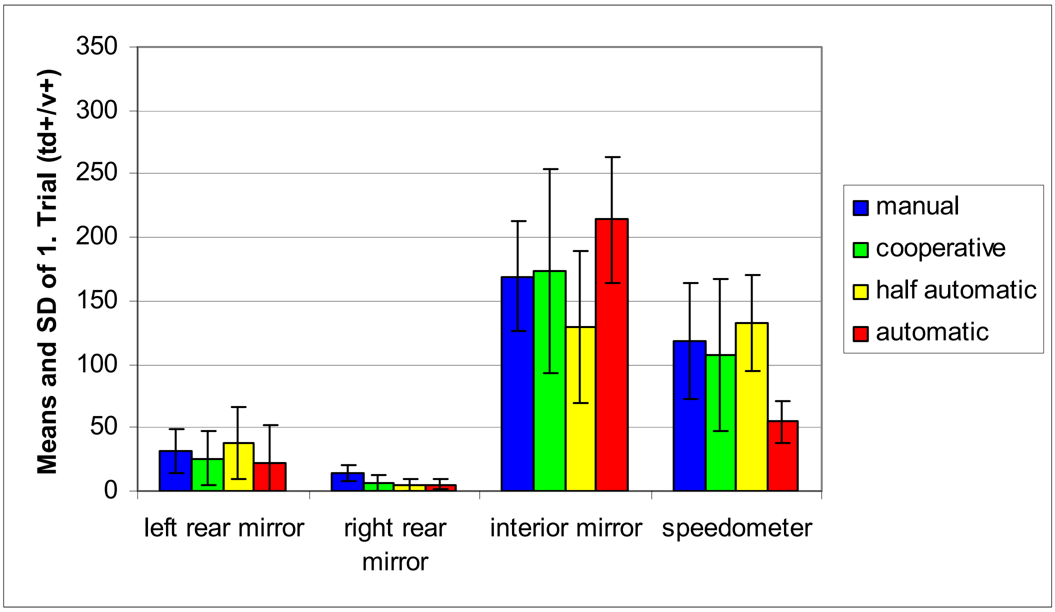


Figure A IX - 7: Means of looks for the three different mirrors and the speedometer during the 1. Trial (high traffic density (td+) and visibility more than 450 meters (v+)).

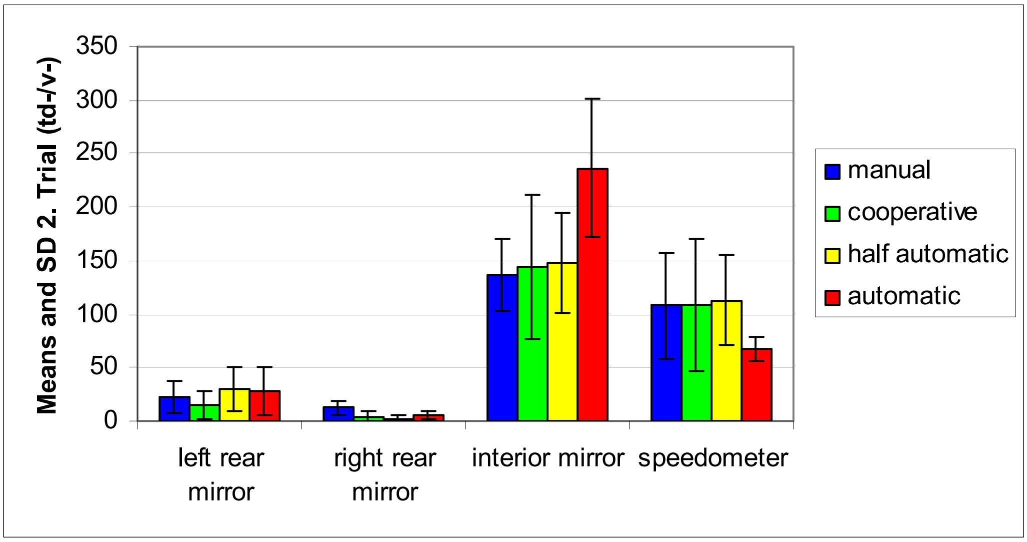


Figure A IX - 8: Means of looks for the three different mirrors and the speedometer during the 2. Trial(low traffic density (td-) and visibility less than 250 meters (v-)).

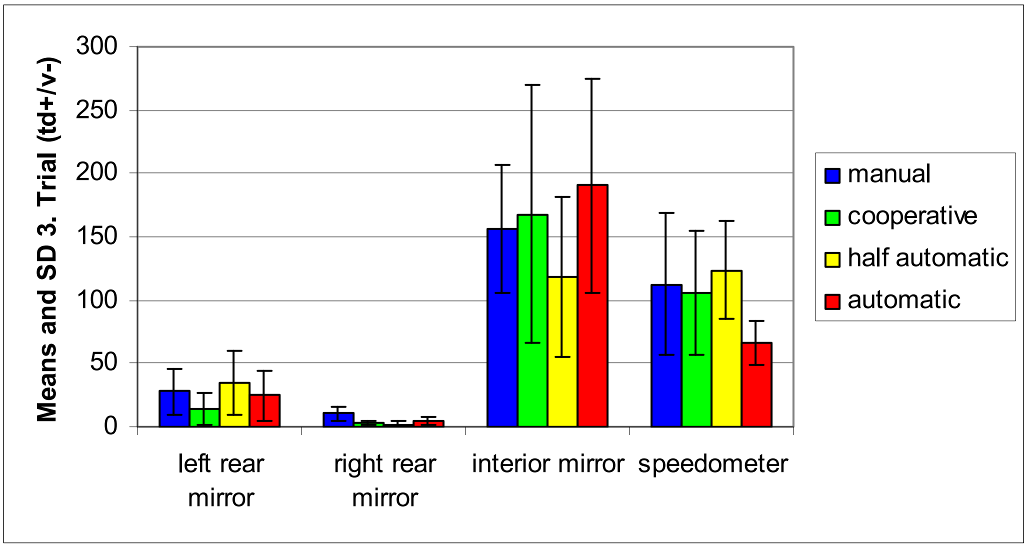


Figure A IX - 9: Means of looks for the three different mirrors and the speedometer during the 3. Trial(high traffic density (td+) and visibility less than 250 meters (v-)).

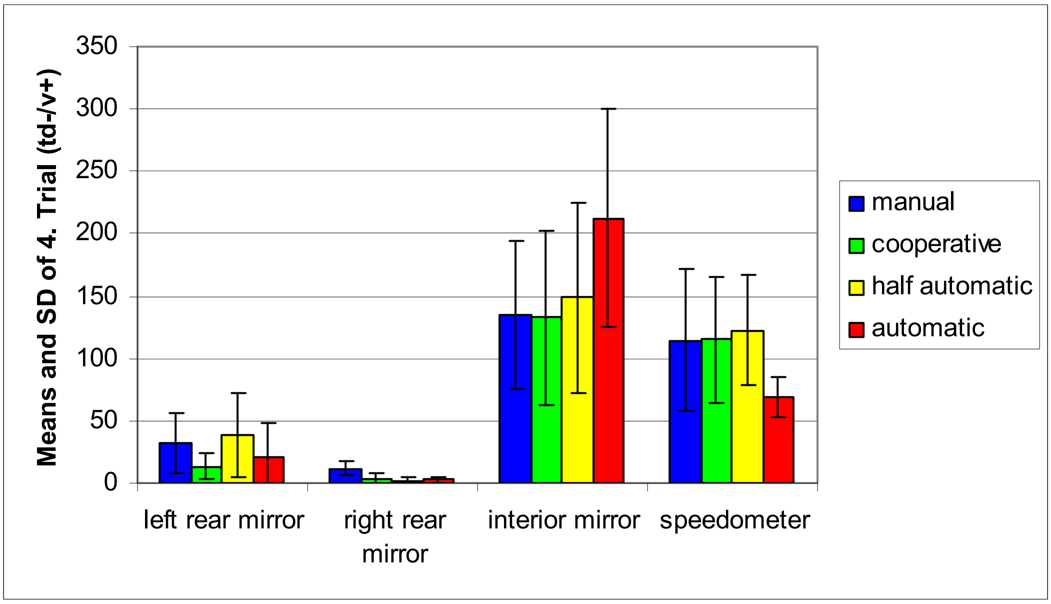


Figure A IX - 10: Means of looks for the three different mirrors and the speedometer during the 4. Trial (low traffic density (td-) and visibility more than 450 meters (v+)).

Results of hypothesis 2:

Structural characteristics

Table A IX - 17: Means and ANOVA significance results for the comparison of the conditions against each other relating the critical incidents over all four trials.

	F	Sig.	t	df	Sig. (2-tailed)	Mean Differer	95% Confidence Interval of the Difference	
							Lower	Upper
Situation awareness	1.4059	0.2408	2.4588	56	0.0171	0.5472	0.1014	0.9930
Motivation for task execution	0.1982	0.6579	2.2140	56	0.0309	0.5293	0.0504	1.0081
Ability for decision making regarding driving tasks	0.2142	0.6453	2.9736	56	0.0043	0.6726	0.2195	1.1258
Surveillance and control of driving situation	7.3104	0.0091	4.5612	56	0.0000	1.2736	0.7142	1.8329
Information integration for decision making	3.0102	0.0882	4.7211	56	0.0000	1.0155	0.5846	1.4464
Coordination of partial actions	0.4803	0.4912	2.8785	56	0.0056	0.5998	0.1824	1.0172
Mutual processing feedback of action results	3.1269	0.0825	1.3238	56	0.1910	0.2521	-0.1294	0.6336
Quality of action execution	0.1735	0.6786	2.9617	56	0.0045	0.8578	0.2776	1.4380

Workload – subjective measures (NASA TLX)

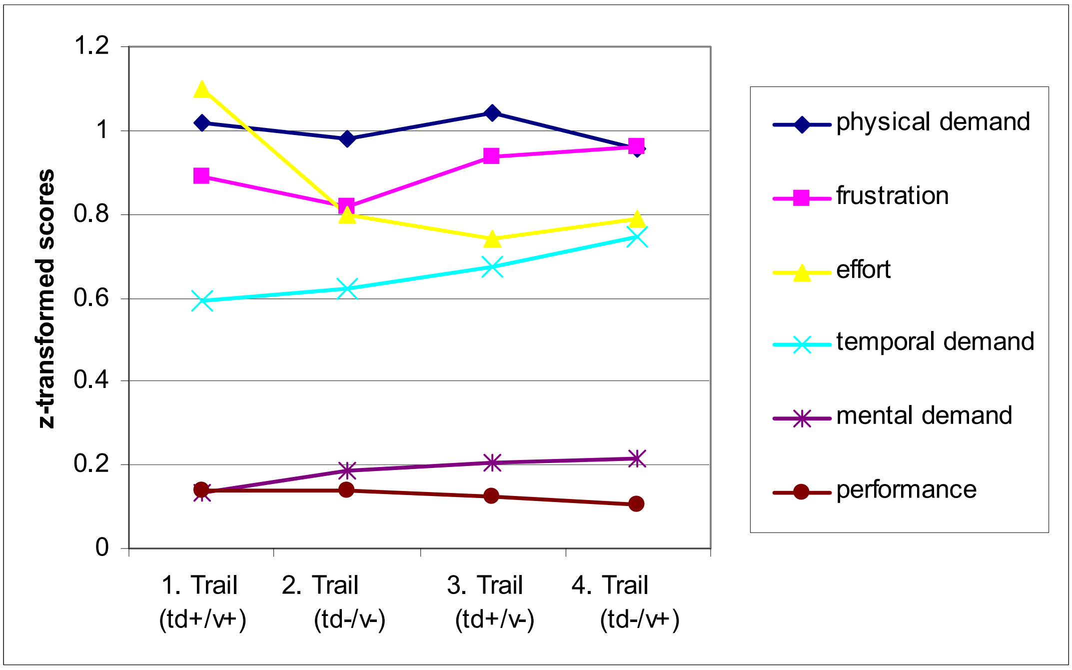


Figure A IX - 11: Item gradient of the NASA TLX for the four measuring times (traffic density high/low (td+/td-) and visibility more than 450 meters/lower than 250 meters (v+/v-)).

Results for the ergonomic design

In this question part the participants were asked to give information about the usability of the system according to DIN EN ISO 9241 part 10 (Timpe et al., 2000). Figure A IX – 11 shows that the three system variants cooperative, half automatic, and automatic are directly comprehensible. Good feedback, however, was given only on the cooperative and half automatic system variants. The transparency of the actions of the two former mentioned system variants were also rated as good while on the contrary for the automatic system variant only as partly good.

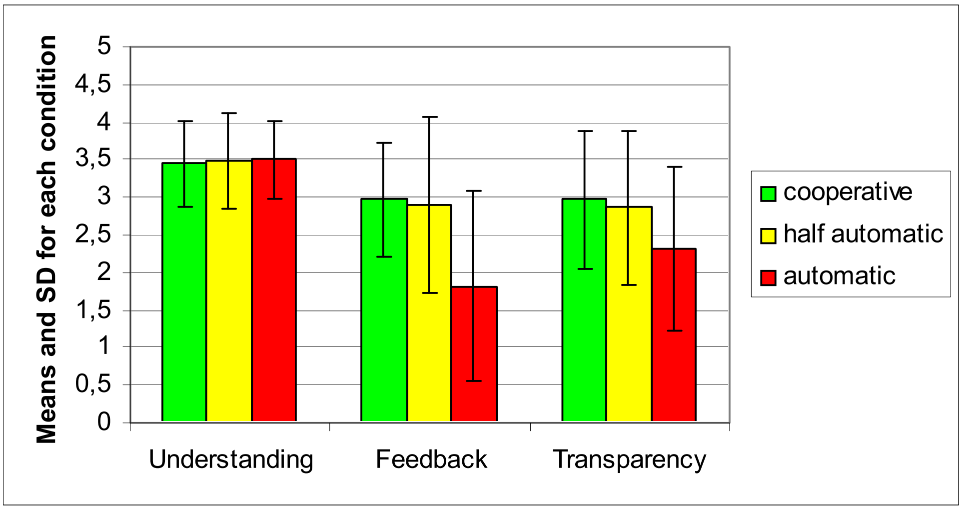


Figure A IX - 12: Means and standard deviation of usability answers after the experiment for each condition.

An exchange between different system variants was requested by 68 percent of all participants from the half automatic and automatic condition, 26 percent requested no exchange and the remaining 6 percent of the interviewees requested no system at all. This allows the argumentation that the systems were well articulated by the participants as they had a clear opinion on this question.

Appendix X: Experimental design of experiment 2

	Trial 1		Trial 2	
	High traffic density		Low traffic density	
All cells Men between 25-40; Average mileage per year 10000-20000 Km	Left turning (inner city): 2 types x 5 (+-crossings and T-crossings)	Left turn (country roads): 2 types x 5 (+-crossings and T-crossings)	Left turning (inner city): 2 types x 5 (+-crossings and T-crossings)	Left turn (country roads): 2 types x 5 (+-crossings and T-crossings)
Condition Manual				
Condition Cooperative				

- Between 12-20 subjects per Condition
- 2 trials a 27 Kilometers
- Duration about 31 Minutes per trail
- Avoidance of sequence effects with mixing of turn taking types

Appendix XI: Questionnaire of experiment 2

Nach der zweiten Fahrt

1) Fragen zum augenblicklichen Zustand

Wir möchten nun gern wieder wissen, wie sich diese Tätigkeit in Ihrem Erleben widerspiegelt. Deshalb bitten wir Sie, Ihren augenblicklichen Zustand, so wie er von Ihnen erlebt wird, zu beschreiben.

Zu Ihrer Unterstützung haben wir eine Liste mit verschiedenen Begriffen (Eigenschaftswörtern) vorbereitet. Diese Begriffe werden mehr oder weniger auf Ihren augenblicklichen Zustand zutreffen. Jedem Begriff ist eine 6-stufige Skala zugeordnet, die Ihnen als „Maßstab“ dienen soll. Wir möchten Sie bitten mit Hilfe dieses Maßstabes, Ihren augenblicklichen Zustand zu beschreiben.

Die 6 Skalenstufen lauten wie folgt:

1 = kaum (so gut wie nicht)

2 = etwas zutreffend

3 = einigermaßen zutreffend

4 = ziemlich zutreffend

5 = überwiegend zutreffend

6 = völlig (so gut wie völlig) zutreffend

Zum Beispiel bei dem Wort „fröhlich“ würden Sie, falls es momentan überwiegend zutrifft, folgendermaßen ankreuzen:

Fröhlich 1 2 3 4 5 6

Je mehr ein Begriff auf Ihren augenblicklichen Zustand zutrifft, desto höher wird die Zahl sein, die Sie ankreuzen (und umgekehrt). Bitte gehen Sie jetzt die Begriffsliste Zeile für Zeile durch, kreuzen Sie jeweils nur eine Zahl an.

Es gibt dabei keine richtigen und falschen Antworten, sondern nur Ihre ganz persönliche Einschätzung, die uns interessiert.

	kaum	etwas	einiger-maßen	ziemlich	überwiegend	völlig
	1	2	3	4	5	6
aufgeschlossen						
teilnahmslos						
abgespannt						
überdrüssig						
leistungsfähig						
anstrengungsbereit						
entspannt						
ausgelaugt						
hellwach						
ruhebedürftig						
energiegeladen						
reaktionsschnell						
angespannt						
ruhig						
gleichgültig						
ausdauernd						
angewidert						
beharrlich						
kraftvoll						
gelangweilt						
nervös						
konzentrationsfähig						
entschlussfreudig						
schläfrig						
kribbelig						
hektisch						
beherrscht						
arbeitsfreudig						
gehetzt						
angestrengt						
munter						
schwungvoll						
ermüdet						
interessiert						
reizbar						
leistungsstark						
müde						
unlustig						

verkrampft						
aufmerksam						
matt						
besonnen						
überreizt						
sicher						
lustlos						
ausgeruht						

2) Fragen zur Simulation

Jetzt haben wir ein paar Fragen an Sie, wie Sie die Simulation erlebt haben.

2.1 Wie haben Sie sich während der Simulation gefühlt?

		Stimmt völlig...Stimmt gar nicht				
1.	Ich fühlte mich normal.	☐	☐	☐	☐	☐
2.	Ich war irritiert.	☐	☐	☐	☐	☐
3.	Mir war schwindelig.	☐	☐	☐	☐	☐
4.	Mir war übel.	☐	☐	☐	☐	☐
5.	Ich fühlte mich nicht gut.	☐	☐	☐	☐	☐
6.	Ich hatte Kopfschmerzen.	☐	☐	☐	☐	☐
7.	Ich hatte Schwierigkeiten Objekte zu fokussieren.	☐	☐	☐	☐	☐
8.	Ich fühlte mich müde.	☐	☐	☐	☐	☐
9.	Meine Augen wurden überanstrengt.	☐	☐	☐	☐	☐
10.	Ich hatte Schwierigkeiten mich zu konzentrieren.	☐	☐	☐	☐	☐
11.	Ich empfand generelles Unbehagen.	☐	☐	☐	☐	☐

2.2 Fühlten Sie sich während der Simulatorfahrt durch irgendetwas abgelenkt?

___

___

___

2.3 Hatten Sie Probleme mit dem System? Wenn ja, welche konkret?

___

___

___

3) Bewertung des Systems

3.1 Nachstehend finden Sie mehrere Adjektivpaare mit gegensätzlicher Bedeutung. Sie werden nun gebeten, das von Ihnen im Simulator erlebte System mit Hilfe dieser Adjektivpaare zu bewerten. Beachten Sie, dass die Wörter eher im übertragenen Sinne, also "gefühlsmäßig" zu verstehen sind. Markieren Sie im Folgenden also jene Position zwischen den Wortpaaren, welche nach Ihrem spontanen Empfinden das System am besten beschreibt. Machen Sie bitte in jeder Zeile ein Kreuz.

Ich finde das System:						
anregend	☐	☐	☐	☐	☐	ermüdend
dynamisch	☐	☐	☐	☐	☐	statisch
müde	☐	☐	☐	☐	☐	frisch
stark	☐	☐	☐	☐	☐	schwach
aktiv	☐	☐	☐	☐	☐	passiv
schnell	☐	☐	☐	☐	☐	langsam
unangenehm	☐	☐	☐	☐	☐	angenehm
effektiv	☐	☐	☐	☐	☐	ineffektiv
erstrebenswert	☐	☐	☐	☐	☐	nicht erstrebenswert
kontrollierbar	☐	☐	☐	☐	☐	unkontrollierbar
gut	☐	☐	☐	☐	☐	schlecht
ideenlos	☐	☐	☐	☐	☐	innovativ
langweilig	☐	☐	☐	☐	☐	interessant
nützlich	☐	☐	☐	☐	☐	nutzlos
unbequem	☐	☐	☐	☐	☐	komfortabel
kühl	☐	☐	☐	☐	☐	gefühlvoll
wichtig	☐	☐	☐	☐	☐	unwichtig
gefährlich	☐	☐	☐	☐	☐	sicher
erfreulich	☐	☐	☐	☐	☐	ärgerlich

3.2 Nachdem Sie das System allgemein beurteilt haben, bitten wir Sie nun um eine genauere Bewertung. Lesen Sie sich dazu bitte die folgenden Aussagen genau durch und kreuzen Sie an, ob die Aussagen Ihrer Meinung nach auf das eben im Fahrsimulator erlebte System zutreffen.

	trifft gar nicht zu				trifft völlig zu
Das System ist modern.	☐	☐	☐	☐	☐
Das System fördert die körperliche Entspannung beim Fahren.	☐	☐	☐	☐	☐
Dieses System wirkt glaubwürdig.	☐	☐	☐	☐	☐
Das System erhöht den Fahrgenuss.	☐	☐	☐	☐	☐
Das System lenkt davon ab, Gefahren rechtzeitig zu erkennen.	☐	☐	☐	☐	☐
Fahren mit dem System macht keinen Spaß.	☐	☐	☐	☐	☐
Das System erhöht die Verkehrssicherheit.	☐	☐	☐	☐	☐
Das System leistet einen positiven Beitrag zum Umweltschutz.	☐	☐	☐	☐	☐
Das System ist nur im Stadtverkehr vorteilhaft.	☐	☐	☐	☐	☐
Das System verführt dazu, seine fahrerischen Grenzen auszuprobieren.	☐	☐	☐	☐	☐
Mit dem System kann man sportlich fahren (schnell / Kurven / Beschleunigen).	☐	☐	☐	☐	☐
Das System schadet dem Image des Fahrers.	☐	☐	☐	☐	☐
Das System macht das Autofahren langweilig.	☐	☐	☐	☐	☐
Das System fördert Stress beim Fahren.	☐	☐	☐	☐	☐
Mit dem System erhöht sich der Komfort des Autofahrens.	☐	☐	☐	☐	☐
Beim Bedienen des Systems kommt man mit wenig Aufwand zum gewünschten Ergebnis.	☐	☐	☐	☐	☐
Das System kann seine Aufgabe nicht fehlerfrei erfüllen.	☐	☐	☐	☐	☐
Das System kann vor kleineren Verkehrsverstößen bewahren.	☐	☐	☐	☐	☐
Das System gibt zu wenig Rückmeldungen.	☐	☐	☐	☐	☐
Das System gibt dem Fahrer das Gefühl, die Funktionen seines Fahrzeugs selbst beeinflussen zu können.	☐	☐	☐	☐	☐
Das System wird gern von Leuten gefahren, die sich im Straßenverkehr nicht sicher fühlen.	☐	☐	☐	☐	☐
Mit diesem System kann man beim Fahren gut Frust und Stress abbauen.	☐	☐	☐	☐	☐
Ich vertraue darauf, dass das System in meinem Interesse handelt.	☐	☐	☐	☐	☐
Dieses System wirkt verlässlich.	☐	☐	☐	☐	☐

4) Folgen des Systems

4.1 Wenn Sie das System in Ihrem Auto hätten, wie würden Sie damit umgehen bzw. was könnte sich durch die Nutzung des Systems ändern. Bitte geben Sie an, für wie wahrscheinlich Sie folgende Konsequenzen halten, die sich aus dem Kauf des Systems ergeben könnten.

Wenn ich das System in meinem Auto hätte …					
	sehr unwahrscheinlich			sehr wahrscheinlich	
... würde ich mich beim Autofahren sicherer fühlen.	☐	☐	☐	☐	☐
... würde ich schneller/rasanter fahren können.	☐	☐	☐	☐	☐
... würde ich mich mehr auf die Fahraufgabe selbst konzentrieren können.	☐	☐	☐	☐	☐
... hätte ich mehr Spaß am Autofahren.	☐	☐	☐	☐	☐
... könnte ich das Autofahren mehr genießen.	☐	☐	☐	☐	☐
... würde ich gestresster sein.	☐	☐	☐	☐	☐

5) Meinung Anderer

5.1 Was glauben Sie, denken andere über dieses System?

	trifft gar nicht zu			trifft völlig zu	
Andere würden es gut finden, wenn ich dieses System hätte.	☐	☐	☐	☐	☐
Wenn ich mir ein Auto kaufe, ist es mir egal, was meine Freunde dazu sagen.	☐	☐	☐	☐	☐
Personen, die mir wichtig sind, würden es ablehnen, wenn ich mir dieses System kaufe.	☐	☐	☐	☐	☐
Meine Freunde würden mich darin bestärken, mir das System zu kaufen.	☐	☐	☐	☐	☐
Mit diesem System könnte ich mich bei meinen Freunden sehen lassen.	☐	☐	☐	☐	☐
Meine Familie würde es begrüßen, wenn ich dieses System in meinem Auto habe.	☐	☐	☐	☐	☐
Ich kann mir gut vorstellen, dass sich meine Freunde das System kaufen.	☐	☐	☐	☐	☐

6) Kauf und Nutzung des Systems

6.1 Bitte entscheiden Sie spontan, in wie weit die folgenden Aussagen auf Sie persönlich zutreffen.

	trifft gar nicht zu				trifft völlig zu
Ich würde dieses System gern in meinem Auto besitzen.	☐	☐	☐	☐	☐
An Komfort-Zusatzausstattungen spare ich beim Autokauf nicht.	☐	☐	☐	☐	☐
Ob ich dieses System kaufe, hängt nur von mir selbst ab.	☐	☐	☐	☐	☐
Ich werde in näherer Zukunft kein Fahrzeug erwerben, für das dieses System angeboten werden könnte.	☐	☐	☐	☐	☐
Ich werde das System beim nächsten Autokauf in Betracht ziehen.	☐	☐	☐	☐	☐
Ich werde dieses System auf keinen Fall kaufen.	☐	☐	☐	☐	☐
Beim Autokauf berücksichtige ich die Wünsche meiner Familie.	☐	☐	☐	☐	☐

6.2 Nachdem Sie sich so viele Gedanken über das System gemacht haben: Wie beurteilen Sie für sich selbst den Kauf und die Nutzung eines solchen Systems?

Das erlebte System zu kaufen und zu nutzen finde ich …						
gut	☐	☐	☐	☐	☐	schlecht
nutzlos	☐	☐	☐	☐	☐	nützlich
angenehm	☐	☐	☐	☐	☐	unangenehm
unwichtig	☐	☐	☐	☐	☐	wichtig
nachteilig	☐	☐	☐	☐	☐	vorteilhaft

Stellen Sie sich nun bitte noch einmal die Situationen, die Sie während der Fahrt erlebt haben, vor.

7a) An welchen Stellen würden Sie aufgrund des Systems mit Vorteilen im Hinblick auf ihre Fähigkeiten (def. als gegenwärtiges Potential, etwas zu tun) rechnen?

7b) An welchen Stellen würden Sie aufgrund des Systems mit Nachteilen im Hinblick auf ihre Fähigkeiten (def. als gegenwärtiges Potential, etwas zu tun) rechnen?

7c) An welchen Stellen würden Sie aufgrund des Systems mit Vorteilen im Hinblick auf ihre Fertigkeiten (def. als gelernte Integration gut ausgeführter Leistungen, die durch Übung verbessert werden können; z.B. Steuern des PKW, Abwehr von Schlingern etc.) rechnen?

7d) An welchen Stellen würden Sie aufgrund des Systems mit Nachteilen im Hinblick auf ihre Fertigkeiten (def. als gelernte Integration gut ausgeführter Leistungen, die durch Übung verbessert werden können; z.B. Steuern des PKW, Abwehr von Schlingern etc.) rechnen?

8) Hat das System Ihr Interesse an einer Kooperation/Zusammenarbeit mit technischen Systemen gesteigert oder gesenkt?

Ergonomische Gestaltung des Systems

		Stimmt gar nicht	Stimmt kaum	Stimmt teilweise	Stimmt über-wiegend	Stimmt völlig
9)	Das System war mir unmittelbar verständlich	❍	❍	❍	❍	❍
10)	Das System gab mir ausreichend Rückmeldung	❍	❍	❍	❍	❍
11)	Die Abläufe des Systems waren für mich transparent	❍	❍	❍	❍	❍

12) Hätten Sie sich gewünscht, dass es die Möglichkeit gegeben hätte zwischen mehreren Varianten des Systems zu wechseln?

13) Beschreiben Sie bitte mit eigenen Worten, was das System während der Fahrt gemacht hat.

Fragen zur Kommunikation mit dem System im Fahrzeug

Nun haben wir ein paar Fragen zum Kommunikationsverhalten des Systems an Sie.

Wie beurteilen Sie das Kommunikationsverhalten des Systems?

Mit Kommunikationsverhalten ist der Prozess der Übermittlung von Bedeutungen oder Sinngehalten durch das System in Form von Sprache, bildlichen Darstellungen, optischen und akustischen Signalen gemeint.

		links trifft zu.........................rechts trifft zu							
		3	2	1	0	1	2	3	
14.1	zu kurz	❍	❍	❍	❍	❍	❍	❍	zu ausführlich
14.2	vertrauenswürdig	❍	❍	❍	❍	❍	❍	❍	nicht vertrauenswürdig
14.3	distanziert	❍	❍	❍	❍	❍	❍	❍	persönlich
14.4	indirekt	❍	❍	❍	❍	❍	❍	❍	direkt
14.5	glaubwürdig	❍	❍	❍	❍	❍	❍	❍	unglaubwürdig
14.6	sympathisch	❍	❍	❍	❍	❍	❍	❍	unsympathisch
14.7	angenehm	❍	❍	❍	❍	❍	❍	❍	unangenehm
14.8	anstrengend	❍	❍	❍	❍	❍	❍	❍	entspannend
14.9	informativ	❍	❍	❍	❍	❍	❍	❍	disinformativ
14.10	relevant	❍	❍	❍	❍	❍	❍	❍	unrelevant
14.11	technisch	❍	❍	❍	❍	❍	❍	❍	menschlich

		einfach	eher einfach	weder noch	eher schwierig	schwierig
14.12	Wie war die Stimme des Systems verständlich?	❍	❍	❍	❍	❍

		nicht abgelenkt	eher abgelenkt	überwiegend abgelenkt	abgelenkt	sehr abgelenkt
14.13	Fühlten Sie sich durch die Kommunikation mit dem System abgelenkt?	❍	❍	❍	❍	❍

		Sprache	eher Sprache	weder noch	eher Touchscreen	Touchscreen
14.14	Welchen Modus der Interaktion würden Sie bevorzugen?	❍	❍	❍	❍	❍

		Command -sprache	eher Command -sprache	weder noch	eher normale Alltagssprache	normale Alltags-sprache
14.15	Welche Art des Dialogs würden Sie bevorzugen?	❍	❍	❍	❍	❍

15) Abschließend möchten wir Sie bitten einzuschätzen, wie sich das Zusammenspiel mit dem *System für Sie ausgewirkt hat.*

		positiv	....	....	....	negativ
15.1	Durch die Kooperation mit dem System veränderte sich meine Wahrnehmung der Gesamtsituation...	❍	❍	❍	❍	❍
15.2	Durch die Kooperation mit dem System veränderte sich meine Motivation zur Aufgabenerfüllung…	❍	❍	❍	❍	❍
15.3	Durch die Kooperation mit dem System veränderte sich meine Entscheidungsfähigkeit im Hinblick auf die Fahranforderungen...	❍	❍	❍	❍	❍
15.4	Durch die Kooperation mit dem System veränderte sich meine Überwachung und Kontrolle der Fahrsituation…	❍	❍	❍	❍	❍
15.5	Durch die Kooperation mit dem System veränderten sich meine Möglichkeiten zur Integration von Informationen in die notwendigen Entscheidungsprozesse...	❍	❍	❍	❍	❍
15.6	Durch die Kooperation mit dem System veränderte sich die Koordination meiner Teilhandlungen...	❍	❍	❍	❍	❍
15.7	Durch die Kooperation mit dem System veränderte sich die gegenseitige Rückmeldung über Ergebnisse von Handlungen...	❍	❍	❍	❍	❍
15.8	Durch die Kooperation mit dem System veränderte sich die Ausführungsqualität der Aufgabe…	❍	❍	❍	❍	❍

		Nicht relevant…………..Relevant				
16.1	In welchem Ausmaß bot Ihnen das System <u>relevante</u> Informationen bezüglich seiner Aktivitäten an?	❍	❍	❍	❍	❍
		Nie……………………..……..Immer				
16.2	In welchem Ausmaß erhielten Sie relevante Informationen vom System rechtzeitig genug, um davon zu profitieren?	❍	❍	❍	❍	❍
		Nie………………………...Immer				
16.3	In welchem Ausmaß verstanden Sie die Informationen, die das automatische System Ihnen anbot, sofort bzw. unmittelbar?	❍	❍	❍	❍	❍
		Nie………………………...Immer				
16.4	In welchem Ausmaß vollzog das automatische System die von Ihnen gewünschten Aktivitäten (z.B. Fragen beantworten)?	❍	❍	❍	❍	❍
		Nie………………………...Immer				
16.5	In welchem Ausmaß vollzog das automatische System die Aktivitäten, die Sie erwarteten?	❍	❍	❍	❍	❍
		Sehr schlecht………..…..Sehr gut				
16.6	Wie würden Sie die Kooperation zwischen Ihnen und dem System insgesamt charakterisieren?	❍	❍	❍	❍	❍

!! Vielen Dank für ihre Mitarbeit !!

Appendix XII: Instructions and interaction concept for the cooperative system variant

Instructions for the cooperative system variant

Herzlich Willkommen bei einem Bereich der Bosch Forschung. Wir freuen uns, dass Sie am Fahrversuch teilnehmen.

<u>Vorbereitende Bemerkungen:</u>

- Stellen Sie sich bitte zunächst den Sitz auf die für Sie optimale Position ein.
- Sie finden im Cockpit mehrere Bedienelemente, die Sie im Rahmen der Simulation benutzen sollen:
  - Lenkrad
  - Gaspedal und Bremse
  - Blinkhebel

  → Alle anderen Bedienelemente im Simulator dürfen nicht verwendet werden!
- Bitte stützen Sie sich beim Ein- und Aussteigen aus dem Fahrzeug nicht am Lenkrad ab.
- Sie werden während der Fahrt per Video überwacht. Sollten Sie sich unwohl fühlen, so können Sie dies jederzeit der Sie betreuenden Person durch entsprechende Zeichengabe signalisieren. Bitte versuchen Sie nicht, alleine aufzustehen!
- Bitte betätigen Sie bis zum Start der Simulation durch den Versuchsleiter keine Bedienteile und bringen Sie das Lenkrad in Mittelstellung.
- Wenn Sie die Strecke sehen können, treten sie bitte auf die Bremse.
- Nach dem Ende der Fahrt möchten wir Sie bitten ruhig sitzen zu bleiben. Der Versuchsleiter wird dann umgehend zu Ihnen kommen.
- Zunächst absolvieren Sie eine Probefahrt
- Im folgenden Versuch geht es darum, dass Sie im Stadtverkehr und auf der Landstrasse ca. 60 Kilometer zurücklegen.
- Wenn ein blaues Schild mit einem weißen Pfeil erscheint, möchten wir Sie bitten, an der nächsten Kreuzung links über den Gegenverkehr abzubiegen. Das Linksabbiegen stellt für uns den wichtigsten Teil der Fahrt dar.
- Bitte fahren Sie dabei bis an die Haltelinie vor, auch wenn Sie dann die Ampel nicht mehr sehen können.
- Während der Fahrt sind die Verkehrsregeln einzuhalten, insbesondere die Geschwindigkeitsbegrenzungen (für Stadt 50 km/h und für Land 100 km/h).

Zur Simulation im engeren Sinne

- Während der nun kommenden Fahrt steht Ihnen als Prototyp ein neues **kooperatives** System zur Verfügung. Dieses System ist sprachbasiert.
- **Wir möchten Sie bitten mit diesem System beim Linksabbiegen über den Gegenverkehr zusammenzuarbeiten.**
- Das System namens „**VIRA“** weist das folgende funktionale Verhalten auf:

  - Es hilft beim Geschwindigkeitsmanagement
  - Es detektiert Fahrzeuge im „Toten Winkel“ und erkennt Gefahren.
  - Es hilft bei der Planung und Entscheidung wann Linksabbiegen über den Gegenverkehr sinnvoll und möglich ist.
  - Es errechnet Lückengrößen zwischen Fahrzeugen.
  - Es erkennt die Abstände, Geschwindigkeiten im Verhältnis zu und das Bremsverhalten von anderen Fahrzeugen während eines Abbiegevorganges.
  - Das System kann Blinken.
  - Das System erkennt Fußgänger.

- Es gelten folgende Kommunikationsregeln mit **„VIRA“**:

  - Sie können dem System jederzeit Fragen bezüglich der Fahrsituation und Fahraufgabe stellen und es bitten, Aufgaben zu übernehmen oder wieder abzugeben.
  - Das System kann Ihnen Fragen zur Informationsgewinnung stellen.
  - **„VIRA“** kann von sich aus Unterstützung anbieten.
  - Das System wird Ihnen Antworten geben, die für die Fahrsituation relevant sind. Falls Sie eine Systemausgabe nicht verstanden haben, können Sie es bitten die Ausgabe zu wiederholen.
  - Für Fragen jenseits des Systemumfangs erhalten Sie die Rückmeldung **„Hierzu liegen mir keine Informationen vor“!**

Gute Fahrt!

Interaction concept for the cooperative system variant:

Initial und während normaler Fahrt

1. Die Strasse ist trocken

2. Bei Stau auf unserer Strecke melde ich mich

3. Hallo ich bin das System "VIRA", ich werde Sie auf der kommenden Fahrt begleiten !

4. Soll ich die Abstände vom Gegenverkehr beobachten?

5. Soll ich die Geschwindigkeit vom Gegenverkehr beobachten?

6. Kann ich Ihnen beim Geschwindigkeitsmanagement behilflich sein?

7. Ja, kann ich übernehmen

8. Ich helfe Ihnen bei der Herstellung der erforderlichen Geschwindigkeit!
9. Wir sind momentan schneller als 60 Km/h
10. Wir sind momentan schneller als 110 Km/h
11. Wir sind momentan etwas zu schnell!
12. Auf dieser Strecke gilt eine Geschwindigkeitsbegrenzung auf 100 Km/h
13. Sie müssen eine größere Lücke nehmen, um sinnvoll abbiegen zu können
14. Die entgegenkommenden Autos fahren circa 55 Km/h
15. Die entgegenkommenden Autos fahren circa 75 Km/h
16. Bitte nicht so weit vorfahren!
17. Bitte weiter zur Linie vorfahren!
18. Kann ich bei der Überwachung der entgegenkommenden Fahrzeuge behilflich sein?
19. Soll ich nach den Lücken auf der Gegenfahrbahn schauen?
20. Da kommt eine Kolonne mit mehreren Fahrzeugen auf der Gegenfahrbahn
21. Es ist genug Platz
22. Ich achte auf die entgegenkommenden Autos und sage Bescheid, wenn sich etwas Relevantes tut
23. Die Lücke reicht noch nicht aus
24. Die Lücken sind unterschiedlich groß!
25. Nach 4 Autos ist eine Lücke für das Linksabbiegen.
26. Nach drei Autos ist eine Lücke für das Linksabbiegen.
27. Nach zwei Autos ist eine Lücke für das Linksabbiegen.
28. Nach dem nächsten Auto ist eine gute Lücke für das Linksabbiegen.
29. Abbiegen wäre jetzt sinnvoll
30. Ja, kann ich übernehmen
31. Haben Sie das Auto eben selbst gesehen?
32. Ein Fußgänger kommt links auf die Ampel zu
33. Es ist kein Fußgänger auf der linken Seite
34. Bitte nicht so weit vorfahren
35. Bitte weiter zur Linie vorfahren
36. Der Gegenverkehr hält
37. Die Ampel für den Gegenverkehr schaltet auf rot, der Gegenverkehr hält
38. Bitte bis zur weißen Linie vorfahren
39. Vorsicht, die Straßenkreuzung ist schlecht zu sehen

40. Momentan ist hinter Ihnen alles frei!
41. Abbiegen wäre jetzt sinnvoll
42. Die Lücke die wir genommen haben, war eigentlich zu klein
43. Die Lücke entsprach nicht den rechtlich notwendigen Sicherheitsabständen
44. Soll ich den Blinker setzen?
45. Ich werde immer den Blinker setzen, wenn Sie es nicht machen!
46. Soll ich immer den Blinker setzen, wenn Sie es nicht machen?

Durchführung des Abbiegevorgangs

47. Kann ich Ihnen bei der Durchführung des Linksabbiegens behilflich sein?
48. Da ist doch noch ein Auto!
49. Jetzt ist frei
50. Im Moment ist alles in Ordnung
51. Wir sollten etwas schneller fahren
52. Wir können ruhig etwas langsamer fahren
53. Wir fahren zu dicht auf
54. Wir fahren zu weit links!
55. Wir fahren zu weit rechts!
56. Wir schlingern!
57. Soll ich den Blinker zurücksetzen?
58. Soll ich den Blinker ab jetzt immer zurücksetzen
59. Soll ich beim erneuten Anpassen der Geschwindigkeit behilflich sein?
60. Sie fahren aktuell noch etwas langsamer als die anderen Fahrzeuge!

Evaluation

61. Bei was soll ich Sie beim nächsten Linksabbiegen mehr unterstützen?
62. Über was wünschen Sie beim nächsten Mal mehr Informationen?
63. Ja, kann ich machen!

Appendix XIII: Results experiment 2

1. Auxiliary equipment in the automobile of the participants

Table A XIII - 1: Results of the auxiliary equipment in the automobile of the participants in percent

	Non existent (in %)	Existent (in %)
Navigation system	87.5	12.5
Cruise control	84.4	15.6
Multifunctional steering wheel	84.4	15.6
Adaptive criuse control (ACC)	100	0
Parking assistant	84.4	15.6
Phone	81.3	18.7
Car radio	0	100
CD-Changer	25.0	75.0
Air condition	50.0	50.0
On-board computer	65.6	34.4
Electronic stabilization program (ESP)	81.3	18.3
Automatic	87.5	9.4
Anti-lock brake system	21.9	75.1
Speech control	90.6	9.4

2. Results of the control variables

Results for the control belief and technology

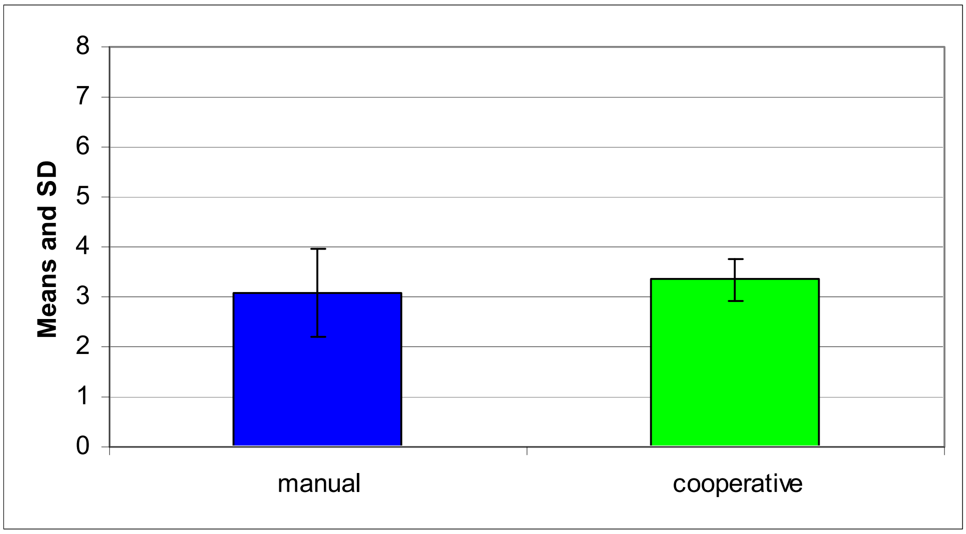


Figure A XIII - 1: Means and standard deviation of the KUT index for each condition.

Table A XIII - 2: Baseline measurement results for the psychopsychological data for both conditions

	Manual	Cooperative
Heart rate	74.21	74.67
Finger	31.15	31.29

Manipulation check for hypothesis 1:

For both test conditions effects of personality characteristics (i.e. KUT, TO-value of the BIP, age) on the most important psychophysiological parameters as well as observable performance data can be ruled out.

For seven of the eight test trials no mistakes on level 3 were measured for all subjects of both conditions by applying the value limits according to Glaser (2005). These fields therefore stay empty or are crossed out.

The personality characteristic control belief when handling technology shows for the manual and cooperative condition no influence on the psychophysiological parameter in the high as well as in the low traffic density situation with one exception (see table A XIII - 3). This exception is a significant influence of the KUT on the heart rate for the cooperative variant in the trial with the low traffic density ($F = 4.744$; $df = 4$; $p = 0.025$).

Table A XIII - 3: ANOVA significance results for the psychophysiological data for each condition and trial on all three mistake episode levels (HD= high traffic density; LD=Low traffic density) (level of significance: ** = *p*≤0.01; * = *p*≤0.05).

		Heart rate Trial HD	Heart rate Trial LD	Finger temperature Trail HD	Finger temperature Trail LD
KUT	Manual	0,255	0,675	0,935	0,712
	Cooperative	0,497	0.025*	0,617	0,674
TO-value	Manual	0,540	0,293	0,337	0,194
	Cooperative	0,533	0,232	0,472	0,762
Age	Manual	0,527	0,468	0,176	0,223
	Cooperative	0,529	0,699	0,905	0,910

The driving performance data for the manual and cooperative system variant show significant influences from the control belief on the parameter *exceeding the compulsory speed limit* and additionally for the manual condition on the parameter *unsafe lane keeping* like table table A XIII - 4 indicates.

Table A XIII - 4: ANOVA significance results for the driving parameter exceeding the compulsory speed limit for each condition and trial on all three mistake episode levels (HD= high traffic density; LD=Low traffic density) (level of significance: ** = p≤0.01; * = p≤0.05).

		Speed E1 HD	Speed E2 HD	Speed E3 HD	Speed E1 LD	Speed E2 LD	Speed E3 LD
KUT	Manual	0.040*	0.168	0.727	0.031*	0.168	-------
	Cooperative	0.683	0.019*	<0.001	0.683	0.016*	-------
TO-value	Manual	0.312	0.021*	0.473	0.312	0.017*	-------
	Cooperative	0.246	0.037*	<0.001	0.246	0.025*	-------
Age	Manual	0.760	0.198	0.321	0.760	0.198	-------
	Cooperative	0.570	0.783	<0.001	0.570	0.783	-------

The TO-value as a measure for the team orientation of the subjects shows for both conditions no influence on the psychophysiological parameters. However, the TO-value shows a significant influence on the driving performance data of both conditions in both trials on mistake level 2 and on the parameter *lateral interval too small* only for the cooperative system variant on the first mistake level in the trial with low traffic density.

The age shows for the subjects of both conditions neither an influence on the psychophysiological parameters nor on the driving performance data.

Table A XIII - 5: ANOVA significance results for the driving parameter unsafe lane keeping for each condition and trial on all three mistake episode levels (HD= high traffic density; LD=Low traffic density) (level of significance: ** = *p*≤0.01; * = *p*≤0.05)

		UnsafeLK E1 HD	UnsafeLK E2 HD	UnsafeLK E3 HD	UnsafeLK E1 LD	UnsafeLK E2 LD	UnsafeLK E3 LD
KUT	Manual	0.039*	0.052	-------	0.052	0.035*	-------
	Cooperative	0.799	0.572	-------	0.572	0.503	-------
TO-value	Manual	0.312	0.800	-------	0.800	0.602	-------
	Cooperative	0.254	0.328	-------	0.328	0.383	-------
Age	Manual	0.760	0.581	-------	0.581	0.542	-------
	Cooperative	0.591	0.512	-------	0.512	0.715	-------

Table A XIII - 6: ANOVA significance results for the driving parameter unintended lane leaving for each condition and trial on all three mistake episode levels (HD= high traffic density; LD=Low traffic density) (level of significance: ** = *p*≤0.01; * = *p*≤0.05)

		LL E1 HD	LL E2 HD	LL E3 HD	LL E1 LD	LL E2 LD	LL E3 LD
KUT	Manual	0.727	0.507	-------	0.055	0.088	-------
	Cooperative	0.095	0.483	-------	0.903	0.898	-------
TO-value	Manual	0.494	0.560	-------	0.467	0.639	-------
	Cooperative	0.698	0.994	-------	0.526	0.159	-------
Age	Manual	0.361	0.585	-------	0.694	0.571	-------
	Cooperative	0.581	0.213	-------	0.508	0.120	-------

Table A XIII - 7: ANOVA significance results for the driving parameter lateral interval to small for each condition and trial on all three mistake episode levels (HD= high traffic density; LD=Low traffic density) (level of significance: ** = *p*≤0.01; * = *p*≤0.05).

		LI E1 HD	LI E2 HD	LI E3 HD	LI E1 LD	LI E2 LD	LI E3 LD
KUT	Manual	0.818	0.313	-------	0.716	0.766	-------
	Cooperative	0.055	0.237	-------	0.958	0.225	-------
TO-value	Manual	0.868	0.752	-------	0.556	0.809	-------
	Cooperative	0.206	0.355	-------	0.011*	0.176	-------
Age	Manual	0.701	0.173	-------	0.664	0.426	-------
	Cooperative	0.983	0.066	-------	0.100	0.378	-------

Manipulation check for hypothesis 2:

Effects of personality characteristics (i.e. KUT, TO-value of the BIP, age) on the most important subjective respectively behavioral data can be ruled out for both test conditions.

The personality characteristic KUT shows besides one exception for both conditions no influence on the inquired four subjective and behavior data respectively. However, there is for the cooperative test condition a significant influence on the dependent variable trust ($F = 4.838$; $df = 5$; $p < 0.017$) like table 22 shows.

Table A XIII - 8: ANOVA significance results for the subjective data indices for each condition (level of significance: ** = p≤0.01; * = p≤0.05).

		Index acceptance	Index attractiveness	Index trust	Index behavior intention
KUT	Manual	0,718	0,292	0,920	0,490
	Cooperative	0,181	0,078	0.017*	0,920
TO-value	Manual	0,592	0,174	0,858	0,061
	Cooperative	0,986	0.004**	0,198	0,564
Age	Manual	0,902	0,541	0,640	0,765
	Cooperative	0,418	0.010**	0,176	0.034*

The TO-value of the subjects also shows no influence on the subjective parameters of both conditions besides one exception. However, for the cooperative test condition there is a highly significant influence on the dependent variable attractiveness (F = 7.850; df = 3; p < 0.004).

The age also shows for the manual test group no significant influence on the subjective data. For the cooperative test group a significant relation between age and attractiveness index (F = 5.991; df = 3; p < 0.034) as well as the behavior intention was noticed (F = 4.004; df = 3; p < 0.034).

3. Results of the hypothesis 1
4.

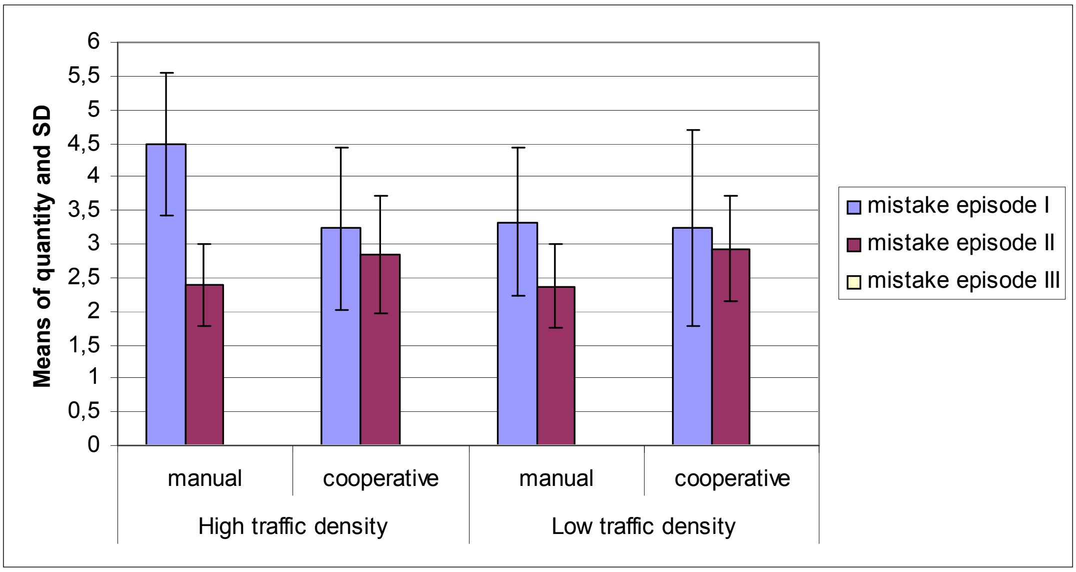


Figure A XIII - 2: Means of quantity and standard deviation of mistake episode 1-3 of the driving parameter unsafe lane keeping per trial and each condition.

Table A XIII - 9: Means and ANOVA significance results for the comparison of the cooperative system with the manual system relating the driving parameter unsafe lane keeping of each trial and all three mistake episode levels (M=manual; C=cooperative; HD= high traffic density; LD=Low traffic density) (level of significance: ** = p≤0.01; * = p≤0.05)

	Mean C/M ; p-value C/M
UnsafeLK E1 HD	4.47/5.03 ; 0.503
UnsafeLK E2 HD	2.55/2.86 ; 0.555
UnsafeLK E3 HD	0.00/0.00 ; -------
UnsafeLK E1 LD	2.95/3.96 ; 0.054
UnsafeLK E2 LD	1.87/2.21 ; 0.315
UnsafeLK E3 LD	0.00/0.00 ; -------

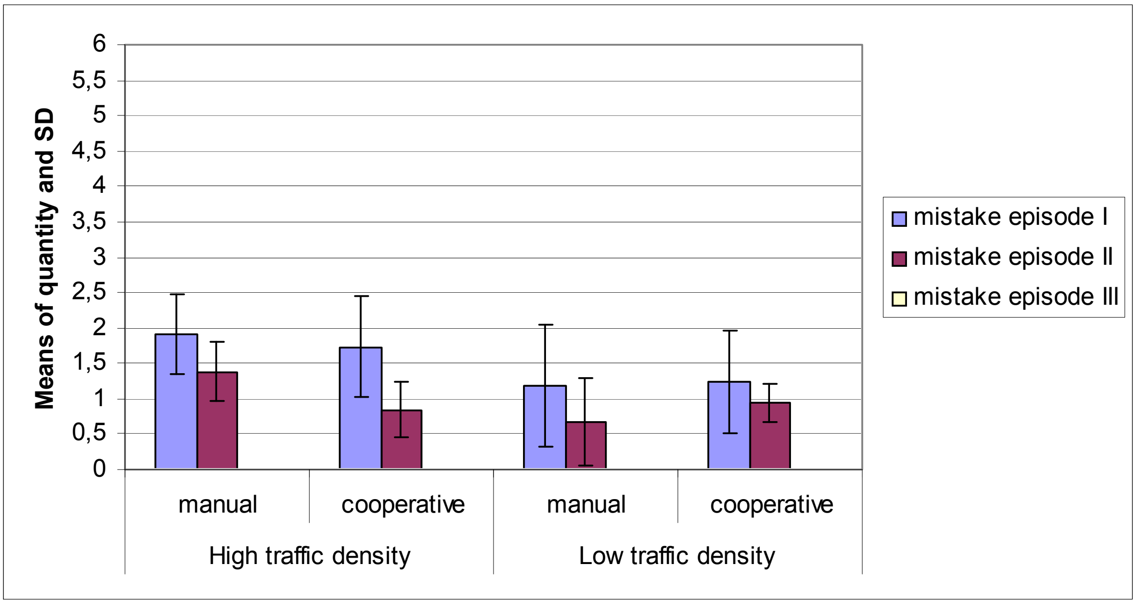


Figure A XIII - 3: Means of quantity and standard deviation of mistake episode 1-3 of the driving parameter lateral interval too small per trial and each condition.

Table A XIII - 10: Means and ANOVA significance results for the comparison of the cooperative system with the manual system relating the driving parameter lateral interval to small of each trial and all three mistake episode levels (M=manual; C=cooperative; HD= high traffic density; LD=Low traffic density) (level of significance: ** = *p*≤0.01; * = *p*≤0.05).

	Mean C/M ; p-value C/M
LI E1 HD	0.87/1.33 ; <0.001**
LI E2 HD	0.63/0.68 ; 0.737
LI E3 HD	0.00/0.00 ; -------
LI E1 LD	0.53/1.22 ; <0.001**
LI E2 LD	0.51/0.48 ; 0.861
LI E3 LD	0.00/0.00 ; -------

4. Results of the hypothesis 2

Behavior control

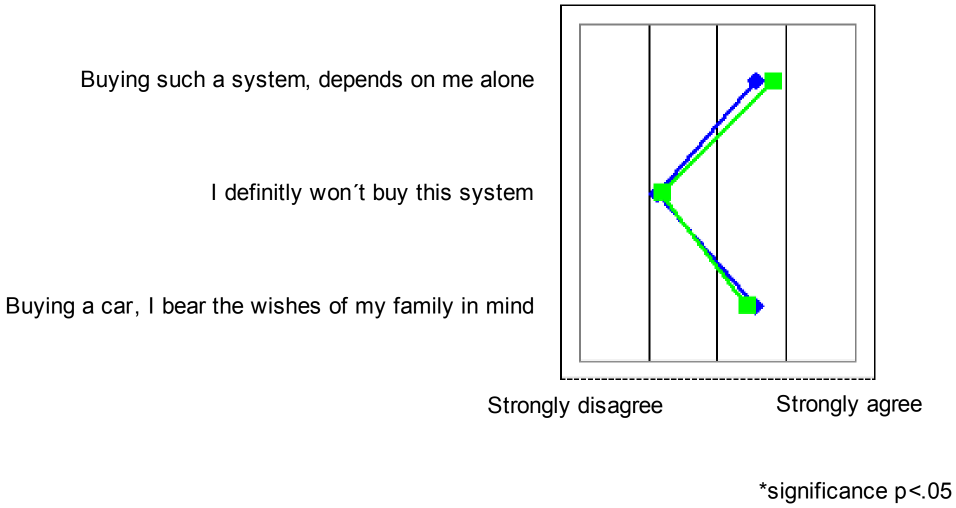


Figure A XIII - 4: Means of behavior control for low traffic density

Ergonomic design

In this question block the participants of the cooperative system variant were asked to give information about the usability of the system. Figure 57 shows that the cooperative system variant was directly comprehensible.

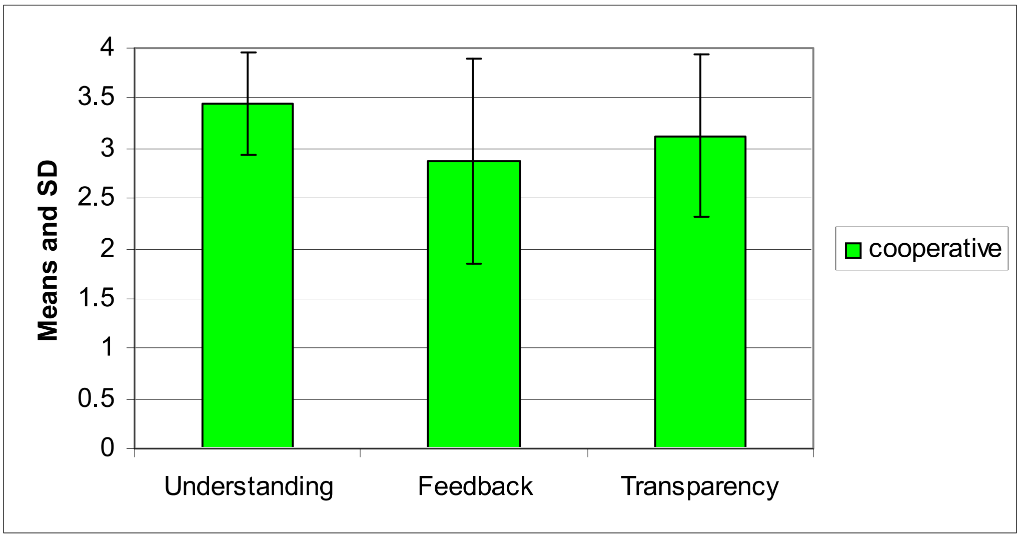


Figure A XIII - 5: Means and standard deviation of usability answers of the subjects experiencing the cooperative system.

Furthermore the participants found that sufficient feedback had been provided; the transparency of the sequences were as well rated as good.

Workload – subjective measures

Table A XIII - 11: Comparison of the Z scores and the significance results of psychophysiological and BLV-data for the cooperative condition at two measuring times (1: after high traffic density, 2: after low traffic density)

	Z-score C, asymp. Sig. (2-tailed)
Psychological strain with Heart rate Trial 1 HD	`-1,78 ; 0.07
Current performance with Heart rate Trial 1 HD	`-2,20 ; 0.03
Achievement motivation with Heart rate Trial 1 HD	`-1,36 ; 0.17
Fatigue 1 with Heart rate Trial 1 HD	`-1,57 ; 0.12
Psychological strain with Finger temperature Trial 1 HD	`-1,57 ; 0.12
Current performance with Finger temperature Trial 1 HD	`-1,99 ; 0.04
Achievement motivation with Finger temperature Trial 1 HD	`-1,57 ; 0.12
Fatigue with Finger temperature Trial 1 HD	`-0,94 ; 0.35
Psychological strain with Heart rate Trial 2 LD	`-0,73 ; 0.46
Current performance with Heart rate Trial 2 LD	`-0,52 ; 0.60
Achievement motivation with Heart rate Trial 2 LD	`-1,15 ; 0.25
Fatigue 2 with Heart rate Trial 2 LD	`-1,15 ; 0.25
Psychological strain with Finger temperature Trial 2 LD	`-1,36 ; 0.17
Current performance with Finger temperature Trial 2 LD	`-1,15 ; 0.25
Achievement motivation with Finger temperature Trial 2 LD	`-1,15 ; 0.25
Fatigue with Finger temperature Trial 2 LD	`-1,36 ; 0.17

Table A XIII - 12: Comparison of the Z scores and the significance results of psychophysiological and BLV-data for the manual condition at two measuring times (1: after high traffic density, 2: after low traffic density)

	Z-score C, asymp. Sig. (2-tailed)
Psychological strain with Heart rate Trial 1 HD	`-0,67 ; 0.50
Current performance with Heart rate Trial 1 HD	`-0,17 ; 0.87
Achievement motivation with Heart rate Trial 1 HD	`-0,17 ; 0.87
Fatigue 1 with Heart rate Trial 1 HD	`-0,51 ; 0.61
Psychological strain with Finger temperature Trial 1 HD	`-0,34 ; 0.74
Current performance with Finger temperature Trial 1 HD	`-0,85 ; 0.40
Achievement motivation with Finger temperature Trial 1 HD	`-0,68 ; 0.50
Fatigue with Finger temperature Trial 1 HD	`-0,85 ; 0.40
Psychological strain with Heart rate Trial 2 LD	`0,00 ; 1.00
Current performance with Heart rate Trial 2 LD	`-0,68 ; 0.50
Achievement motivation with Heart rate Trial 2 LD	`-0,17 ; 0.87
Fatigue 2 with Heart rate Trial 2 LD	`-0,34 ; 0.74
Psychological strain with Finger temperature Trial 2 LD	`-0,34 ; 0.74
Current performance with Finger temperature Trial 2 LD	`-0,85 ; 0.40
Achievement motivation with Finger temperature Trial 2 LD	`-1,01 ; 0.31
Fatigue with Finger temperature Trial 2 LD	`-0,68 ; 0.50

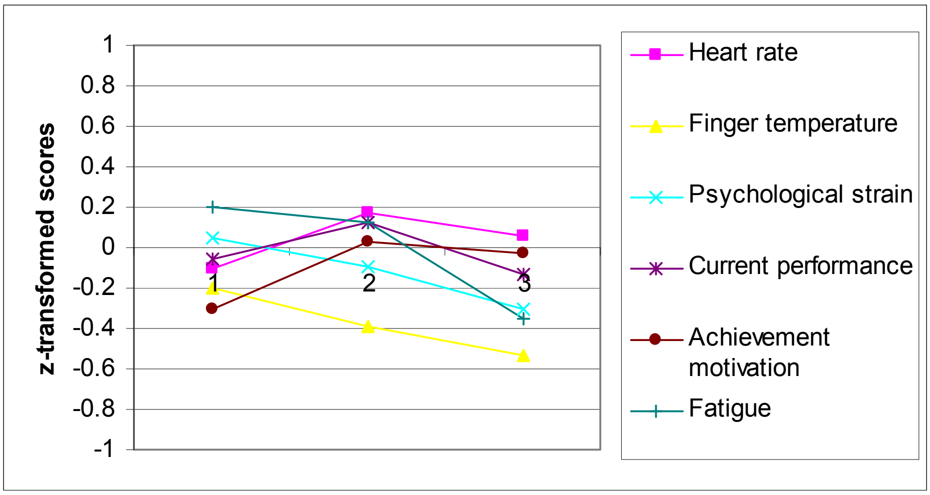


Figure A XIII - 6: Comparison of the z-transformed means of psychophysiological and BLV-data for the cooperative condition at three measuring times (1: baseline before the experiment, 2: after high traffic density, 3: after low traffic density).

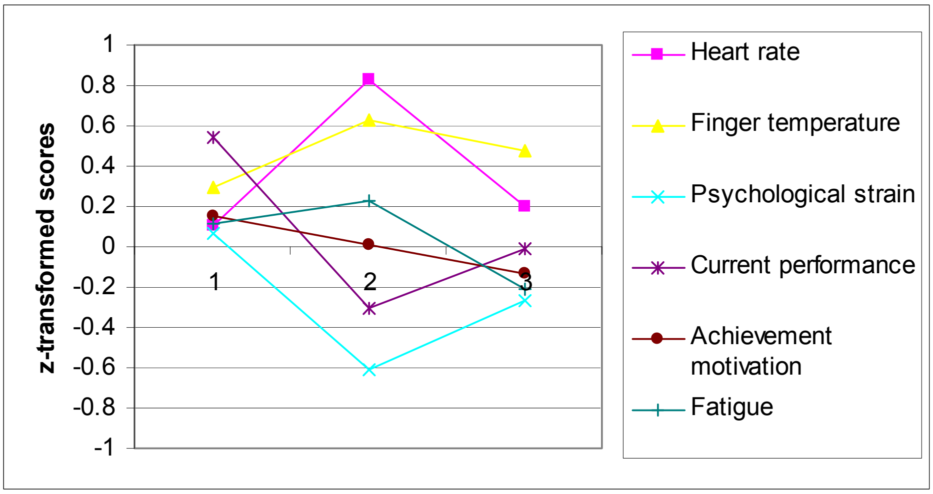
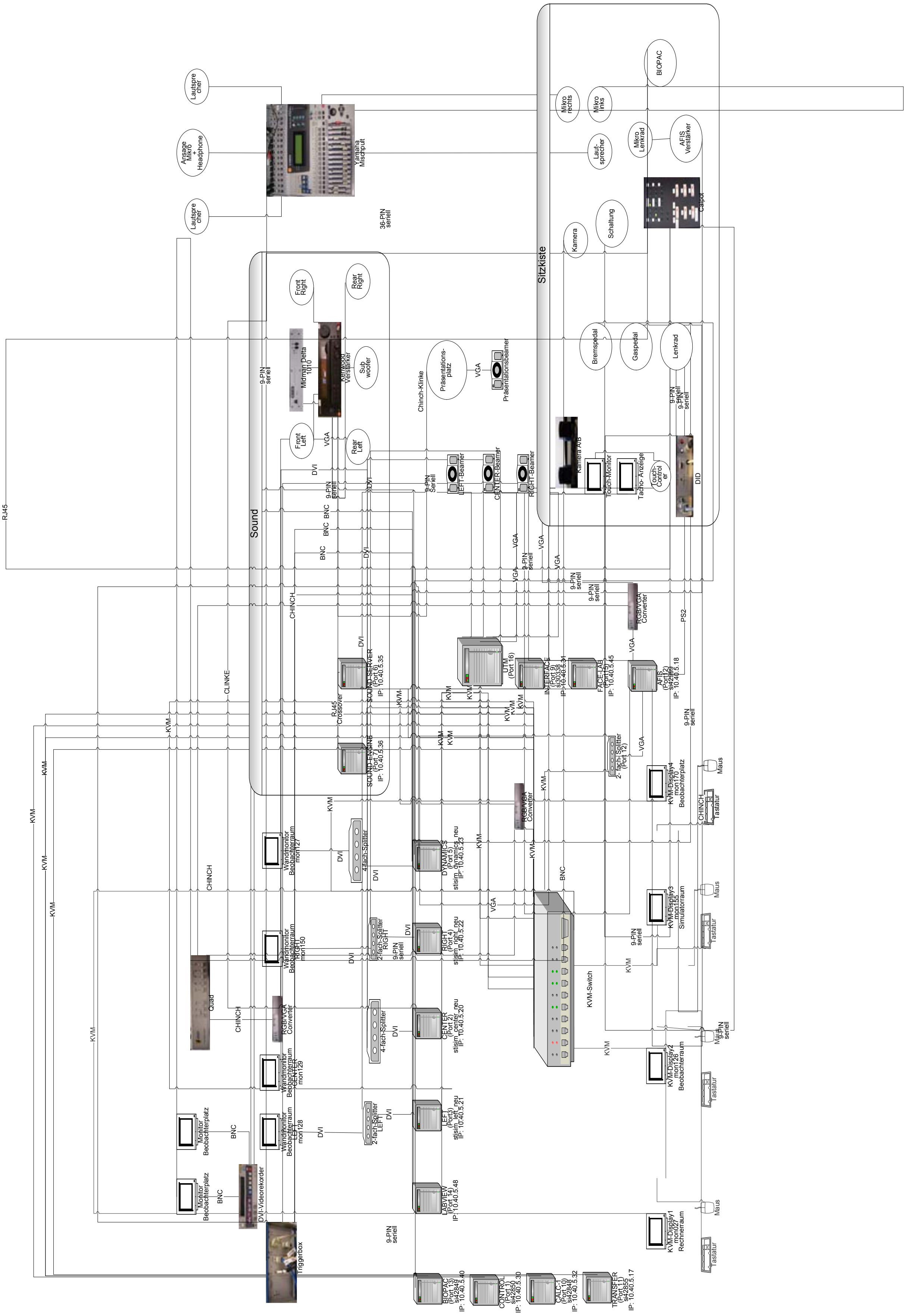


Figure A XIII - 7: Comparison of the z-transformed means of psychophysiological and BLV-data for the manual condition at three measuring times (1: baseline before the experiment, 2: after high traffic density, 3: after low traffic density).

Appendix XIV: Setup of the second driving simulator



Appendix XV: List of driving parameters for both experiments

Number of parameter	Name of parameter / Description of parameter
Parameters recorded with 100 Hz	
1	Simulation Time [s]
2	Corresponding Video Frame Number
3	Distance traveled [ft]
4	Distance traveled [m]
5	Total vehicle longitudinal velocity [m/sec]
6	Longitudinal acceleration at CG [m/sec^2]
7	Tire 1 longitudinal velocity [m/s]
8	Tire 2 longitudinal velocity [m/s]
9	Tire 3 longitudinal velocity [m/s]
10	Tire 4 longitudinal velocity [m/s]
11	Total vehicle lateral velocity [m/sec]
12	Lateral acceleration of Ms [m/s^2]
13	Lateral offset of vehicle venter of gravity from roadway centerline [m]
14	Longitudinal position in global coordinate system [m]
15	Lateral position in global coordinate system [m]
16	Tire 1 terrain height [m]
17	Tire 2 terrain height [m]
18	Tire 3 terrain height [m]
19	Tire 4 terrain height [m]
20	Throttle pedal position [%]
21	Brake pedal force input [N]
22	Steering Wheel Angle [rad]
23	Steering Wheel Angular Rate [rad/s]
24	Steering torque [Nm]
25	Yaw angle [rad]
26	Yaw velocity [rad/s]
27	Yaw acceleration [rad/s^2]
28	Tire 1 steer angle [rad]
29	Tire 2 steer angle [rad]
30	Heading angle error between vehicle and roadway CL [rad]
31	Sprung mass pitch angle [rad]
32	Sideslip angle of Ms at CG [rad]
33	Gravity vector component in body X-axis [m/s^2]
34	Sum of longitudinal forces on sprung mass (along X-axis) [N]
35	Tire 1 cornering stiffness [N/rad]
36	Tire 2 cornering stiffness [N/rad]
37	Tire 3 cornering stiffness [N/rad]
38	Tire 4 cornering stiffness [N/rad]
39	Gear [-]
40	Engine Speed [rad/s]

Parameters recorded with 30 Hz	
41	Simulation time [s]
42	Distance along roadway centerline [m]
43	Position of roadway centerline (X-axis) [m]
44	Position of roadway centerline (Y-axis) [m]
45	Position of roadway centerline (Z-axis) [m]
46	Angle of roadway centerline (X-axis) [rad]
47	Angle of roadway centerline (Y-axis) [rad]
48	Angle of roadway centerline (Z-axis) [rad]
49	Ego vehicle position (X-axis) [m]
50	Ego vehicle position (Y-axis) [m]
51	Ego vehicle position (Z-axis) [m]
52	Ego vehicle angle (X-axis) [rad]
53	Ego vehicle angle (Y-axis) [rad]
54	Ego vehicle angle (Z-axis) [rad]
55	Lateral offset of vehicle center from roadway center line [m]
56	Total vehicle longitudinal velocity [m/s]
57	Longitudinal acceleration [m/s^2]
58	Total vehicle lateral velocity [m/s]
59	Lateral acceleration [m/s^2]
60	Throttle pedal position [%]
61	Brake pedal [-]
62	Steering wheel angle [rad]
63	Steering wheel angular rate [rad/s]
64	Vehicle heading angle [rad]
65	Total vehicle yaw rate [rad/s]
66	Yaw acceleration [rad/s]
67	Angle between vehicle X-axis and roadway center line [rad]
68	Chassis roll angle [rad]
69	Chassis pitch angle [rad]
74	Engine angular rate [rad/s]
75	Gear [-1-4]
76	Crash Flag [0-1]
77	Vehicle1 id [0-9999]
78	Vehicle1 length [m]
79	Vehicle1 width [m]
80	Vehicle1 posX [m]
81	Vehicle1 posY [m]
82	Vehicle1 posZ [m]
83	Vehicle1 angleX [rad]
84	Vehicle1 angleY [rad]
85	Vehicle1 angleZ [rad]
86	Vehicle1 speed [m/s]
87	Vehicle1 acceleration [m/s^2]
88	Vehicle1-Ego range [m]
89	Vehicle2 id [0-9999]

90	Vehicle2 length [m]
91	Vehicle2 width [m]
92	Vehicle2 posX [m]
93	Vehicle2 posY [m]
94	Vehicle2 posZ [m]
95	Vehicle2 angleX [rad]
96	Vehicle2 angleY [rad]
97	Vehicle2 angleZ [rad]
98	Vehicle2 speed [m/s]
99	Vehicle2 acceleration [m/s^2]
100	Vehicle2-Ego range [m]
101	Vehicle3 id [0-9999]
102	Vehicle3 length [m]
103	Vehicle3 width [m]
104	Vehicle3 posX [m]
105	Vehicle3 posY [m]
106	Vehicle3 posZ [m]
107	Vehicle3 angleX [rad]
108	Vehicle3 angleY [rad]
109	Vehicle3 angleZ [rad]
110	Vehicle3 speed [m/s]
111	Vehicle3 acceleration [m/s^2]
112	Vehicle3-Ego range [m]
113	Vehicle4 id [0-9999]
114	Vehicle4 length [m]
115	Vehicle4 width [m]
116	Vehicle4 posX [m]
117	Vehicle4 posY [m]
118	Vehicle4 posZ [m]
119	Vehicle4 angleX [rad]
120	Vehicle4 angleY [rad]
121	Vehicle4 angleZ [rad]
122	Vehicle4 speed [m/s]
123	Vehicle4 acceleration [m/s^2]
124	Vehicle4-Ego range [m]
125	Vehicle5 id [0-9999]
126	Vehicle5 length [m]
127	Vehicle5 width [m]
128	Vehicle5 posX [m]
129	Vehicle5 posY [m]
130	Vehicle5 posZ [m]
131	Vehicle5 angleX [rad]
132	Vehicle5 angleY [rad]
133	Vehicle5 angleZ [rad]
134	Vehicle5 speed [m/s]
135	Vehicle5 acceleration [m/s^2]

136	Vehicle5-Ego range [m]
137	Vehicle6 id [0-9999]
138	Vehicle6 length [m]
139	Vehicle6 width [m]
140	Vehicle6 posX [m]
141	Vehicle6 posY [m]
142	Vehicle6 posZ [m]
143	Vehicle6 angleX [rad]
144	Vehicle6 angleY [rad]
145	Vehicle6 angleZ [rad]
146	Vehicle6 speed [m/s]
147	Vehicle6 acceleration [m/s^2]
148	Vehicle6-Ego range [m]
149	Vehicle7 id [0-9999]
150	Vehicle7 length [m]
151	Vehicle7 width [m]
152	Vehicle7 posX [m]
153	Vehicle7 posY [m]
154	Vehicle7 posZ [m]
155	Vehicle7 angleX [rad]
156	Vehicle7 angleY [rad]
157	Vehicle7 angleZ [rad]
158	Vehicle7 speed [m/s]
159	Vehicle7 acceleration [m/s^2]
160	Vehicle7-Ego range [m]
161	Vehicle8 id [0-9999]
162	Vehicle8 length [m]
163	Vehicle8 width [m]
164	Vehicle8 posX [m]
165	Vehicle8 posY [m]
166	Vehicle8 posZ [m]
167	Vehicle8 angleX [rad]
168	Vehicle8 angleY [rad]
169	Vehicle8 angleZ [rad]
170	Vehicle8 speed [m/s]
171	Vehicle8 acceleration [m/s^2]
172	Vehicle8-Ego range [m]
173	Temperature Finger [□C]
174	Temperature Room [□C]
175	Steering Angle [Degree]
176	Steering Velocity [Degree/s]
177	Pulse Rate [BPM]
178	Tracking
179	Blinking

Appendix XVI: Driving mistake definitions

1. Driving Mistake: Exceeding the compulsory speed limit

Driving mistake	Exceeding the compulsory speed limit
Situation	Limited through signs and instructions
Indicator/Measuring variable	Own speed Compulsory speed
Technical requirements	Velocity measurement (accuracy +/- 5 %)
Existing criteria (reference)	Mistake, when exceeding > 10 % (Brookhuis, 1995) Mistake, when exceeding > 20 % (Reichart, 2001) Mistake, when exceeding > 10 km/h (Fastenmeier, 1995) Diverse exceeding levels (Law)
Method criteria	vueproz = (vkmh - vsollkmh) x 100 / vsollkmh With vueproz speed exceeding [%] vkmh driven speed [km/h] vgsollkmh maximal allowed speed [km/h]
Mistake episode beginning from 140 km/h (for experiment 1)	0 when vueproz < 10 % 1 when (vueproz >= 10 %) & (vueproz < 20 %) 2 when (vueproz >= 20 %) & (vueproz < 30 %) 3 when vueproz >= 30 %
Mistake episode beginning from either 50, 70 or 100 km/h (for experiment 2	0 when vueproz < 10 % 1 when (vueproz >= 10 %) & (vueproz < 20 %) 2 when (vueproz >= 20 %) & (vueproz < 30 %) 3 when vueproz >= 30 %

2. Driving Mistake: Longitudinal distance to small in relation to own speed (only for experiment 1)

Driving mistake	Longitudinal distance to small in relation to own speed
Situation	Vehicle following (vehicle ahead with more or less same speed)
Indicator/Measuring variable	Time headway
Technical requirements	Speed measurement (accuracy +/- 2.5%) Distance measurement (accuracy +/- 2 meters)
Existing criteria (reference)	Mistake, when temporal interval < 0,7 s (Brookhuis, 1995) Optimal temporal interval > 1,8 s; equivalent „½ speedometer“ (unofficial rule of thumb)
Method criteria	Time headway: th(t) = d (t)/ v (t) With th(t) Time headway to the vehicle ahead (seconds) at a certain time (t) d(t) Distance to the vehicle ahead (meters) at a certain time (t) v(t) Speed of own vehicle (m/s) at a certain time (t)
Mistake episode	0 when th > 1.7 sec. 1 when (th <= 1.7 sec.) & (th > 1.2 sec.) 2 when (th <= 1.2 sec.) & (th > 0.7 sec.) 3 when th <= 0.7 sec.

3. Driving Mistake: Longitudinal distance to small for difference speed (only for experiment 1)

Driving mistake	**Longitudinal distance to small for difference speed**
Situation	Approaching a vehicle driving ahead
Indicator/Measuring variable	Minimal approaching distance Time-to-collision (ttc) Time-integrated ttc (tit)
Technical requirements	Speed measurement (accuracy +/- 2.5%) Distance measurement (accuracy +/- 2 meters)
Existing criteria (reference)	critical, when ttc < 4.0 s (Hirst & Graham, 1997; Minderhoud & Bovy, 2001)
Method criteria	Time-to-collision: ttc= v8/ (v68-v14) With ttc Time-to-collision [s] v8 Distance to vehicle driving ahead [m] v68 Speed of own car [m/s] v14 Speed of vehicle ahead [m/s]
Mistake episode	0 when ttc > 4.0 s 1 when (ttc <= 4.0 s) & (ttc > 3.0 s) 2 when (ttc <= 3.0 s) & (ttc > 2.0 s) 3 when ttc <= 2.0 s

4. Driving Mistake: Unsafe lane keeping

Driving mistake	**Unsafe lane keeping**
Situation	Following the lane
Indicator/Measuring variable	(1) Steering angle: Standard deviation (2) Lane position: Standard-Deviation-of-Lane-Position (sdlp) (3) Time-to-Line-Crossing (tlc)
Technical requirements	to (1): Steering angle measurement to (2) und (3): Lane following
Existing criteria (reference)	to (1): Mistake, when standard deviation steering angle >1.5 ° (Brookhuis, 1995) to (2): Mistake, when sdlp > 0.25 m (Brookhuis, 1995) to (3): Mistake, when tlc < 1.1 s (Verwey, 2001) to (3): Mistake, when tlcmin for right lane < 1.3 s Mistake, when tlcmin for left lane < 1.7 s Mistake, when tlcmed for right lane < 3.1 s Mistake, when tlcmed for left lane < 4.0 s (Brookhuis, 1995; Reichart, 2001)
Method criteria	(2) Standard-Deviation-of-Lane-Position: sdlp (3) Time-to-line-crossing: tcl= xq/v68 x sin ψ With tlc Time-to-line-crossing [s] xq Cross aberration in relation to lane limitation [m] v68 Speed of vehicle [m/s] ψ yaw angle
Mistake episode (sdlp)	0 when sdlp <= 0.25 m 1 when (sdlp > 0.25 m) & (sdlp <= 0.35 m) 2 when (sdlp > 0.35 m) & (sdlp <= 0.5 m) 3 when sdlp > 0.5 m
Mistake episode (tlc)	0 when tlc >= 1.3 s 1 when (tlc < 1.3 s) & (tlc >= 0.9 s) 2 when (tlc < 0.9 s) & (tlc >= 0.3 s) 3 when tlc < 0.3 s

5. Driving Mistake: Leaving the lane (unintended)

Driving mistake	Leaving the lane (unintended)
Situation	Following the lane
Indicator/Measuring variable	Position in relation to lane
Technical requirements	Lane tracing
Existing criteria (reference)	Mistake, when leaving the lane is longer than 0.25 s (Glaser et al., 2005)
Method criteria	Crossing the lane limitations with the outlines of the car (Measurement with the driving data from the simulator)
Mistake episode	0 when deviation <= 0.1 m 1 when (deviation > 0.1 m) & (deviation <= 0.25 m) 2 when (deviation > 0.25 m) & (deviation <= 0.5 m) 3 when deviation > 0.5 m

6. Driving Mistake: Lateral interval to small (only for experiment 2)

Driving mistake	Lateral interval to small
Situation	Passing of oncoming vehicles
Indicator/Measuring variable	Lateral interval [m]
Technical requirements	Lateral interval measurement (accuracy +/- 0.05 m)
Existing criteria (reference)	Opposite direction: Minimal interval to lane limitations while passing oncoming vehicles 0.25 m (Reichart, 2001)
Mistake episode	0 when lateral interval >= 1.5 m 1 when lateral interval < 1.5 m 2 when lateral interval < 1.0 m 3 when lateral interval < 0.5 m

Appendix XVII: List of influence factors on simulator sickness rate

1. Simulator sickness arises from mismatch between visual motion cues and the vestibular system
2. Simulator sickness has similiar symptoms like motion sickness
3. Great individual differences
4. Angle of Video-Beamer
5. Perceived speed
6. Angle of cars motion (perceived curve behavior)
7. Bright imagery is more likely to induce sickness than nighttime scenes (Helman, 1993)
8. Wide fields of view cause more problems than near ones (Helman, 1993)

Appendix XVIII: Discourse between Biester/Moosbrugger about optimal sample sizes.

Anfrage Lars Biester zu Effektstärke und optimalem N bei der mehrfaktoriellen ANOVA – Antwort von H. Moosbrugger

Die Zahlen von Bortz und Döring (2002) sowie des Programms GPower lassen sich anhand der von Cohen (1988) gegebenen Formeln und Tabellen nachvollziehen; in beiden Quellen ist die erforderliche **Stichprobengröße pro Zelle** für den **Nachweis der Interaktion in einem 2x3-Design** unter Annahme eines kleinen, mittleren oder großen Effekts bei $\alpha = 0{,}05$ und $1\text{-}\beta = 0{,}80$ nach den Formeln und Tabellen aus Cohen (1988) angegeben (s. unten). Die kleinen Abweichungen zwischen B&D und dem Programm GPower sind wahrscheinlich auf Rundungsfehler zurückzuführen.

Allgemeines zur Bestimmung des optimalen *N* bei der mehrfaktoriellen ANOVA

In einer mehrfaktoriellen ANOVA ist die Berechnung des optimalen Stichprobenumfangs von der jeweiligen zu prüfenden Hypothese abhängig, wobei unterschiedliche optimale Stichprobenumfänge für unterschiedliche Hypothesen resultieren.

In Varianzanalysen werden Hypothesen mittels eines F-Tests geprüft:

$$F = \frac{QS(Effekt)}{QS(Fehler)} \cdot \frac{df_e}{df_h} \qquad (1)$$

Es ist also selbstverständlich, dass unterschiedliche Hypothesen mit unterschiedlichen Tests geprüft werden: Für jede Hypothese gehen in den F-Bruch jeweils unterschiedliche Quadratsummen [QS(Effekt)] und unterschiedliche *dfh* ein.

Die Stichprobengröße und die zu testende(n) Hypothese(n) (Kontraste) drücken sich in *dfh* und *dfe* aus: *dfe* = N - r - 1 mit N = Stichprobengröße, r = Anzahl der Zellen. *dfh* ist abhängig von der zu testenden Hypothese: Je nach Design (also Zahl der Faktoren und Zahl der Faktorstufen).

müssen für das Testen der unterschiedlichen Hypothesen über die Haupteffekte und Interaktionen (Wechselwirkungen) unterschiedlich viele Kontraste formuliert werden; *dfh* ist dann die Zahl der Kontraste, die zum Testen einer bestimmten Hypothese erforderlich sind.

Daraus folgt auch, dass für unterschiedliche Hypothesen unterschiedliche optimale Stichprobenumfänge resultieren: Selbst wenn man annehmen würde, dass durch die unterschiedlichen Hypothesen (Haupteffekte, Wechselwirkungen) jeweils gleiche erklärte Quadratsummen [QS(Effekt)] resultieren, so ergeben sich für die unterschiedlichen Hypothesen unterschiedliche *dfh* ein.

Ersetzt man in (1) *dfe* durch N – r - 1

$$F = \frac{QS(Effekt)}{QS(Fehler)} \cdot \frac{N-r-1}{df_h}$$

so zeigt sich, dass bei gegebenem Varianzverhältnis und r der F-Wert größer wird, wenn *dfh* kleiner wird oder wenn N größer wird. Das steigende F bei steigendem N ist nichts weiter als das bekannte Ansteigen der Power bei größerer Stichprobe; das steigende F bei weniger *dfh* ist es, worauf sich wahrscheinlich die Anmerkung "Wir erwarteten, dass bei steigenden Faktorstufenanzahlen die Stichprobengrößen je Faktorstufe größer werden müssten" bezieht. Darauf soll weiter unten eingegangen werden.

Zunächst ist aber festzuhalten: Die optimale Stichprobengröße richtet sich nach der zu testenden Hypothese.

In Bortz und Döring (2002) sind dabei für die mehrfaktoriellen Designs die optimalen Stichprobenumfänge zum Testen der jeweils höchsten Interaktion verzeichnet. Begründet wird dies damit, dass die Hypothese für die höchste Interaktion in den meisten Fällen die wichtigste Hypothese eines mehrfaktoriellen Designs ist.

Für die praktische Anwendung ist dabei zu beachten, dass in der Tabelle die optimalen Stichprobenumfänge pro Zelle verzeichnet sind und nicht der Gesamtumfang.

Problem unterschiedlicher Power für unterschiedliche *dfh*

Warum haben nun Tests mit komplexeren Hypothesen eine größere Power (d.h. für größere Zahlen von Faktorstufen werden geringere Stichprobengrößen benötigt), auch wenn die *dfh* in den Nenner des F-Bruchs eingehen?

Dieser zunächst vielleicht irritierende Umstand, der von Ihnen angesprochen wird, lässt sich dadurch erklären, dass komplexere Hypothesen mehr Festlegungen des Forschers beinhalten – eine größere Anzahl von *dfh* bedeutet, dass weniger zufällige Varianzquellen in den Hypothesentest eingehen. Dieser Sachverhalt soll an einem kleinen Beispiel verdeutlicht werden: Zwei Gruppen werden unter zwei unterschiedlichen experimentellen Treatments untersucht, es handelt sich also um ein einfaktorielles Design mit zwei Faktorstufen. Der Unterschied zwischen beiden Gruppen äußert sich darin, dass ein gewisser Anteil der Varianz in der AV durch die Gruppenzugehörigkeit aufgeklärt werden kann. Dennoch gibt es aber auch einen Varianzanteil der AV innerhalb der Gruppen

("Fehlervarianz"). An denselben Experimentalgruppen sei nun aber auch das Geschlecht mit erhoben worden, das ebenfalls in einem gewissen Zusammenhang mit der AV steht. Damit kann nun mehr Varianz zwischen den (nun vier anstatt zwei) Gruppen aufgeklärt werden, die Varianz innerhalb der Gruppen reduziert sich (vgl. dazu Moosbrugger, 2003, S. 150). Damit kann also festgestellt werden, dass die Power zum Aufdecken eines Effektes in der Varianzanalyse nicht nur mit der Stichprobengröße, sondern (in gewissem Maße) auch mit der Anzahl der Faktorstufen bzw. der Anzahl der Faktoren steigt. Aus wissenschaftstheoretischer Perspektive ist dieses Phänomen aber kritisch zu beleuchten: Durch die Aufnahme immer weiterer Faktorstufen oder Faktoren wird ein Modell "überparameterisiert", d.h. es besteht (genau wie bei zu großen Stichproben) die Möglichkeit, dass an sich zufällige Effekte signifikant werden (für eine wissenschaftstheoretische Diskussion vgl. z.B. Mulaik, 2001).