CHEMNITZ UNIVERSITY OF TECHNOLOGY

Be motivated to pay attention!

How driver assistance system use experience influences driver motivation to be attentive

Dissertation

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Für Elias und Miko.

Denn -ihr- seid die Zukunft.

“Nothing is as practical as a good theory.“

„Nichts ist so praktisch wie eine gute Theorie.”

Kurt Lewin (1890 - 1947)

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List of included Publications

This thesis is based on the following publications:

Publication	relevant for…	State of publication (December, 9th, 2015)	Contribution of the Co-Authors	
Haupt, J., Risser, R. (2014). Motivational factors when investigating ADAS impacts on driver behaviour. In A. Stevens, C. Brusque, & J. Krems (Eds). *Driver adaptation to information and assistance systems*. IET published book. ISBN: 978-1-84919-639-0; E-ISBN: 978-1-84919-640-6.	Chapter 1 (pp.1-39)	published	Ralf Risser	commented on the chapter
Haupt, J., Kahvedžić-Seljubac, A., Risser, R.(2015). The role of driver assistance experience, system functionality, gender, age and sensation seeking in attitudes towards the safety of driver assistance systems. *IET Journal of Engineering*, *9*(7), 716-726. doi: 10.1049/iet-its.2014.0199	Summary (short description of Study IIb, pp.ix, x), Chapter 4 (the whole chapter, pp.91-107)	published	Amila Kahvedžić-Seljubac	supported the literature research and proof-reading the paper
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Publication	relevant for…	State of publication (December, 9^{th}, 2015)	Contribution of the Co-Authors	
Haupt, J., Van Nes, N., Risser, R. (2015). Look where you have to go! A field study comparing looking behaviour at urban intersections using a navigation system or a printed route instruction. *Transportation Research Part F, 34*, 122-140. doi:10.1016/j.trf.2015.07.018	Summary (short description of Study III, p.x), Chapter 5 (the whole chapter, pp.117-1613.), Chapter 6 (discussion parts of this study, pp.158f., 162f., 170f.)	published	Nicole Van Nes	contributed to the analysis of the qualitative data; supported the interpretation of the results; commented on the paper and supported in proof-reading
			Ralf Risser	commented on the paper

Summary

Distraction and inattention are two major factors contributing to road traffic accidents (e.g. Stutts, Reinfurt, Staplin & Rodgman, 2001; Klauer, Dingus, Neale & Sudweeks, 2006; McEvoy, Stevenson & Woodward 2007). A plethora of studies have been done so far in order to investigate potential influence factors that increase the level of driver inattention and distraction (e.g. Wege, 2014). Driver assistance systems (DAS) are assumed to potentially influence driver inattention and distraction negatively (e.g. see Wege, Pereira, Victor & Krems, 2013). The majority of recent and past studies investigating the effects of DAS on human behaviour have focused on changes in cognitive processes like the level of driver attention, situation awareness, workload, etc. (e.g. Popken, 2009; Wege, 2014; Dotzauer, 2015). The relevance of this kind of research is clear: paying attention to the environment while driving in order to be able to react appropriately to the given situation obviously represents both driver cognitive processes and the tactical level of the driving task that is often treated as 'the' driving task (e.g. Nilsson, 2005). However, as introduced with hierarchical driver behaviour models: driving involves more than the steering and reacting to the situation appropriately which is represented in Hatakka's (1998, 2000) driver behaviour model two lowest levels: vehicle manoeuvring and mastering traffic situations. It also concerns driver attitudes towards traffic safety and safe behaviour in traffic, driver perceived risk and other motivational factors, represented on higher levels of the driving task: goals and context of living (1998, 2000) or the strategic level of driving according to Michon (1985).

This thesis has four main general objectives. Firstly, it aims to identify the relevance and role of motivational factors when the effects of DAS are investigated. Secondly, in contrast to past and the majority of recent studies (e.g. Vadeby, Wiklund & Forward, 2011; Wallén Warner & Åberg, 2008), this work aims at investigating the influence of actual DAS use experience. Thirdly and fourthly, this work intends to gain a better understanding of influencing variables on driver attitudes towards and of the effects of motivational processes on cognitive processes in response to traffic safety measures.

In order to achieve these objectives, three empirical studies addressing four different research questions were carried out: a focus group study, a questionnaire study and a field operational test study. Within these studies, qualitative and quantitative methods were applied in order to collect subjective (e.g. perception of risk, beliefs concerning DAS, beliefs concerning carrying out secondary activities while driving) and objective data (e.g. glance data, speed). The qualitative approaches included focus group studies and their analysis based on the Grounded Theory (Glaser & Strauss, 1967), and behaviour observations of video data collected within a field driving study.

Study I: This study which is introduced in Chapter 2, was conducted to identify relevant motivational aspects that may be influenced when DAS are used. The main objective of this study was to develop a theoretical model of motivational factors that determine the engagement in secondary activities. Thereby, drivers' DAS use experience was handled as key variable. It was aimed to identify the role of drivers' DAS use experience on motivational factors and consequently on drivers' engagement in carrying out secondary activities while driving. Focus group discussions were conducted and analysed by applying elements of grounded theory. Four motivational categories that are affected by DAS use experience and that determine drivers' engagement in secondary activities were identified. These are safety-related beliefs concerning DAS, perceived behavioural control, perceived risk and safety-related beliefs concerning carrying out secondary activities. Based on these results, a theoretical model was established: the STADIUM model (*S*econdary Ac*T*ivity Eng*A*gement *D*epending on the *I*nfl*U*ence of DAS use experience on *M*otivational factors). The STADIUM model postulates that DAS use experience directly determines drivers' safety-related beliefs concerning DAS and drivers' perceived behavioural control. Perceived behavioural control is additionally expected to be influenced by safety-related beliefs concerning DAS, safety-related beliefs concerning carrying out secondary activities and the actual execution of secondary activities. Moreover, perceived behavioural control is hypothesized to affect drivers' perceived risk and drivers' safety-related beliefs concerning secondary activities, which determine the actual engagement in secondary activities. The interplay of motivational factors is assumed to be affected by a number of other external variables (beside actual DAS use experience) like the type/state of the vehicle, the traffic situation, other road users etc. The STADIUM model helps to better understand the role of motivational factors for the execution of secondary activities while driving, and the way they are affected by DAS use experience.

Study IIa: The purpose of this study that is introduced in Chapter 3 was to test the core assumptions of this STADIUM model. Thereby, it firstly focused on the stated relations how the actual DAS use experience influences directly and indirectly several motivational factors. Secondly, it focused on the hypothesized relations how driver intentions to carry out secondary activities while driving are directly and indirectly affected by those motivational factors and the DAS use experience. Two hundred and eleven drivers participated in this questionnaire study. Data about participants' DAS use experience and the motivational constructs: perceived risk, perceived behavioural control, safety-related beliefs concerning DAS, safety-related beliefs concerning secondary activities and intentions to carry out secondary activities while driving were collected. As hypothesized in the STADIUM model, a path analysis showed that DAS use experience significantly correlated with perceived behavioural control and safety-related beliefs concerning DAS. The results revealed that DAS use experience indirectly affects driver safety-related beliefs concerning carrying out secondary activities that were found, as expected, to be significantly linked to driver intentions to carry out secondary activities. Additionally, results showed that intentions to carry out secondary activities while driving are indirectly influenced by perceived behavioural control. The results of this study provide evidence on the influence of DAS use experience on motivational variables, the effect of the motivational variables on driver intention to carry out secondary activities, and the role of DAS use experience on the intention to carry out secondary activities. Seven of nine hypotheses stated in the STADIUM model could be confirmed. Reasons why two hypotheses could not be confirmed are discussed in terms of methodological limitations of this study.

Study IIb: In Study IIa (see Chapter 3) DAS use experience and driver attitudes towards DAS were found to play an important role. In this study IIb (see Chapter 4), the questionnaire data were used to investigate driver safety-related attitudes towards DAS in more detail. Drivers were asked about their safety-related attitudes towards 29 different systems that are currently available on the market. Potential influencing variables that were expected to affect driver safety-related attitudes towards DAS were considered: gender, age, level of driver sensation seeking and driver DAS usage experience. Results show that, in terms of safety, there is great variation in how drivers evaluate the 29 systems. Consequently, system functionality and the time when the system was launched are discussed. No general effects were found for gender and level of driver sensation seeking on safety-related attitudes towards DAS. Driver age correlated positively with indirect safety-related attitudes towards 26 of the 29 systems. Controlling the variable 'DAS use experience,' 22 relations between age and attitudes towards DAS were found. Results reveal that the more experience drivers have in using DAS, the higher they judge DAS in terms of safety. On the basis of the study results, research issues for future research on traffic safety related to DAS were identified.

Study III: In this study, introduced in Chapter 5, experienced navigation system users (*N* = 20) drove a given unfamiliar route twice: once with the navigation system activated and once with a printed instruction including a route instruction. Driver video and vehicle speed data were conducted. Driver glance behaviour was analysed quantitatively and qualitatively. Speed behaviour was analysed quantitatively. Quantitative analysis indicated that drivers passed intersections slower when they used the printed instruction than when they used the navigation system. Drivers looked more often and in proportion longer to the side scene when they used the printed instruction and made less and proportionally shorter glances away from the road scene and to the instruction than when they were supported by the navigation system. No difference was found between these two conditions in the total number of glances and the amount and duration of glances to the forward scene. A qualitative analysis provided understanding of the quantitative results: the type of route guidance was identified to influence drivers' motive for scanning the side road scene. When the navigation system was used the motive was primarily to look for potential hazards and when the printed instruction was used the motive was more focused to look for salient orientation points. The outcomes of the study are discussed in terms of looking motive and the 'look but failed to see' phenomenon (Brown, 2005).

Concluding, this work provides an in-depth-view of driver motivational aspects when DAS are considered (Chapters 1, 2, 3, 4 and 5). Thereby, the role of driver actual experience with DAS use was also identified and highlighted (see Chapters 2, 3 and 4). A central outcome of this thesis is the STADIUM model describing the interplay of motivational factors that determine the engagement in secondary activities while taking actual DAS use experience (see Chapters 2 & 3) into account. The role of motives in showing attentive behaviour depending on DAS (the navigation system) could also be underlined in the field study introduced in Chapter 5. The relevance, enrichment and need of combining qualitative and quantitative approaches when the effects of safety countermeasures on driver behaviour are investigated could also be shown.

The results are discussed in terms of hierarchical driver behaviour models, the theory of planned behaviour and its extended versions and the strengths of the introduced studies and limitations. Implications for traffic safety are provided and future research issues are recommended.

Zusammenfassung

Ablenkung und Unaufmerksamkeit sind zwei der Hauptursachen für Verkehrsunfälle (z.B. Stutts, Reinfurt, Staplin & Rodgman, 2001; Klauer, Dingus, Neale & Sudweeks, 2006; McEvoy, Stevenson & Woodward 2007). Es existieren eine Reihe an Studien, die untersuchten, ob FahrerInnen unaufmerksamer oder/und abgelenkter sind, wenn sie Fahrerassistenzsysteme nutzen (z.B. Wege, 2014). Es wird angenommen, dass sich die Nutzung von Fahrerassistenzsystemen (FAS) potentiell negativ auf den Grad der Aufmerksamkeit und der Ablenkung des Fahrers/der Fahrerin auswirken können (z.B. siehe Wege, Pereira, Victor & Krems, 2013). Die meisten der aktuellen und auch vergangenen Studien, die die Effekte von FAS auf das menschliche Verhalten untersucht haben, fokussierten auf Änderungen in kognitiven Prozessen, wie z.B. Grad der Aufmerksamkeit, des Situationsbewusstseins und des Workloads, etc. des/der Fahrers/Fahrerin (z.B. Popken, 2009; Wege, 2014; Dotzauer, 2015). Dies ist zweifelsohne sehr relevant, denn aufmerksam zu sein und die Umgebung während des Fahrens zu beobachten, um situationsangemessen reagieren zu können, repräsentiert beides: einerseits die kognitiven Prozesse des Fahrers/der Fahrerin und andererseits die ‚taktische Ebene' der Fahraufgabe, welches oft als ‚die' Fahraufgabe gesehen wird (z.B. Nilsson, 2005). Wie in hierarchischen Modellen des Fahrerverhaltens aufgezeigt wurde, beinhaltet Fahren jedoch mehr als die Steuerung des Autos und auf Situationen angemessen reagieren zu können, was lediglich auf den zwei niedrigsten Ebenen des Fahrerverhaltensmodels von Hatakka (1998, 2000) repräsentiert ist: ‚Fahrzeugmanövrierung' und ‚Bewältigung von Verkehrssituationen'. Es beinhaltet außerdem die Einstellungen von FahrerInnen bezüglich Verkehrssicherheit, die Einstellungen bezüglich der Tendenz, sich sicher im Verkehr zu verhalten, das wahrgenommene Risiko von FahrerInnen und andere motivationale Faktoren, welche höhere Ebenen des FahrerInnenverhaltens repräsentieren: die Ziele und den Kontext des Lebens (vgl. Hatakka, 1998, 2000) oder die strategische Ebene des FahrerInnenverhaltens (nach Michon, 1985).

Diese Arbeit verfolgte vier primäre, allgemeine Ziele. Erstens war es Ziel, relevante motivationale Faktoren zu identifizieren, die durch die Nutzung von FAS beeinflusst werden. Im Gegensatz zu vergangenen und der Mehrheit der aktuellen Studien zielte diese Arbeit zweitens darauf ab, den Einfluss der *tatsächlichen* Erfahrung mit FAS zu untersuchen. Drittens und viertens war es Ziel, einerseits ein besseres Verständnis über die Variablen, die die Einstellungen von FahrerInnen bezüglich FAS beeinflussen, zu erlangen und andererseits die Effekte von motivationalen Prozessen auf kognitive Prozesse besser zu verstehen, wenn die Effekte von FAS untersucht werden.

Um diese Ziele zu erreichen wurden drei empirische Studien durchgeführt, die vier verschiedene Forschungsfragen untersuchten: eine Fokusgruppenstudie, eine Fragebogenstudie und eine Feldstudie. Im Rahmen dieser Studien wurden qualitative und quantitative Methoden angewendet, um subjektive (z.B. das wahrgenommene Risiko, Einstellungen zu FAS, Normen bezüglich dem Durchführen von anderen Aktivitäten während des Fahrens) und objektive (z.B. Blickdaten, Geschwindigkeit) Daten zu erheben. Die qualitativen Ansätze beinhalteten Fokusgruppendiskussionen, welche basierend auf der 'Grounded Theory' (Glaser & Strauss, 1967) analysiert wurden und Beobachtungen, die ebenso systematisch analysiert wurden.

Studie I: Diese Studie, welche in Kapitel 2 vorgestellt wird, wurde durchgeführt, um einerseits relevante motivationale Faktoren zu identifizieren, welche beeinflusst werden, wenn FAS benutzt werden. Andererseits war primäres Ziel dieser Studie, ein theoretisches Modell zu entwickeln. Dieses Modell soll das Zusammenspiel dieser identifizierten motivationalen Faktoren erklären und wie diese Faktoren wiederrum bedingen, ob andere Aktivitäten (z.B. Telefonieren, Radio bedienen, etc.) während des Fahrens ausgeführt werden. Schlüsselvariable, welche dabei mit einbezogen wurde und deren Rolle aufgezeigt werden sollte, ist die tatsächliche Erfahrung mit FAS. Es wurden Fokusgruppendiskussionen durchgeführt, die analysiert wurden, indem Elemente der ‚Grounded Theory' angewandt wurden. Folgende vier motivationale Variablen wurden als jene identifiziert, die einerseits durch die Nutzung und Erfahrung mit FAS beeinflusst werden und andererseits in ihrem Zusammenspiel bedingen, ob FahrerInnen andere Tätigkeiten während des Fahrens ausführen: (1.) sicherheitsbezogene Überzeugungen zu FAS, (2.)

wahrgenommenes Risiko, (3.) sicherheitsbezogene Überzeugungen zum Ausführen anderer Tätigkeiten während des Fahrens und (4.) die wahrgenommene Verhaltenskontrolle. Basierend auf den Ergebnissen wurde ein theoretisches Modell, das STADIUM (*S*econdary Ac*T*ivity Eng*A*gement *D*epending on the *I*nfl*U*ence of DAS use experience on *M*otivational factors) Modell, entwickelt. Das Modell erklärt das Zusammenspiel zwischen den identifizierten relevanten motivationalen Variablen, wie diese motivationalen Faktoren durch die tatsächliche Erfahrung mit FAS beeinflusst werden und was die bewusste Entscheidung, andere Dinge während des Fahrens zu tun, bedingt. Das STADIUM Model postuliert, dass die tatsächliche Erfahrung mit FAS direkt die sicherheitsbezogenen Überzeugungen zu FAS und die wahrgenommene Verhaltenskontrolle bedingt. Das Modell nimmt außerdem an, dass die wahrgenommene Verhaltenskontrolle zusätzlich durch die sicherheitsbezogenen Überzeugungen zu FAS und der tatsächlichen Ausführung von Tätigkeiten während des Fahrens beeinflusst wird. Darüber hinaus wird die Hypothese aufgestellt, dass die wahrgenommene Verhaltenskontrolle bedingt, welches Risiko beim Fahren wahrgenommen wird und wie sicher es bewertet wird, andere Tätigkeiten während des Fahrens auszuführen, was wiederum beeinflusst, ob tatsächlich andere Tätigkeiten während des Fahrens ausgeführt werden. Es wurden neben der tatsächlichen Erfahrung mit FAS eine Reihe von externen Variablen identifiziert, von denen durch das Modell angenommen wird, sich auf dieses Zusammenspiel der motivationalen Faktoren auszuwirken, z.B. der Zustand des Fahrzeugs, der Fahrzeugtyp, die Verkehrssituation, andere VerkehrsteilnehmerInnen, etc. Das STADIUM Model trägt dazu bei, die Rolle der Erfahrung mit FAS und der motivationalen Faktoren und ihren Einfluss darauf, andere Tätigkeiten während des Fahrens auszuführen, besser zu verstehen.

Studie IIa: Der Zweck der Studie, die in Kapitel 3 vorgestellt wird, war es, die Kernannahmen des STADIUM Modells quantitativ zu testen. Fokussiert wurde dabei auf die erklärten Beziehungen im Modell, einerseits darauf, wie sich die tatsächliche Erfahrung mit FAS direkt und indirekt auf verschiedene motivationale Faktoren auswirkt und andererseits darauf, wie die Fahrerintentionen, andere Tätigkeiten während des Fahrens auszuführen, direkt oder indirekt durch diese motivationalen Faktoren und die tatsächliche Erfahrung mit FAS beeinflusst werden. Zweihundertelf FahrerInnen nahmen an dieser Fragebogenstudie teil. Folgende Variablen wurden erhoben: die tatsächliche Erfahrung mit FAS, wahrgenommenes Risiko, wahrgenommene Verhaltenskontrolle, sicherheitsbezogene Überzeugungen zu FAS, sicherheitsbezogene Überzeugungen dazu, andere Aktivitäten während des Fahrens auszuführen und die Intention dies zu tun. Die Berechnung der Pfadanalyse zur Testung des Modells zeigte, dass die Erfahrung mit FAS, wie im STADIUM Modell angenommen, signifikant mit der wahrgenommenen Verhaltenskontrolle und den sicherheitsbezogenen Überzeugungen zu FAS zusammenhängt. Die Ergebnisse zeigten, dass die Erfahrung mit DAS indirekt die sicherheitsbezogenen Überzeugungen dazu, andere Tätigkeiten während des Fahrens auszuführen, beeinflusst. Der letztgenannte Faktor hing signifikant, wie durch das Modell erwartet, damit zusammen, ob FahrerInnen tatsächlich beabsichtigen andere Tätigkeiten während des Fahrens auszuführen, was zusätzlich indirekt mit der wahrgenommenen Verhaltenskontrolle korrelierte. Die Ergebnisse der Studie zeigen den Einfluss der Erfahrung mit FAS auf motivationale Faktoren und wie diese motivationalen Faktoren damit zusammenhängen, ob während des Fahrens andere Tätigkeiten ausgeführt werden. Sieben der neun angenommenen Hypothesen des STADIUM Modells konnten durch die Analyse bestätigt werden. Die Gründe weshalb zwei Hypothesen durch die Daten nicht bestätigt werden konnten, werden hinsichtlich methodischer Grenzen der Studie diskutiert.

Studie IIb: In Studie IIa (siehe Kapitel 3) stellte sich heraus, dass die tatsächliche Erfahrung mit FAS und die Einstellungen von FahrerInnen zu FAS eine wichtige Rolle spielen. In dieser Studie IIb (siehe Kapitel 4) wurden die Fragebogendaten genutzt, um die sicherheitsbezogenen Einstellungen von FahrerInnen zu FAS detaillierter zu untersuchen. Die FahrerInnen wurden bezüglich ihrer risikobezogenen Einstellungen zu 29 verschiedenen Systemen befragt, die auf dem Markt erhältlich sind. Potentielle Einflussvariablen, von denen angenommen wurde, dass sie einen Einfluss auf die Einstellung zu FAS haben wurden betrachtet: Geschlecht, Alter, die Ausprägung von ‚Sensation Seeking' der FahrerInnen und die tatsächliche Erfahrung mit FAS. In den Ergebnissen zeigt sich, dass FahrerInnen die 29 Systeme bezüglich der wahrgenommenen Sicherheit unterschiedlich bewerten.

Als Gründe dafür werden die Systemfunktionalität und die Zeit, wann ein System auf den Markt eingeführt wurde, diskutiert. Es wurden keine Effekte für Geschlecht und ‚Sensation Seeking' auf die Einstellungen zu FAS gefunden, die eine allgemeine Aussage zulassen. Das Alter korrelierte signifikant mit den indirekten sicherheitsbezogenen Einstellungen zu 26 der 29 abgefragten FAS. Als die Variable ‚Erfahrung mit FAS' kontrolliert wurde, fanden sich noch immer 22 signifikante Korrelationen. Dabei wurden die FAS als sicherer bewertet desto älter die FahrerInnen waren. Die Ergebnisse zeigten, je erfahrener FahrerInnen mit der Nutzung von FAS waren, umso besser bewerten sie FAS bezüglich ihrer wahrgenommenen Sicherheit. Basierend auf den Studienergebnissen wurden zukünftige relevante Forschungsfragen im Bereich Verkehrssicherheit und FAS identifiziert.

Studie III: In dieser Studie, welche in Kapitel 5 vorgestellt wird, fuhren erfahrene NavigationssystemnutzerInnen (N = 20) zweimal eine ihnen unbekannte Route: einmal mit dem aktivierten Navigationssystem und einmal mit einer gedruckten Karte, die eine Instruktion beinhaltete. Fahrzeuggeschwindigkeit und Videodaten wurden erhoben. Das Fahrerblickverhalten wurde quantitativ und qualitativ analysiert, die Fahrgeschwindigkeit wurde quantitativ untersucht. Die quantitative Analyse zeigte, dass FahrerInnen langsamer durch Kreuzungen fuhren, wenn sie die gedruckte Instruktion nutzten als wenn sie vom Navigationssystem unterstützt wurden. FahrerInnen schauten öfter und anteilig länger zur Seite wenn sie die gedruckte Instruktion nutzten. Sie machten weniger und anteilig kürzere Blicke weg von der Straße und zur Instruktion als wenn sie vom Navigationssystem navigiert wurden. Es wurde kein Unterschied in der absoluten Anzahl der Blicke und der Menge und Dauer der Blicke nach vorn gefunden zwischen den zwei Bedingungen. Die qualitative Analyse lieferte eine Erklärung der quantitativen Ergebnisse: die Art der Orientierungshilfe beeinflusst die Motive der FahrerInnen, die Seiten zu scannen. Wenn das Navigationssystem als Orientierungshilfe diente, waren die Motive zur Seite zu sehen vorwiegend um nach potentiellen Gefahren zu sehen, während wenn die gedruckte Instruktion genutzt wurde, das Motiv eher war, nach salienten Orientierungspunkten zu schauen. Die Ergebnisse der Studie werden bezüglich der Motive des Blickverhaltens und dem 'Look but failed to See' Phänomen (Brown, 2005) diskutiert.

Diese Arbeit liefert einen gründlichen Einblick, welche Rolle motivationale Aspekte spielen, wenn FAS genutzt werden (Kapitel 1, 2, 3, 4 und 5). Dabei wurde auch die Funktion der tatsächlichen Erfahrung mit FAS identifiziert und hervorgehoben (siehe Kapitel 2, 3 und 4). Ein zentrales Ergebnis dieser Arbeit ist das STADIUM Modell, welches das Zusammenspiel motivationaler Faktoren in Abhängigkeit von der tatsächlichen Erfahrung mit FAS erklärt, die wiederum bestimmen, inwieweit und ob andere Aktivitäten während des Fahrens ausgeführt werden (siehe Kapitel 2 & 3). Außerdem konnte unterstrichen werden, welche Rolle Motive spielen, aufmerksames Verhalten in Abhängigkeit von der Nutzung von FAS (dem Navigationssystem) zu zeigen (Kapitel 5). Zusätzlich konnte dargestellt werden, wie relevant, bereichernd und nützlich es ist, qualitative und quantitative Methoden zu kombinieren, wenn die Effekte von FAS auf das FahrerInnenverhalten untersucht werden.

Die Ergebnisse werden diskutiert indem auf hierarchische Fahrerverhaltensmodelle, auf die Theorie des geplanten Verhaltens und ihre erweiterten Versionen und auf die Stärken und Schwächen der Studien Bezug genommen wird. Es werden Implikationen dargestellt und zukünftige Forschungsfragen und Problemstellungen empfohlen.

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1. Introduction

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"In the middle of difficulty lies opportunity."

(Albert Einstein, 1879-1955)

1.1. Outline

This thesis has 6 chapters. Chapter 1 provides an overview of the theoretical background while taking into consideration driver behaviour models, motivational factors and driver assistance systems (DAS). Additionally, the main general research questions of this work are highlighted. Subsequently, in Chapters 2 to 5, three empirical studies that address the research issues of this thesis are introduced. Chapter 2 describes a focus group study in which a new theoretical model, the STADIUM-model (*S*econdary Ac*T*ivity Eng*A*gement *D*epending on the *I*nfl*U*ence of experience on *M*otivational factors) was developed. The STADIUM-model characterizes the theoretical interplay of motivational factors determining drivers' engagement to carry out secondary activities like for example using the mobile phone while driving. As an external influencing variable, the model takes the driver's actual experience in using DAS into account. In Chapter 3, a study is presented that tested the core assumptions of this STADIUM-model quantitatively by using data of a conducted questionnaire survey. The study that is introduced in Chapter 4 also deployes the data of the conducted questionnaire study while taking certain potential moderating variables (gender, driver level of sensation seeking and driver experience in using DAS) that may have an influence on driver's attitude formation towards DAS into account. Chapter 5 describes a study that investigated driver glance behaviour at urban intersections. It compares the conditions of driving while using a printed map and route instruction with driving while being navigated by a navigation system. Chapters 2 to 5 are structured equally: first, the background to the particular research issue is introduced in detail; secondly, the applied methods are described; third, the results and findings are presented and the chapters close with the discussion of the outcomes. Finally, Chapter 6 provides overall conclusions of the outcomes based on the obtained results and suggests implications issues for a future research.

1.2. *Theoretical Background*

1.2.1. ***Understanding driver behaviour: models and approaches that aim at describing driver behaviour.***

When investigating the effects of DAS on driver behaviour, it is necessary first to understand the driver's behaviour and its related internal and external processes and aspects.

The driving task itself is a complex, dynamic control-task (Rouse, 1981). According to Nilsson (2005) the driving task includes the continuous monitoring of the environment, knowledge where and when to look, identification of the most important and relevant available information, appropriate responses to unexpected events as well as the ability to revise and change planned actions. In general, the driving task can be divided in three task categories: primary-, secondary driving tasks and tertiary tasks (see Vollrath & Krems, 2011; Loehmann & Hausen, 2014). The division underlines the complexity of driving. Primary driving tasks include all actions that are directly related to driving, like for instance steering the vehicle or accelerating. Secondary driving tasks are actions that support the primary driving tasks such as activating the direction indicator or high beam. Tertiary[1] tasks include actions that control in-vehicle systems, like for instance operating the navigation system or the radio. Talking to passengers can be assigned to tertiary tasks, too. Essentially, the driving task contains two basic modules: having the knowledge and applying it (top down processes) as well as reacting appropriately to (sudden) events (bottom up processes).

From this perspective is clear that external factors, in addition to the driver characteristics which are relevant for the observed driving behaviour, are also important.

[1] Note: Tertiary tasks are sometimes also termed as secondary tasks (see Vollrath & Krems, 2011). In this work either the term 'tertiary tasks' or the term 'secondary activities' are used.

Fastenmeier and Gstalter (2007) drew an analogy to working behaviour by describing both working and driving behaviour as behaviours distinctly related to special situational circumstances. Another analogy that can be drawn is of a person being sick and going to see the doctor: not only the visible symptoms are relevant for understanding and identifying the illness but also the causes. These causes might be internal, external or both. The 'Diamond' (see Chaloupka-Risser, Risser & Zuzan, 2011, Figure 1) illustrates five areas that influence road user behaviour and hence contribute to certain problems in traffic.

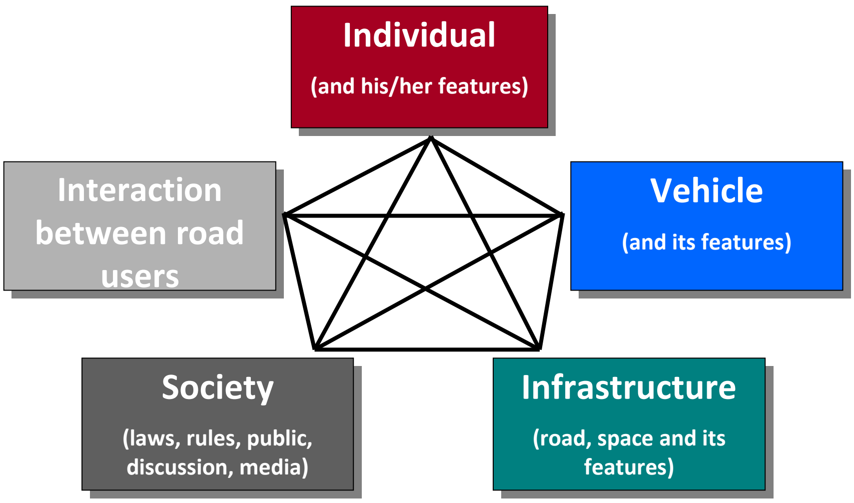


Figure 1. The diamond-interaction-model of relevant factors of the traffic system (see Chalopouka-Risser, Risser & Zuzan, 2011).

Since traffic is embedded in a complex interplay between several factors, usually no simple respectively clear deterministic cause-effect relationship can be exemplified. In order to derive a holistically enriching statement, the factors shown in Figure 1 and their interactions should be considered. The figure shows the interplay of influencing factors on road user behaviour: (a) the individual including for instance internal processes like motives, attitudes, experiences, state, etc.; (b) the vehicle including physical aspects such as height and technical features like assistance systems, etc.; (c) infrastructure including road and space characteristics such as road width and –surface, etc.; (d) society including existing laws and traffic rules as well as public discussions like discussed conflicts between cyclists and car drivers, etc.; and (e) the interaction between road users including non-verbal gestures such as showing the hand to say 'thank you' or verbal abuse such as an angry car driver shouting at the crossing pedestrian, etc. The overall idea behind the diamond model of traffic-influencing factors is that any characteristics and changes in one factor influence the other factors and vice versa.

By focusing on the 'individual' within this factor, it is apparent that a lot of aspects may have an influence on driver behaviour since driving is a multi-dimensional activity. Indeed, recent as well as older studies of driver behaviour have shown that appropriate driving performance skills (handling the vehicle) are not enough to perform safe driving behaviour on the road (e.g. Hatakka, 1998, 2000). Thus, research has highlighted that not only observable (driving) performance factors but also motivational aspects are relevant for safe driving behaviour (e.g. Wilde, 1994, Fuller, 2011). Simply explained, a driver may have the necessary skills to handle the vehicle safely but if he/she is not willing to make use of these skills for safe driving but, instead, prefers to drive in a risky manner, he/she will ultimately exhibit a risky driving behaviour on the road. Or, to provide another example, the driver in one case might have a reason to turn his/her head and glance to the right because a person he/she knows is just walking there while in another case because he/she is expecting hazard coming from the right. Different driver behaviour models aim at explaining the complexity of the 'individual' and hence of driver behaviour. An overview of several functional models of driver behaviour was conducted by Ranney (1994) and is presented in Figure 2 (see p.6). In this section, the hierarchical approaches will be considered in more detail. In section 1.2.2.2, the motivational models of driver behaviour will be introduced. For further information and references about the other approaches of driver behaviour see Ranney (1994).

Hierarchical approaches that aim at explaining driver behaviour usually follow the consideration that any changes on a certain level may influence aspects on another level. There are numerous hierarchical models that intend to describe the specific levels of the driving task and its interaction (e.g. Michon, 1985; Moe, 2008).

Two hierarchical approaches that are sometimes related to the levels of the driving task are the behaviour taxonomy of Rasmussen (1987) and the extended control model (ECOM, Hollnagel, Nåbo & Lau, 2003; Hollnagel & Woods, 2005).

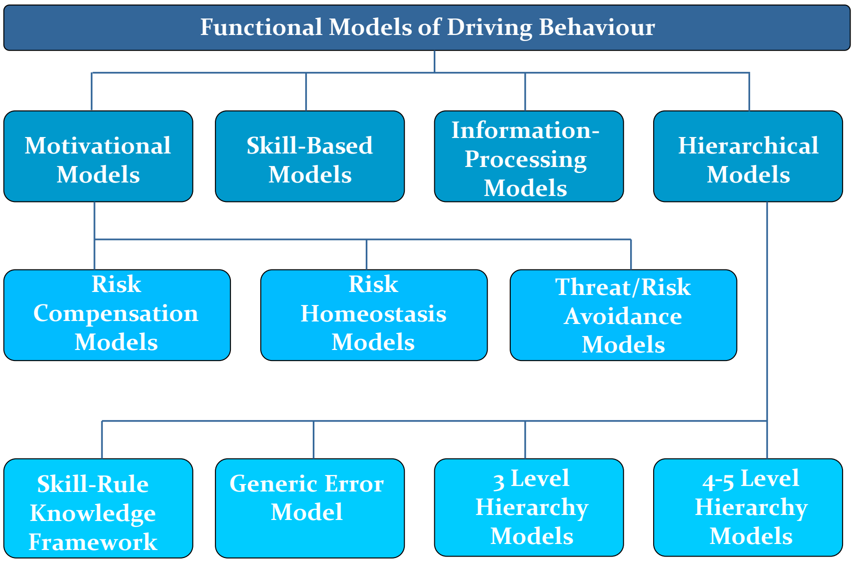


Figure 2. Functional Models of Driving Behaviour (adapted from Ranney, 1994, Hatakka, 1998, 2000, Keskinen, Peräaho & Laapotti, 2010).

Indispensable conditions to perform the driving task correctly are taken into account in the driving task models, but relevant human characteristics that may have a significant influence on the driving performance and thus on the driver behaviour are usually neglected. One exemplary hierarchical model that takes these aspects into account and which was established in the driver behaviour research is the model of Hatakka (1998, 2000). The driver behaviour model considers four levels of driving (see Figure 3, p.7) that will be subsequently explained in more detail.

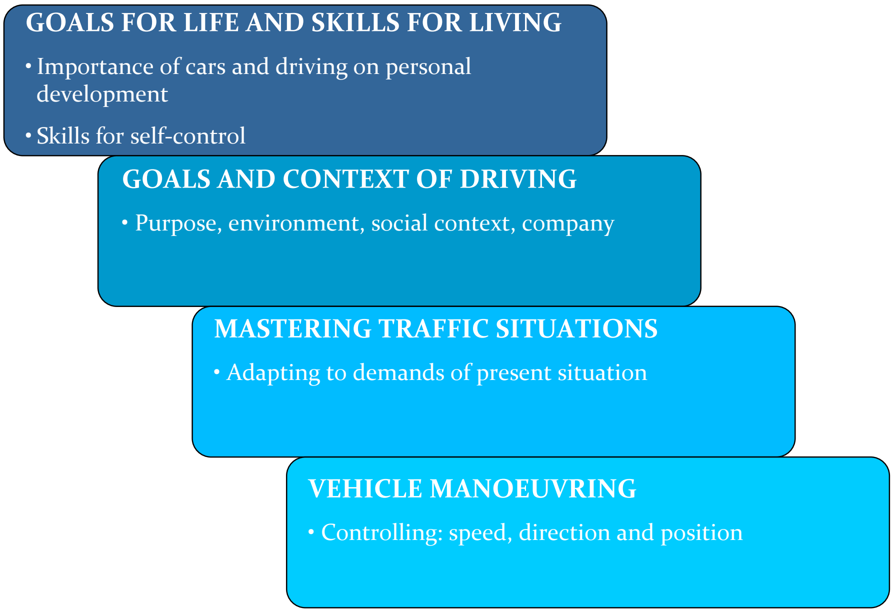


Figure 3. Hierarchical model of driver behaviour[2] (see Hatakka, 2000).

1. Vehicle Manoeuvring. This level of driver behaviour refers to the basic skills that are required for handling the vehicle. Thus, this includes knowledge of how the vehicle works, how to start it, how to steer it, how to operate gear change, gas and breaking pedal, switches (e.g. the indicator); how to control speed; and, how to determine direction and position of the vehicle. The majority of studies that investigate driver behaviour conduct variables of this level which represent the driver performance: lane deviation, speed, acceleration, deceleration, etc. This basic level is a precondition for a person to become a driver. In the case of a driver who is lacking skills that are necessary for a successful performing of the driving task on this level, the driving task cannot be completed. Therefore, to have the skills that are necessary to perform the driving task is the vital condition to be able to drive a vehicle.

Driver performance on this level can be influenced by external factors (not driver-related) such as faulty components of the vehicle. In addition, it can also be affected by changes on higher levels of this hierarchical model: Imagine the driver is a young man of 25 years of age. It is statistically proven that young male drivers are

[2] In the meanwhile the model was extended by adding a fifth 'organisational' level representing Company awareness, Characteristics and safety situation. (see Keskinen, Peräaho & Laapotti, 2010)

the driver group that is most often involved in fatal accidents (e.g. Horvath, Lewis & Watson, 2012). Individuals in this group (young males aged 25 or so) are usually highly influenced by their peers (e.g. Rienzi et al., 1996, Møller & Haustein, 2014). The driver's friends may tempt him that it is "cool" to drive without a seat-belt, not to indicate direction changes, that it is alright to speed, drink and drive or even to take drugs. As the young male driver wants to be a part of this group, he might agree and approve of their opinion and thus start to behave like his peers would do. This social effect reflects the fourth level, *Goals for life and skills for Living*, of the driver behaviour model. Consequences in this case may be a young male driving without operating the indicator, driving while drunk or speeding. Thus, his performance on this basic level of driving can be influenced by certain characteristics of a higher level of driver behaviour, in this case: the social influence by the peer group and the resulting attitudes of the driver.

This basic level of driving behaviour is almost always considered in models that depict the driving task, and is deemed as the 'base of driving'. For instance, in Moe's driving process model, vehicle manoeuvring is reflected in 'acting'. The level is also represented in Michon's hierarchical driving task approach (1985) and as in the other models it is also the lowest level, labelled 'operational' level. Some of the tasks that have to be completed on this manoeuvring level are also included in Michon's second tactical level of driving. The 'tracking' level suggested by the ECOM (Hollnagel, Nåbo & Lau, 2003; Hollnagel & Woods, 2005) reflects the vehicle manoeuvring level when it is used for describing driving behaviour. Taking Rasmussen's framework (1987) into account, performance on this level is mainly skill-based. The driver has to operate directly, on-site and does not have much time to act. But there are also conditions, in which this task level may require rule- or knowledge based behaviour. For instance, in cases where a driver drives an unfamiliar car for the first time he/she acts more rule-based than if he/she was already familiar with the vehicle and would hence drive more or less automatically. In case the person is a novice driver and drives the car for the very first time he/she behaves knowledge-based. Considering the diamond interaction model of relevant factors (see Chaloupka-Risser, Risser & Zuzan, 2011), this driver behaviour level involves two 'diamond-corners': *the individual* and *the vehicle*. Any changes in one of these two dimensions may lead to changes in performance on this level.

2. *Mastering Traffic Situations*. The traffic system is diverse: there are different road types (rural-, urban road, highway), traffic light regulated, no traffic lights, different road widths, presence of other road users like other vehicles, cyclists, pedestrians, etc. In order to drive safely, the driver must adjust the driving performance to different scenarios. This requires first the observation of the environment and then the detection and recognition of the particular situation/event. The driver needs a certain level of awareness and anticipation in order to be able to perceive potential hazards. Further on, the driver has to be able to evaluate the situation and subsequently to make decision(s) regarding how to (re)act to it. It is not sufficient to be able to steer a vehicle to have the skills that are necessary to fulfil the tasks on this second level of driver behaviour. However, in order to drive safely and take part in traffic without increasing risk on the road it is vital that the driver has the skills that are required on this level. Therefore, the driver must have knowledge of the traffic rules and has to be trained to recognise, evaluate and appropriately react to certain situations in order to be able to perform an automatic behaviour. For instance, the driver must be able to stop immediately when the lights turn red or in case of a pedestrian crossing the road or when another road user has the right of way.

Driver behaviour on this level may also be affected by both internal and external variables. The internal factors may include issues induced on a higher level of this hierarchical driver behaviour approach. Let us go back to the example of the 25 years old male driver. In addition to being influenced by his peer group, he enjoys risk-taking and is therefore more prone to risk taking activities. He is single, has no children and is not particularly worried about the possibility of incurring an injury or damaging his car or his future in general. Driving may in fact serve for him as a status symbol. His attitudes to life, to risk taking behaviour and how he defines himself may also be reflected in his attitudes to risky driving and will consequently be reflected in: not caring for priority rules in traffic, ignoring speed limits (preferring rather 'sporty' driving) or non-wished-for attitudes towards other road users. These motives and goals of driving are part of the third level of driving behaviour model known as "G*oals and context of Driving"*. This example serves as illustration that performance on this level may be influenced by the characteristics of higher levels. Therefore, even if the 25 year old male driver has the necessary skills to perform the task of driving on this level correctly, on the higher level he might set his priorities differently which can result in failures in driving performance. External variables that may affect the performance of this level are for example: the infrastructure (e.g. road type, lights, road width, etc.), traffic rules (e.g. priority rules like 'right before left', speed limits, etc.) and other road users. These three factors and their particular characteristics are determining the situations which the driver may experience and to which he/she has to adapt to.

So, getting back to the Diamond interaction model of traffic relevant factors (see Chaloupka-Risser, Risser & Zuzan, 2011), this driver behaviour level is influenced by the characteristics and the interplays of its 'corners': *the individual*, *the infrastructure*, *the society* and *the interaction*. This level of driver behaviour is also represented in the driving task models of Moe (2008) and of Michon (1985); Moe proposed three hierarchical steps that are included in this level: detecting, recognizing and deciding and Michon's tactical level can be seen as equivalent. In Rasmussen's approach (1987), this level of driving is reflected usually in rule-based actions, i.e. to follow rules regarding how to behave in particular situations. But in some circumstances it may also require skill-based (e.g. automated activities in cases such as the passing of a familiar intersection) or knowledge-based behaviour (e.g. when a driver encounters a rare situation like for instance getting a skidding vehicle under control). If the ECOM (Hollnagel, Nåbo & Lau, 2003; Hollnagel & Woods, 2005) is used in order to explain driver behaviour, the actions and skills necessary for the *mastering of traffic situations* level reappear on the 'regulating' and 'monitoring' levels.

3. Goals and Context of Driving. As already shown with the example of the 25 year old male driver, the driving performance variables on the first two levels, *vehicle manoeuvring* and *mastering traffic situations* are not the only internal factors that represent driver behaviour. This third level of driver behaviour considers motives, goals and circumstances of driving. The following questions must be asked: Why is the person driving? What function does driving have for the person? When is the person driving? What are the starting point and the destination of the driver? Which route does the driver choose, and why? Who joins the driver as a passenger? In which condition is the driver: Is he/she tired? Is he/she driving under the influence of medicine, alcohol or drugs? Etc. What is the purpose of the trip (e.g. private, professional, leisure etc.)? On this level, it is critical to assess whether the driver fails in this part of driver behaviour or not. For instance, in the example of driving under the influence of any mind-altering substances it is apparent that competent driving requires of the driver to be able to perform the task without being influenced by any substances. If the driver 'fails' on this level it is because he/she is dependent on drugs. But for instance, it is not possible to assess the purpose of a trip or the choice of a certain destination as 'failure' or 'success'. Nevertheless, as already demonstrated by the example of the 25 year old male driver, any behaviour of the driver reflected on this level affects the lower levels of driver behaviour. As an example, the choice of the route determines the situation the driver is going to experience. The driver has to adapt to the 'chosen' situation that affects behaviour variables of level two. Driving under the influence of alcohol may affect *mastering traffic situations*, e.g. by changes in awareness, visual field of view, reaction time, etc. (e.g., West, Wilding, French, Kempi & Irving, 1993; Christoforou, Karlaftis & Yannis, 2013). It may also affect *vehicle manoeuvring*, e.g. not being able to start the vehicle, having problems to keep the vehicle in the driving lane, etc. (e.g., Harrison & Fillmore, 2011, Veldstra et al. 2012). Thus, to fulfil this third level of driver behaviour, the driver needs decision and planning skills; to choose destination, route, starting time etc. Further on, the driver must have the correct attitude towards the driving task and any driving related issues and must show a clear understanding of his/her motives; e.g. to correctly answer the question: 'Is it okay to drink and drive, or not?'

Within the diamond interaction model (Figure 1, p.4, see Chaloupka-Risser, Risser & Zuzan, 2011) this third level of driver behaviour is also represented in the 'corner' as *the individual*. Since persons have an opinion about most matters (more or less consciously), all 'corners' of the diamond model and its characteristics may influence this third level of driver behaviour. Depending on the kind of vehicle (e.g. type, year of car certification, colour, horsepower), the condition of infrastructure (e.g. road type, surface, width, design of priority issues), the structure of society (e.g. applicable laws & rules, informal norms), the presence or absence of other road users (e.g. other vehicles, vulnerable road users), and the individual characteristics (e.g. level of sensation seeking, health status) drivers may develop different opinions about these factors. The ECOM model (Hollnagel, Nåbo & Lau, 2003; Hollnagel & Woods, 2005) takes actions that are related to this *goals and context of driving* level within its 'targeting' level into account. In comparison, relevant issues of this third level are not considered in Moe's (2008) driving process model and are seldom reflected in Michon's (1985) driver- and Rasmussens' (1987) behaviour models. Instead, these approaches take the decision processes on the strategic level (Michon, 1985) into account, as is the case for choosing the route, which can be considered as knowledge-based behaviour (Rasmussen, 1987). However, attitudes towards are neglected in these cases. A person may have the skills that are required for this level, may have an opinion about all driving relevant issues, may think strategically and be able to plan a route etc., but it is possible, that this person is not able to drive. In this case, attitudes may be irrelevant and one has to consider the mere driving task. However, for example driving under the influence of alcohol or thinking that speed limits are not relevant may affect the practical behaviour in traffic negatively. Then it is important for the road safety to take *goals and context of driving* behaviour into account when investigating driver behaviour.

4. Goals for Life and Skills for Living. The highest level of the Hatakka's driver behaviour model (1998, 2000) refers not only to issues that are linked to driving directly but to other important factors too: personal status, personal motives and attitudes are regarded from broader contexts that are not necessarily focused on driving and traffic. This level yields a number of questions. Under what circumstances does the driver live? What kind of lifestyle does he/she have? How old is the driver? To which social group, -culture and –position does the driver belong? Consideration of these factors is relevant since past studies have shown that personal variables such as age (e.g. Balogun, Shenge & Oladipo, 2012), social status (e.g. Taubman-Ben-Ari & Katz-Ben-Ami, 2012) and gender (e.g. Cestac, Paran &

Delhomme, 2011) may have an influence on driver performance (that is reflected on the two lower levels). Although, several studies have detected certain effects, other hierarchical models do not consider the fourth level of the driver behaviour model that to a large degree reflects motivational factors into account. The reason might be the same as for the neglect of some variables on the third level: everyone belongs to a social group, is of a certain age and gender, and has his/her own attitudes and goals in life. However, not everyone is a driver. These personal, internal variables that belong to the 'corner' of the individual of the diamond model (see Chaloupka-Risser Risser & Zuzan, 2011) are not a condition to ensure driving ability. Furthermore, motivational factors are 'invisible' in the driving performance itself. However, as they are relevant for the behaviour outcomes on the lower levels and thus with some probability influence road safety, it is necessary to take motivational factors into account when driving behaviour is investigated.

*1.2.2. **Motivation and driving.***

Motivation is related to human behaviour and more specifically relates to internal processes that determine our behaviour when a particular goal is aimed to be achieved (Ajzen & Fishbein, 2005). Motivation manages available resources. A person is motivated to make an effort and to act in a certain way in order to satisfy his/her needs and to achieve a certain wish/goal. Thus, motivation drives people to act, to behave, to evaluate, to judge, to feel and to believe in their actions.

> "Motivated behaviour is energized, directed, and sustained." (Santrock, J., 1997, p.425)

Human beings and their behaviour are very complex. Approaches to justify human behaviour and internal related processes are diverse. To make the distinction between 'right' and 'wrong,' it is necessary to consider all relevant perspectives. Therefore, when driver behaviour is described as a whole, it is important to consider motivational factors in addition to cognitive and regulatory processes and performance variables. In the following, some motivational driver behaviour models and simultaneously, the role of particular motives will be dealt with in more detail.

Homeostasis is an adaptive mechanism that describes how a system aims to achieve or maintain an equilibrium or a steady state in the response to the presence of certain stimuli. In relation to this, Wilde (1982, 1994) proposed the risk homeostasis theory. Wilde's basic assumption is that individuals have a stable subjectively perceived level of risk which they accept. If the perceived risk changes due to any changes in the traffic system (see the diamond interaction model, Figure 1, p.4), for instance if technical support systems are installed in the vehicle, the drivers' level of perceived risk may change (Rajaonah, Tricot, Anceaux, Millot, 2007). It may increase or decrease. In order to restore the usually accepted level of risk, the driver adopts an alternative behaviour. If the perceived risk increases, he/she drives more carefully (slower, pays more attention to potential hazards, etc.); if it decreases, the driver exhibits more risky driving (higher speeds, overtaking, paying less attention to the driving task, etc.).

Another motivational approach that also considers risk is represented in the risk-threshold-models (e.g. Näätänen, Summala, 1974; Näätänen, Summala, 1976; Summala, 1985; Summala, 1988). In this approach, risk is taken into account from two perspectives; from the (1) subjective and from the assumed (2) objective points of view. The postulate is that drivers try to keep subjective and (assumed) objective risk in balance – i.e. they want to have the risk under control. It is also assumed that drivers are aware of a range of traffic situations that they perceive as safe. The upper limit of this safety margin serves as a threshold. The situation is perceived as being risky when the limit is exceeded. Two issues determine the level of perceived risk: the perceived likelihood of experiencing a hazardous situation and how the driver assesses the potential consequences of such a situation. The most recent version of the risk-threshold models is the risk allostasis theory proposed by Fuller (2011). His theory proposes that drivers strive to maintain a level of risk which they subjectively perceive within a preferred range. The theory highlights the role of driver feelings and decision making. Representatives of risk-threshold models assume that the subjectively perceived risk determines the driver behaviour. In general, drivers perceive a low risk in traffic ('Zero-risk theory') and feel rather safe. If the perceived risk increases and exceeds the subjective threshold, the driver shows compensatory behaviour such as slower and more careful driving and is more attentive in order to bring perceived risk back below its subjective threshold.

Fuller (1984) proposed the risk/threat-avoidance model in which he assumes that drivers have two main motives: to reach a destination and to avoid experiencing any hazardous situations. Participation in traffic increases the probability of being exposed to hazards. Thus, the motivation to reach a destination conflicts with the motivation to avoid hazards. In order to reach the intended destination, the driver must interact with other vehicles and road users (e.g. vulnerable road users), road construction sites, technical issues of the vehicle, etc. It is clear that from the starting point of the journey to the final destination, the driver is continuously confronted with potential hazards and obstacles. Nevertheless, instead of avoiding these hazards, persons proceed with their intended expeditions from start to finish. In the end, driving and experiencing many different situations serves to inform what kind of situations can be assessed as 'hazardous', and how, with necessary precautions, these may be avoided.

Motivational driver behaviour models show the relevance of taking motivational factors into account when driver behaviour is investigated. In the following, the role of motivation in behavioural adaptation due to driver assistance system use is considered.

1.2.3. *The role of motivation in behavioural adaptation due to driver assistance system use.*

1.2.3.1. *Driver assistance systems*

Driver assistance systems (DAS) are systems that support the driver by taking over or facilitating parts of the driving task. Generally, DAS can be categorised into systems that 1) provide information to the driver (such as the Navigation System that provides the information about the route), 2) warn the driver of potential hazards (such as the Lane Departure Warning System that warns the driver when she/he is about to cross the road markings) or 3) intervene in the driving task (such as the Emergency Brake Assist that automatically initiates an emergency brake in case of the detection of a hazardous situation). Systems may combine two or all three characteristics of system functionality. Eskandarian (2012) categorised DAS into five categories according to their respective level of intervention:

- informational;
- warning-alerting;
- partial semi-control;
- automatic full-control and
- autonomous driver assistance systems (see Table 1).

Table 1. *Classification of driver assistance systems based on their level of intervention according to Eskandarian (2012).*

Classification of DAS	Function or task (perception: sensing, estimating, computing)	Interaction with driver or intervention in driving task (response action)
(1.) Informational	Sense environment, road, weather, retrieve real-time or archival data	Enhance situational awareness and monitor conditions: display and present the relevant information
(2.) Warning-alerting	Sense condition, evaluate situations and potential hazards, decide when and what to do, decide corrective action	Alert the driver to potential hazards and possibly recommend corrective actions (slow down, brake, steer)
(3.) Partial (semi) control	Sense condition, evaluate situations and potential hazards, decide when and what to do, decide corrective actions	Provide both warnings/alerts and partial control functions (e.g., apply partial brake force, stiffen gas pedal to retard speeding)
(4.) Automatic (full) control	Sense condition, evaluate situations and potential hazards, decide when and what to do, decide corrective actions	Apply the vehicle control function as needed (automatically apply the brakes, ESP, etc.)
(5.) Autonomous control	Have a trip plan (from origin to destination), have navigation plan, vehicle guidance and control, sense condition, evaluate situations and potential hazards, decide when and what to do, decide corrective actions	Execute the trip plan, generate navigation, guidance, trajectory plan, and execute vehicle control; execute collision avoidance and redirection, and reroute plan and control as necessary

This work includes all proposed categories by Eskandarian (2012). DAS in this thesis is regarded as any technical assistance that supports the driver on a certain level or category of the driving task. The studies presented in Chapter 2, 3 and 4 consider a variety of DAS and consider systems from all categories. In chapter 5, a study is presented that investigated the effect of using the navigation system. Navigation system can be assigned to the first category of DAS (informational DAS) quite in line with Eskandarian's classification. Using the navigation system requires skills of the secondary driving task category (understanding and implementing information provided by the navigation system) and tertiary task category (operating the navigation system, according to the categorisation presented in Vollrath & Krems, 2011 and Loehmann & Hausen, 2014).

As different DAS cover different functions, they support different parts of the driving task: for instance primary driving tasks by keeping the vehicle in the lane actively, exemplarily secondary driving tasks by automatically switching the lights on or for example the strategic level of driving by providing route information. DAS support on the different levels of driving may seem to be very differently, however, every DAS support simplifies driving and contributes to a safe completion of driving task as a whole. By adding DAS to the driving task and driving context, a new component is added to the traditional diamond-interaction-model (see Figure 4, p.18). This change may lead to certain adaptations in driving behaviour.

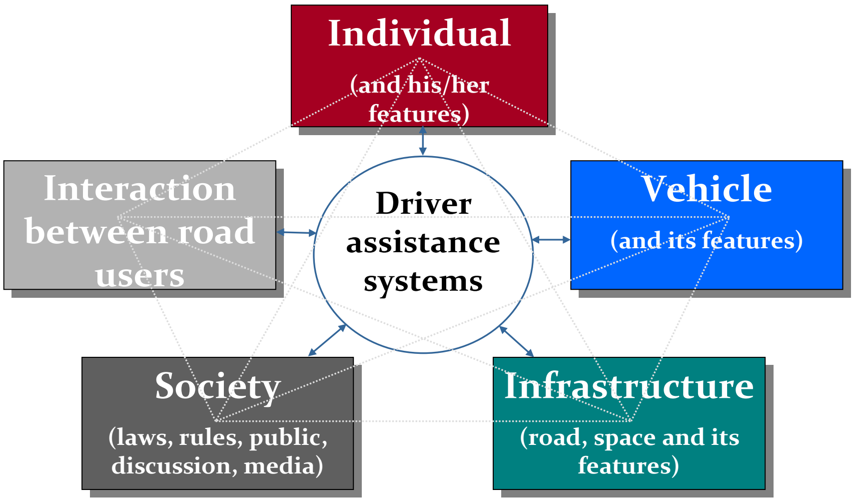


Figure 4. Addition of driver assistance systems as a sixth component to the diamond-interaction-model adapted from PROMETHEUS (1989) and the diamond interaction model (see Chaloupka-Risser, Risser and Zuzan, 2011)

These adaptations can be related to traffic safety in a positive, neutral or even negative manner. Behavioural adaptations were defined by the OECD (1990) as:

> "… those behaviours which may occur following the introduction of changes to the road-vehicle-user system and which were not intended by the initiators of the change. Behavioural adaptations occur as road users respond to changes in the road transport system in a way that their personal needs are achieved as a result. They create a continuum of effects ranging from positive increase in safety to a decrease in safety."

Behavioural effects induced by the use of DAS raised much awareness in the research sector. Earlier and recent studies investigated the influence of the use of DAS on driver behaviour (Brouwer & Hoedemaeker, 2006; Popken, 2009; Wege, 2014; Dotzauer, 2015). In his thesis, based on his own research findings and that of Nilsson, Stevens, Roskes and Heinrich (2001), Jenssen (2010) concluded that changes in driver behaviour invoked by DAS use can be grouped into six categories. Table 2 gives an overview of these six categories and links the levels of driver behaviour accordingly to the hierarchical approaches of Hatakka (1998, 2000, see Figure 3, p.7).

Table 2. *Categorization of Behavioural Effects due to DAS use adapted from Nilsson, Stevens, Roskes & Heinrich (2001), Jenssen (2010) and Hatakka (1998, 2000).*

Category	**Affected dimensions**	**Level of driver behaviour**
Perception	Auditive, visual, haptic, tactile	Mastering traffic situations
Cognition	Comprehension, Interpretation, Selection, Decisions	Mastering traffic situations
Performance	Lateral- & Longitudinal Control, Acceleration- & Deceleration, System handling, Driving errors	Vehicle manoeuvring
Driver state	Levels of attention, awareness, workload, stress, drowsiness	Mastering traffic situations
Attitudes	Acceptance, degree of reliance, trust and mistrust, rejection	Goals and context of driving
Adaptation to environmental conditions	Weather, infrastructure, visibility	Mastering traffic situations

Jenssen (2010) proposed five learning phases of behavioural adaptation, covering a time window of two years. He proposed that after using the system for one year and longer, the behaviour displayed is settled and stable. Below, the five phases of behavioural adaptation are described:

1. *The First Encounter Phase*. This first learning phase represents the first contact with the system. The driver is made aware of how the system works and how to adapt to it while driving. In this phase, drivers may be distracted by the

actual handling of the system. A collateral effect that may arise is that drivers may not trust the system. This phase is characteristic for the initial one to six hours when the system is used or when the covered distance is less than 50 km. Both the time of this phase and the potential negative side effects that could occur depend heavily on the human machine interface and interaction (HMI&I). If the system is self-explaining and intuitive in its use, the duration of this period will be shorter. The opposite is true if the system confronts the driver with various problems and challenges.

2. *The Learning Phase*. The learning phase is characterised by the driver gaining control over the handling of the system. Indeed, the driver becomes more confident in using the system and gets familiar with its limitations. In this phase, depending on the HMI&I design, the driver may be distracted by using the system while driving. This learning phase follows directly the first encounter phase and lasts three to four weeks, corresponding to 10-40 hours of driving or a distance up to 1,000 km. The behaviour shown in this time window is still unstable.

3. *The Trust Phase*. During this period, the driver starts to gain trust in the system and its functioning. Consequently, the driver allows the system to take control of the tasks for which it was intended. Gaining trust in the DAS, however, is also associated with the danger of over-reliance on the system which may result in a passive driving behaviour and low attention levels. Typically, this phase starts after one month of the system use and ends with relatively stable driver behaviour around the sixth month of using the system.

4. *The Adjustment Phase*. In this phase the driver adapts the amount of trust acquired in the third phase. It can be assumed that it takes up to twelve months until the driver experiences all 'typical' or relevant situations. In twelve consecutive months, the driver also experiences all seasons. A further assumption is that within one year the driver has the opportunity to drive on all kinds of roads several times and to learn to know how the system works under those conditions and in different driving situations that may arise. The driver may also encounter new situations that could potentially reveal system limitations which are not experienced earlier. The

trust that was gained in phase three is now blended with a certain amount of grudge against the system.

5. *The Readjustment Phase*. With further experience the driver learns how to handle the system limitations. The "grudge" turns into mistrust for distinct conditions. The driver learns when to trust the system and when it is necessary to stay alert in order to be able to intervene actively, if necessary. When trust develops, the risk that the driver will lose skills arises which is a considerate problem in the case of a system breakdown or system malfunction.

The six categories of Nilsson, Stevens, Roskes and Heinrich (2001) and the five learning phases of Jenssen (2010) are based on studies that investigating the effect of DAS on driver behaviour. A fact, that is definitely an important issue, is the suggested time-windows of the phases. Depending on the kind of system, its human-machine-interface design and the usability, the time-windows of the phases may differ from the suggested ones. In particular, the first two phases may vary due to design and functionality issues. The focus of most studies that dealt with this subject was the two lower levels of driver behaviour proposed by Hatakka (1998, 2000). Mainly the effects of DAS on cognitive and regulatory processes and on driving performance were investigated (e.g. Brouwer & Hoedemaeker, 2006; Popken, 2009; Wege, 2014; Dotzauer, 2015). Motivational aspects were not dealt with so exhaustively. Two motivational variables that are considered in Nilsson's et al. (2001) categories and Jenssen's (2010) learning phases are trust and acceptance. A closer look into Hatakka's (1998, 2000) hierarchical model of driver behaviour will clarify why it is important to take motivational factors into account.

Vehicle Manoeuvring Level and DAS. When a driver starts to use DAS, he/she has to adapt his/her skills and performance to the vehicle manoeuvring level. Functions, reactions of the vehicle, switches, human-machine-interface and interaction may seem new with added DAS. The driver must acquire new skills that are necessary for operating this new technology and to perform the tasks on this level correctly; he has to adapt to this new situation in order to fulfil the vehicle manoeuvring tasks correctly. Taking the learning phases of Jenssen (2010) into account, changes on this level of driver behaviour will occur in the first two phases; the encounter and the learning phase. After driving for one week with the system, the driver should have gained the skills to be able to fulfil this level of the driving task successfully.

Mastering Traffic Situations Level and DAS. Driver assistance systems "interfere" in various traffic situations: a car in front (e.g. Adaptive Cruise Control), intersection (e.g. Navigation System), snow and skid-risk (e.g. Electronic Stability Control), presence of pedestrians (e.g. Intelligent Video Surveillance), speed limits (e.g. Intelligent Speed Adaptation), etc. The idea behind many systems is to support the drivers in these contexts and to help them master certain traffic situations. Many studies have investigated whether DAS might have negative effects on driver behaviour on this level (e.g. Brouwer & Hoedemaeker, 2006; Popken, 2009; Wege, 2014; Dotzauer, 2015). Drivers might react with a reduced level of attention (e.g. Hoedemaeker & Kopf, 2001; Llaneras, Salinger & Green, 2013) or might lose the skills to fulfil tasks on this level in case of the system breakdown (e.g. Brouwer & Hoedemaeker, 2006). So, on the one hand, a DAS can tackle tasks that usually have to be completed by the driver while on the other hand, the driver must not lose the appropriate skills required in order to be able to react in case of a system breakdown. Therefore, the use of DAS also changes the preconditions for the driver to fulfil tasks on this level successfully. The driver must adapt to this new situation and now must share part of the responsibility of the task completion which he was used to previously performing independently. At the same time, he/she may not lose the needed skills but has to observe the system functionality continuously. How long the changes invoked by the use of DAS on this level will take depends on the events that the driver experiences while driving, but Jenssen's (2010) assessment (6 months) may well be assumed to be quite accurate in this respect.

Goals and Context of Driving and DAS. As already mentioned, persons form or already have an opinion about most matters. Even before the person starts using a DAS in the vehicle, he/she may have already developed an opinion about the particular DAS. However, when the driver starts using DAS, this opinion may change depending on what he/she will experience: different situations, system limitations, talking to friends and family about the systems and their experiences, etc. According to Jenssen's (2010) learning phase, it can be assumed that within one year drivers will pass different stages of forming an opinion, of developing trust and of knowing when and how to rely on a particular system. For example, when drivers start to use a navigation system, they usually change their strategic procedure when planning a route. The system's task then is to take over navigation while the driver simply has to decide where to go and if he/she wants to take the shortest or quickest route. It is clear that a certain amount of trust is required to follow the instructions given by the system. This level of trust may change: firstly, the driver might not have that much trust in the system because of negative rumours he/she may have heard (e.g. the old lady who arrived 1,400 km away from her destination, die Welt, 2013). Following the initial experience and after having recognised that the system works, the level of trust may increase. Alternatively, it could decrease in the case of negative experiences (e.g. being told to drive onto a one-way-street in the wrong direction, or being led into a closed road because of construction works, etc.). Finally, after having learned how to deal with such situations, the trust might increase again. This variation of trust may impact directly on the driver behaviour. He/she might develop strategies how to deal with negative scenarios, for instance, how to get to the destination in case one if these 'horror stories'. The variables that are considered on the third level of driver behaviour are certainly influenced by the use of DAS. Several studies have investigated how trust in automation and overreliance may influence driver behaviour (e.g. Popken, 2009). Other issues that have been considered are acceptance of DAS (e.g. Hoedemaeker & Brookhuis, 1998; Höltl & Trommer, 2013) and perceived risk in connection with DAS use (e.g. Rajaonah, Tricot, Anceaux & Millot, 2007; Bella & Russo, 2011). But generally speaking, only little research has been carried out in this area.

Goals for Life and Skills for Living and DAS. Several studies have demonstrated the influence of these variables on the behaviour displayed on the road, and they are certainly relevant for the incorporation of DAS into driving. Some DAS aim to support particular groups of drivers; the traffic sign detection system supports older drivers in traffic sign recognition, the alco-lock system is often related to the group of younger drivers, etc. Developers of DAS aim to work out the needs of certain groups in order to adapt the particular system to their needs. It may be assumed that factors on this fourth level of driver behaviour are quite stable. Indeed, gender and social status do not change with the use of DAS while driving. So, this level is different from the other three levels and may be considered to be more a source of moderator variables that can influence driver behaviour and behavioural adaptation processes to DAS on lower levels.

Therefore, by respecting those levels of driver behaviour with the added DAS and Jenssen's (2010) learning phases, the conclusion can be made that in long-term use motivational factors may play a more important role in driver behaviour and traffic safety issues than the cognitive and performance skills that are already developed within the first weeks of DAS use.

1.2.3.2. Actual DAS use experience

Studies on the use of DAS affecting driver behaviour often followed an experimental design (e.g. Buld & Krüger, 2003; Brouwer & Hoedemaeker, 2006; Popken, 2009). Experimental groups were built which made a comparison between driving with a deactivated and with an activated system possible. Most of these studies investigated the effect of only one DAS (e.g. Vadeby, Wiklund & Forward, 2011; Wallén Warner & Åberg, 2008). Few studies considered how driver behaviour is influenced by the use of more than one DAS at the same time (e.g. Brouwer & Hoedemaeker, 2006). However, what does the practice look like? The original idea of this thesis was to compare how drivers that are familiar with using an Adaptive Cruise Control (ACC) system and drivers who have never used an ACC differ in their behaviour in real traffic with respect to motivational factors. When the attempt was made to find participants that either have experience with using only ACC (but with no other assistance system) or have zero experience in using DAS, it turned out that there were no drivers who, while having no experience with other assistance systems, were familiar with an ACC. For example, drivers who use an ACC are also familiar with e.g. Navigation System, Cruise Control, Head-up Display etc. Further on, it was difficult to find drivers who never drove with any DAS at all. Today, the Anti-lock braking system (ABS) for instance is a standard equipment in every European car built after June 2004 (POEL TEC). It became obvious that investigating the effect of one DAS use on motivational changes would not lead to any external valid results.

Changes in motivational processes need time. According to Jenssen (2010) and his proposed phases of behavioural adaptation, changes in driver behaviour may need up to two years. Driving one hour in a driving simulator cannot simulate motivational change. Furthermore, investigating only one system in a strictly experimental design does not reflect reality at all (although it has advantages, e.g. not endangering the participants and controlling potential influence variables). Therefore, it was decided that it is necessary to analyse the actual experience that drivers have by not only considering one, two or three systems, but most of the usual DAS that are currently available on the market. Thus, the actual DAS experience in this study is defined as an interplay of the use duration of DAS, the current frequency of driving with DAS activated, and the subjective familiarity with them.

*1.2.4. **Relevant motivational influence factors based on the Theory of Planned Behaviour.***

A well-established theoretical approach that also reflects a hierarchical structure (like Hatakka's [1998, 2000] driver behaviour model) and that potentially highlights the influence of motivational aspects on behaviour is the *Theory of Planned Behaviour* (TPB, Aizen, 1991).

Approaches that are based on the TBP refer to conscious decisions. Violations are "conscious" types of errors and have been considered in the Generic Error Model System (GEMS) proposed by Reason (1990). Reason divided human failures into errors and violations (see Figure 5, p.26) and categorised three types of errors: (1) skill-related slips and lapses, (2) rule-related mistakes, and (3) knowledge-related mistakes. While these kinds of errors more or less reflect cognitive processes, violations involve an important motivational issue.

Violations are conscious illegal activities that a person actively chooses to do. Thus, even if the individual is aware of what is right and wrong, he/she does not comply and violates against the rules and knowledge. So, as this is a common trait of human behaviour which is driven by certain motives, it may also occur while driving and thus, a person's motives should be taken into account when traffic safety issues are considered.

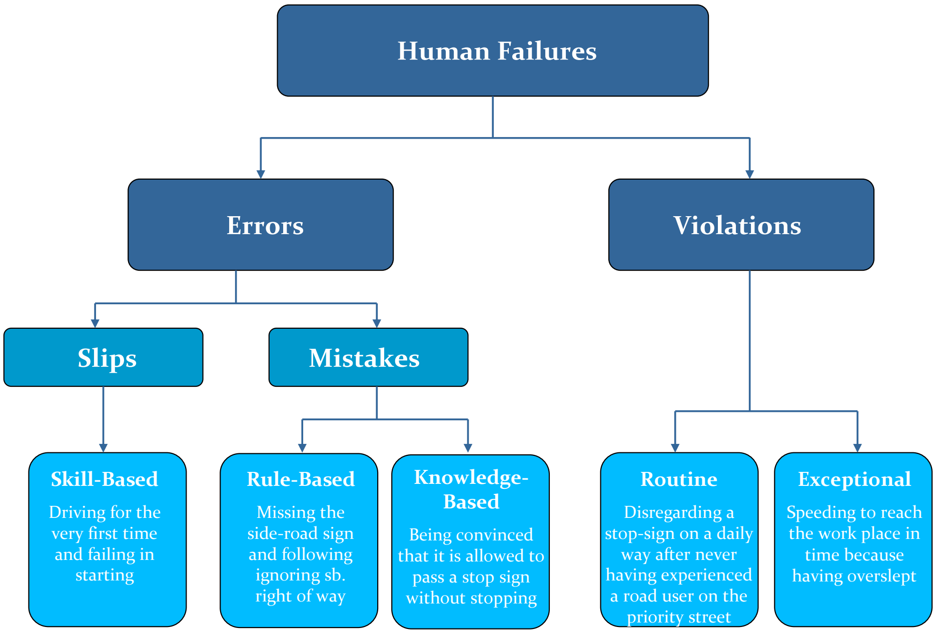


Figure 5. The categorization of human failures (adapted from Reason, 1990).

Normally, the individual is aware of the correct behaviour but he/she may not comply with this knowledge. It is most important to understand a person's motivation lying behind certain behaviour, and this point should be taken into account when traffic safety issues are investigated. The two main statements of the TPB that attempt to explain the predictors of this volitional behaviour are: (1) intentions are the best predictors of behaviour and (2) intentions are affected by perceived behavioural control, social norms and attitudes towards the behaviour. Different studies have extended the theory of planned behaviour by adding factors like perceived risk, moral norms, descriptive norms, anticipated effects, and experiences connected to past behaviour (e.g. Zhou, Horrey & Ruifong, 2009; Holland & Hill, 2008; Forward, 2009). In their study, Zhou et al. added external variables to those originally included in the classical model of the TPB. Based on this step, they created the structure model of compensatory intentions that also includes the consideration of risk compensation (see Figure 6).

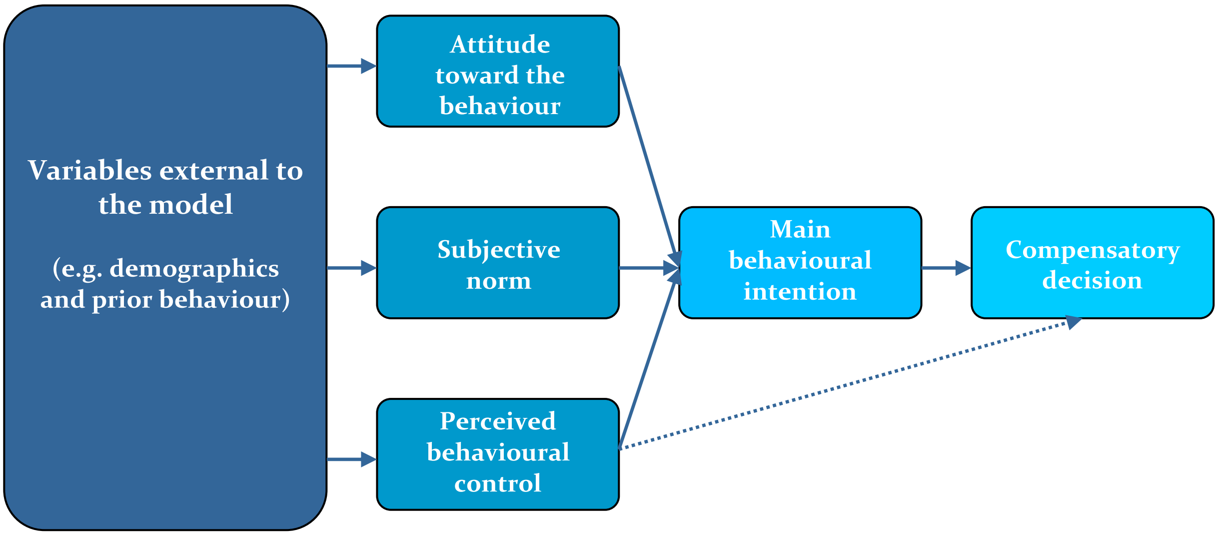


Figure 6. An extended version of the Theory of Planned Behaviour (Zhou, Horrey & Ruifong, 2009)

Motivational factors play an important role in influencing driving behaviour. In order to increase traffic safety, they should be considered when safety measures like DAS are developed and introduced.

A number of studies have used the TPB to investigate driver intentions to act recklessly while driving such as speeding (e.g., Forward, 2009; Cestac, Paran & Delhomme, 2011; Vadeby, Wiklund & Forward, 2011; Delhomme, Cristea & Paran, 2014) and committing driving violations (e.g., Díaz, 2002; Poulter, Chapman, Bibby, Clarke & Crundall, 2008; Forward, 2009). Recent studies successfully applied the TPB to predict driver intentions to use a mobile phone while driving (e.g., Walsh, White, Hyde & Watson, 2008; Zhou, Horrej & Ruifeng, 2009; Zhou, Rau, Zhang & Zhuang, 2012). Using a mobile phone while driving is a secondary activity that distracts the driver and diverts his/her attention away from the driving task. Spiessl and Hussmann (2010) asked drivers "how they would spend time in their car during an automated drive" (p.103). Fifty percent answered that they would use the time to check their e-mails while 53 % would watch TV. This outcome supports the assumption that drivers are more engaged to carry out secondary activities while driving when they are assisted by technical support than when they are not. Since driver distraction and secondary activities are among the main traffic accident-causing factors (e.g. Stutts, Reinfurt, Staplin & Rodgman, 2001; Klauer, Dingus, Neale, Sudweeks & Ramsey, 2006 and McEvoy, Stevenson & Woodward, 2007) and DAS are assumed to lead drivers to carry out such activities (Spiessl & Hussmann, 2010), it is important to investigate the influence of DAS use on driver intentions of exhibiting distracting secondary behaviour while driving. Research on this topic is sparse.

The Theory of Interpersonal Behaviour (TIB, Triandis, 1977) postulates that behaviour is mainly determined by habits. Barr and Prillwitz (2012) consider beside the TPB and the TIB the Social Practices-Approach. This approach focuses on the assumption that intentional behaviour is based on attitudes. Barr and Prillwitz highlight: „[O]ne needs to understand the fundamental motivations (and barriers) underlying consumption which relate to issues such as perceived wants and needs, the symbolic and sign value of goods and services and what it means to have a good quality of life" (p. 808). Concluding, behaviour can be seen as a very stable component that is fundamentally motivated by, e.g., attitudes, norms, perceived behavioural control, and habituation.

Two studies (Vadeby, Wiklund & Forward, 2011; Wallén Warner & Åberg, 2008) used the TPB as a basis to investigate the influence of a system on driver motivation to engage in reckless driving behaviour (speeding or overtaking in an inappropriate situation). Vadeby, Wiklund and Forward (2011) considered the electronic stability control (ESC) system in their study while Wallén, Warner and Åberg (2008) investigated the intelligent speed adaptation (ISA) system. Both studies, which took only the experience using *one* system into account and investigated how this affects driver motivational factors, will be explained in more detail below. Additionally, studies that investigated the effects of DAS use on relevant motivational factors and that highlighted the relevance of motivational factors when driving behaviour is considered will be introduced.

1.2.4.1. *Perceived risk*

It is clear up to this point that DAS systems were introduced in order to support drivers and increase traffic safety. However, already in 1974, Näatänen and Summala stated that innovations which aim at improving driving safety may not necessarily lead to an increase of driving safety and may in fact have adverse effects. They described how an unjustified feeling of safety could contribute to reckless behaviour. This is supported by the findings of Carroll, Howard, Peck and Murphy (2002) and Zhou, Rau, Zhang and Zhuang (2012): feeling safe may lie behind the decision to use the mobile phone while driving. The perceived advantages of using a mobile phone while driving outweigh perceived risks (Lissy, Cohen, Park & Graham, 2000; Walsh, White, Hyde & Watson, 2008). Drivers who participated in a study conducted by Tay and Knowles (2003) declared that they tend to behave inattentively while feeling safe. Hence, low perceived risk is probably an important factor that influences drivers to allow themselves to consciously be inattentive.

Perceived risk can be defined as the extent to which persons judge the probability of a hazardous situation or event that may occur and the expectation of a potential negative outcome following this situation or event (Noland, 1995, Pascoe & Pidgeon, 1995, Deery, 1999, Farrand & McKenna, 2001). This construct is one of the latest variables that was added to extended versions of the TPB (Holland & Hill, 2008, Zhou, Horrey & Ruifeng, 2009; Zhou, Rau, Zhang & Zhuang, 2012). It was found to contribute to the prediction of intentions quite well and thus to be an important factor that should be considered in practical issues concerning traffic safety (Zhou, Horrey & Ruifeng, 2009; Zhou, Rau, Zhang & Zhuang, 2012).

Although past studies have highlighted its importance (e.g. Tay & Knowles, 2004, Zhou, Horrey & Ruifeng, 2009), only few studies have investigated perceived risk in relation to DAS use (e.g., Rajaonah, Tricot, Anceaux, & Millot, 2007; Höltl & Trommer, 2013). In a long-term study Marell and Westin (1999) analysed how perceived risk of drivers is changing as a response to the nine-month use of an information system that provides the driver with information about speed limits.

After using the system drivers reported that they perceived traffic rules more consciously and that they would respect them more in comparison to before. While this study indicated that drivers perceive increased risk when using an informative DAS, Rajaonah, Tricot, Anceaux and Millot (2007) found that drivers who used the actively supportive Adaptive Cruise Control System (ACC) in a driving simulator study less often perceived a higher risk than drivers who used the ACC more often. According to risk compensation and risk homeostasis theories (e.g. Wilde, 1982; Fuller, 1984; Wilde, 1994; Fuller, 2011), reduced perceived risk due to more frequent use of DAS could lead to riskier driver behaviour.

Currently there are too few studies dealing with the effects of DAS on perceived risk to allow reliable conclusions to be made. This work takes this lack of research into account. The studies introduced in Chapter 2 and 3 will address this issue.

1.2.4.2. Perceived behavioural control

Perceived behavioural control refers to the extent persons judge certain behaviours as being easy or difficult to engage in and this variable was recently added to the classical model of the TPB (Ajzen, 1991). The concept relates to individual abilities and circumstances. Thus, perceived behavioural control can be seen as a multidimensional construct that measures how one's own abilities are assessed (self-reported self efficacy) and how environmental circumstances and external barriers are perceived (perceived control). Perceived behavioural control is not only assumed to have a direct influence on the person's intentions to show a certain behaviour, it is also assumed to have a direct effect on behaviour (Manstead & van Eekelen, 1998, Cestac, Paran & Delhomme, 2011).

It has been found that the degree of perceived behavioural control explains the frequency of violations in traffic (like for instance drinking and driving, overtaking in hazardous situations, speeding and lane deviations; Parker, Manstead, Stradling, Reason, Baxter, 1992; Parker, Reason, Manstead & Stradling, 1995; Cestac, Paran & Delhomme, 2011). In general, drivers overestimate their own abilities and driving skills (e.g., Corbett & Simon, 1992; De Craen, Twisk, Hagenzieker, Elffers &

Brookhuis, 2011). The estimation of one's own driving abilities and skills reflects the self efficacy dimension of perceived behavioural control. An exaggerated estimation of one's own driving skills is closely related to both violations (e.g., Parker, Reason, Manstead, & Stradling, 1995, Elliott, Armitage & Baughan 2005, Wallén-Warner & Åberg, 2008) and the conviction that this will not lead to an accident (e.g., Guerin, 1994). In accordance with this, earlier research (e.g. Evans, 1991, Brown, 1986; Horswill & McKenna, 1999; Svenson, 1978) found that perceived control may affect driver decision to drive recklessly. However, it is not only driving behaviour itself that is influenced by perceived behaviour; Zhou, Horrey and Ruifeng (2009) found that the higher (young) drivers scored in perceived behavioural control, the higher was their intention to use a mobile phone while driving. In this study, perceived behavioural control was found to be the strongest predictor of intentional mobile phone use (both hands-free and handheld).

In their questionnaire study, Vadeby, Wiklund and Forward (2011) found that driver perceived behavioural control contributed significantly to predicting reckless behaviour (driving 90 km/h in rainy and slippery conditions and overtaking in icy conditions). Thereby, driver risk susceptibility was higher when they imagined driving a car with electronic stability control (ESC) in comparison to when they imagined to drive one without. Wallen Warner and Åberg (2008) embedded a three-step-questionnaire survey in a field study period from 2000 to 2004. They defined perceived behavioural control by how difficult drivers perceive it to be to comply with a given speed limit. In the beginning of intelligent speed adaptation (ISA) use, perceived control was not affected by the activated ISA; it reduced slightly but not significantly. However, long-term use of the system did affect driver perceived behavioural control; it increased again after three years of system-use and was significantly higher when participants drove the cars with the system activated for the long-term period in comparison to the short time use of the ISA.

Thus, perceived behavioural control was found to be influenced by the imagination of using an ESC. In addition, a long term effect was also found. However, the second result referred to the question of whether the drivers felt that it was difficult to comply with a given speed limit, and not to their perceived behavioural control of driving in general. Both studies considered just one DAS and did not take the drivers' actual DAS use experience in general into account. As DAS use is assumed to potentially increase driver willingness to engage in secondary behaviours while driving, and as perceived behavioural control was found to predict driver intentions to take part in other activities while driving (such as using a mobile phone), in Chapter 2 and Chapter 3, this thesis addresses the question whether there is a link between drivers' actual DAS use experience, perceived behavioural control over driving, and the willingness to engage in distracting secondary activities while driving.

1.2.4.3. Norms

Subjective norms refer to the notion of "how things should be". It is the extent to which others are assumed to approve or disapprove a given behaviour and thereby implies a positive or negative label to the particular behaviour. Thus, subjective norms may be seen as a perceived pressure from others to engage (or not) in a certain behaviour. They can be based on beliefs concerning moral values and societal standards (Azjen, 1991; Neighbors, Lewis & Larimer, 2004; Brauer & Chaurand, 2010). Subjective norms are proposed to influence behaviour through their impact on intentions and along with attitudes account for 33 to 50% of the variance in intentions depending on the subject of the research (Rivis & Sheeran, 2003). Terry, Hogg & White (1999) propose in one of their studies that the effect of a subjective norm depends on the degree to which a person identifies him- or herself with the group that stands for this norm (Forward, 2009). Other research demonstrates that people who perceive subjective approval for any behaviour of interest are more likely to report greater intention and frequency of that behaviour. Subjective norms also explain the intentions behind risky driving (Chan, Wu & Hung, 2010).

Vadeby, Wiklund and Forward (2011) analysed how subjective norms connected to reckless driving (speeding or overtaking in an inappropriate situation) are influenced by imagining driving with or without an electronic stability control (ESC) and how these subjective norms determine self-reported behaviour. In this study, subjective norms were found to predict self-reported speeding but not to predict self-reported inappropriate overtaking behaviours, both when drivers imagined to drive a car with and without ESC. Wallén-Warner and Åberg (2008) found subjective norms concerning speeding to be influenced by the long-term use of ISA. For instance, after long-term use, persons closely related to drivers were estimated to perceive it as less acceptable for the driver to exceed speed limits than after short-term use of the system or prior to using it.

The TPB (Ajzen, 1991) focuses on subjective norms on the behaviour that is aimed to be predicted. This work considers not only driver norms concerning reckless driving, but also driver norms concerning DAS use and whether those norms are affected by experience with DAS; and if they may actively influence driver intentions to carry out concurrent tasks to driving. The norms construct considered within this work is broader than the one involved in the TPB (see Chapter 2 and Chapter 3).

1.2.4.4. Attitudes towards reckless driving

An attitude may be defined as a mental position of a person when he/she is confronted with a specific challenge. An attitude towards certain behaviour is the overall evaluation of that behaviour (Azjen, 1991). Attitudes are determined by beliefs concerning the consequences of a certain behaviour (individual consequences) and an evaluation of the desirability of these consequences (desirability assessments; Hale, Householder and Greene 2002). They are not necessarily based on reasoned evaluations and can be divided into belief-based attitudes (reasoned evaluation and deliberative cost-benefit analysis) and automatic attitudes (spontaneous evaluation of attitude object as an automatic process). Attitudes that an individual is more aware of have a stronger effect on the individual's behaviour.

Attitudes towards reckless driving were found to be the strongest predictors of imagined speeding or overtaking behaviour in an inappropriate situation (Vadeby, Wiklund & Forward, 2011). The proportion of explanation was the same when drivers imagined to use an ESC as when they imagined not using it. Attitudes towards speeding changed over time when an ISA was used. After using the system for more than three years, speeding was valued as less acceptable than before its use and after using it for seven to 14 months. Thus there is evidence that the time of using a system influences driver attitudes towards reckless driving. However, research on the effects of actual DAS use experience on driver attitudes towards carrying out secondary distracting behaviours while driving is scarce. This issue will be considered in this work.

1.2.4.5. Attitudes towards DAS

As introduced previously, DAS are systems that assist drivers in certain respects, e.g. with throttling, braking, or steering. Different DAS have different effects on various personal goals. The success of DAS depends on the willingness of people to use the systems. Factors that influence this decision are, among others, personal goals related to driving, and how these goals influence overall preferences concerning DAS. Such goals can for instance be the personal need to feel safe or the need to achieve self-realization by having the newest technology. Attitudes towards DAS can be defined as “evaluative judgements” (see Gray, 2002) of DAS. "Negative attitudes towards DAS" means that they are perceived as `bad´ or `unsafe´, and "positive attitudes" means that DAS are believed to be ‘good’ or ‘safe’.

The findings of various studies suggest that the acceptance of in-vehicle technologies is high (e.g. Strand, Karlsson & Nilsson, 2014) although some research shows rather neutral assessments of assistance systems by drivers (Marchau, Wiethoff, Penttinen & Molin, 2001). The introduction of DAS can be seen as forfeiting part of the direct control over the vehicle, and drivers are in general not in favour of systems that reduce their control by monitoring activities and invading the privacy (Brookhuis, de Waard & Janssen, 2001; Regan, Mitsopoulos, Haworth & Young, 2002). One reason that DAS are not assessed positively but rather neutrally could be the fact that potential users are not aware of the benefits of the systems

(Molin & Marchau 2004). Long term experience with DAS may, however, result in a higher acceptance. (Katteler, 2005).

Research on the introduction of DAS in vehicles has concluded that perceived changes in safety and comfort affect the preferences of DAS the most; fuel consumption has the least impact. Drivers believe that DAS that warn of possible rear-end collisions may contribute more to safe and comfortable driving compared to DAS that automatically take over driving tasks (Molin & Marchau, 2004; Marchau, Wiethoff, Penttinen & Molin, 2001). DAS studies in China and Sweden have shown participants to be sceptical of DAS if the traffic was too complex. Also if there were, for example, only a few cars with Adaptive Cruise Control (ACC) on the road, then in their opinion, the benefits would be minimal (Lindgren, Chen, Jordan and Zhang, 2008).

Attitudes towards DAS and their role and relevance when the effect of DAS use on driver behaviour is investigated is addressed in Chapter 2, 3 and 4.

1.2.4.6. The intention to carry out concurrent activities to the driving tasks

Intention is defined as the willingness, or the motivation, to try to perform a behaviour which refers to defined actions (Long, Choocharukul & Nakatsuji, 2010). It depends on the kind of behaviour in question, but a general rule could be formulated that when behaviour poses no serious problems of control, it can be predicted from intentions with considerable accuracy (Azjen, 1991). Intentions are a precondition for engaging in certain behaviour and are determined by the persons' attitudes, subjective norms, and perceived behavioural control (self-efficacy); these variables determine the variance in behaviour (Elliott & Armitage, 2009; Smith-McLallen & Fishbein, 2007). However, although intentions are the primary determinants of behaviour, a lack of skills and/or environmental constraints may also prevent one from acting according to one's intentions (Fishbein, Hennessy, Yzer & Douglas, 2003).

The frequency of past behaviour is found to account for variance in later behaviour and this is independent of intentions. When an individual has sufficient control over certain behaviour, they are expected to carry out related intentions when the opportunity arises. Over a long period of time, attitudes and intentions are assumed to be activated automatically and to guide behaviour without the necessity of conscious supervision. This is how routine behaviour develops. As long as the situation remains stable and intentions remain unchanged, there is no reason for behaviour to change. For example, the reason for some people to never wear a seat belt might be that they "forget" to put on the belt despite having the intention to do so. When they are forced to wear one, e.g. when a law and its enforcement are implemented, they will enact their intention and will start putting the seat belt on, until they have become accustomed to the new behaviour (Ajzen, 2002).

In their questionnaire study, Zhou, Rau, Zhang and Zhuang (2012) found the intention to answer the mobile phone while driving to be correlated with perceived behavioural risk and control, attitudes, and subjective norms. Similarly, Walsh, White, Hyde and Watson (2008) asked 801 persons in a questionnaire study about their intentions to use the mobile phone. They found attitudes and subjective norms to be predictors of driver intentions to use the mobile phone while driving. Thereby, positive attitudes towards using the mobile phone and higher perceived normative pressure to answer or use the phone while driving, led to clearer intentions to do so.

Although there are some infrastructural barriers to the implementation of DAS, the main problem remains to be driver behaviour (Lindgren, Chen, Jordan & Zhang, 2008). Sayer, Meffort, Shirkey and Lantz (2005) conducted a field operational test and investigated whether drivers are more prepared to engage in secondary activities when they use DAS in comparison to when manual control is employed. They found that this was not the case. However, the results only indicate that conversations with passengers increased when a DAS was in use. The authors justified this by the fact that it was likely that drivers explained the DAS to passengers. In their study Sayer et al. only considered the Automotive Collision Avoidance System which is a combination of the Forward Collision Warning and the Adaptive Cruise Control system. Thereby, within a 12-month driving period, participants were able to use the system for three weeks. The design of the study made a comparison between times where no DAS was available and where DAS was available. However, this design does not reflect driver familiarity with using DAS. DAS may lead to behavioural adaptations within a time period of up to two years (see Jenssen, 2010). Engagement in secondary activities while driving may occur later than three weeks of DAS use. Further on, it can be assumed that in practice a car would be equipped with more than just an Automotive Collision Avoidance System. For this reason and as already highlighted in section 1.2.3.2, *actual* DAS use experience should be taken into account which will be considered in this work, (see Chapter 2, 3 and 4).

1.2.5. Applying qualitative or quantitative methods when effects of DAS use on driver behaviour are investigated?

Quantitative research has historically been the cornerstone of social- and human science research. Representatives of quantitative methods call for researchers to

> "eliminate their biases, remain emotionally detached and uninvolved with the objects of study and test or empirically justify their stated hypotheses" (Johnson & Onwuegbuzie, 2004, p.14).

In contrast, representatives of qualitative methods support a constructivist or interpreter paradigm and

> "contend that multiple-constructed realities abound, that time-and context-free generalizations are neither desirable nor possible, that research is value-bound, that it is impossible to differentiate fully causes and effects, that logic flows from specific to general and that knower and known cannot be separated because the subjective knower is the only source of reality" (Johnson & Onwuegbuzie, 2004, p. 14).

Human science disciplines such as psychology and sociology have been dominated by positive paradigms and thus, mainly use(d) quantitative methods in their research. By applying quantitative research methods the researcher is able to test set hypotheses and answering the 'if' the hypothesis can be accepted or has to be rejected for the investigated population. Main advantages of quantitative research methods are (1.) that it possible to do precise measuring (e.g. Hartmann, 1970); (2.) to gain manageable information for analysing (e.g. Heinze, 1995); (3.) to be able to identify causal effects (e.g. Treumann, 1986); (4.) to analyse and compare results of different quantitative studies; (5.) to ensure distance between the researcher and participants which enables to investigate 'delicate' research issues (e.g. Bortz & Döring, 2005). However, quantitative research has also limitations. It is criticised that quantitative methods are applied by a variety of researchers without reflecting if the approach is appropriate for the respective research issue (e.g. Flick, 1995, Lamnek, 2005). Additionally it is criticised that the variety of humans gets lost by applying quantitative methods and that results do not reflect reality but a mechanical human image (e.g. Flick, 1991; Girtler, 1992; Bortz & Döring, 2005). Following, it is critical to implement results from quantitative research into praxis (e.g. Saldern, 1995). As critical is also valued that due to the character of quantitative research information is reduced that limits the variety of human science issues. Already at the beginning of the research process, the whole issue gets limited by being considered from a limited perspective: from the hypotheses (e.g. Girtler, 1992; Lamnek, 2005).

Qualitative methods, in contrast, follow an explorative procedure and thus, ensure the precondition to discover new phenomena (e.g. Lamnek, 2005). Thus, qualitative data are in general richer and contain more information than a quantitative measured value (e.g. Bortz & Döring, 2005). This is seen as main strength of qualitative research methods: they are open and flexible and thereby ensure that the methods can be adapted to the respective characteristics of the research issue and the individuals (e.g. Lamnek, 2005). Whereas quantitative methods are able to answer the 'if' of respective research issues and its underlying hypotheses, qualitative methods as for 'how' and 'why' research issues arise. Qualitative research and its results are closer to reality (e.g. Lamnek, 2005). However, a central aspect that is criticised in the quantitative approach is the alleged arbitrariness: qualitative researchers are accused to be not clearly and precise in their research objectives and following to be too less standardised while conducting the research and performing the analysis. It is criticised that getting to the results is elusive, can be not controlled and verified and consequently cannot fulfil the quality criteria validity, reliability and representative nature (e.g. Ferchhoff, 1986, Klüver, 1995). Table 3 contrasts the two approaches and its characteristics.

Table 3. *Contrast of quantitative and qualitative research approaches (see Gelo, Braakmann & Benetka, 2008)*

Quantitative approaches	Qualitative approaches
Sampling	
Probabilistic	
Simple random sampling	
Systematic random sampling	
Stratified random sampling	
Cluster sampling	
Purposive	
	Convenience sampling
Convenience sampling	Homogeneous cases sampling
	Extreme/deviant and Typical case sampling
Data collection	
Primary data	
Tests or standardized questionnaires	Open-ended interviews
Structured interviews	Focus group
Closed-ended observational protocols	Naturalistic observation protocols
Secondary data	
	Official documents
Official documents	Personal documents
Data analysis	
	Description
	Identification of categories/themes
Descriptive statistics	Looking for interconnectedness between categories/themes
Inferential statistics	

Quantitative approaches	Qualitative approaches
Data interpretation	
Generalization	Contextualization
Prediction based (theory-driven)	Interpretation based (data-driven)
Interpretation of theory	Personal interpretation

During the last decades to the present, it became more and more popular in behavioural science to combine quantitative and qualitative research methods in order to benefit from the advantages of both approaches and to avoid losing necessary information and to take the critical issues of both research approaches into account. Combining quantitative and qualitative methods is also called 'mixed method approach'. Creswell and Plano Clark (2011) highlighted that the applied methodological approach has to be appropriate for the respective research issue and became pioneers of applying and underlining the advantages of the mixed method approach in human sciences. Johnson, Onwuegbuzie and Turner (2007) collected a variety of definitions of mixed methods research (pp. 119-121) and derived following two definitions:

> "Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration." (p.123)

> "Mixed methods research is an intellectual and practical synthesis based on qualitative and quantitative research; it is the third methodological or research paradigm (along with qualitative and quantitative research). It recognises the importance of traditional quantitative and qualitative research but also offers a powerful third paradigm choice that often will provide the most informative, complete, balanced, and useful research results." (p.129)

However, although the significance of mixed methods in behavioural science grew the past decades, the majority of research on driver behaviour is determined by quantitative methods. Conducting a literature research of studies that investigated driver behaviour in the past five years (2009-2015) looking for the keywords 'driver behaviour' in all abstracts and considering the first 70 hits, it was found that 95.714% (67 of 70) were studies that applied quantitative methods and 5.714% (four of 70) that conducted qualitative studies too (see 8 Annex, p.209, three studies were literature studies). Only a few studies combined qualitative and quantitative method investigating driver behaviour (e.g. Musselwhite, 2006; Antonson, Mårdh, Wiklund & Blomqvist, 2009; Lenton, Fetherston & Cercarelli, 2010). Antonson et al. highlighted the enrichment and advantages of applying both, qualitative and quantitative methods when driver behaviour is examined.

Since driving is a complex task and a variety of processes is involved to fulfil the driving task successfully, it requires appropriate research methods to be understood as a whole and correctly. According to the complexity of the processes that are involved in performing the driving task, especially when motivational processes are investigated, it is clear that combining qualitative and quantitative methods enriches the research and its outcomes when driver behaviour is examined. Thus, this will be taken into account in this work: Chapter 2 introduces a qualitative study, in Chapter 3 and 4 a quantitative study is presented and in Chapter 5 a study that applied both, quantitative and qualitative methods, is introduced.

1.3. Objectives

As pointed out in the introduction, motivational processes play an important role in determining driver behaviour. The motivational variables introduces previously that are potentially connected to DAS use, may have a significant impact on driver behaviour, and therefore, on traffic safety too. Decisions to drive safely or violate traffic rules relate to these variables. Thus, when DAS effects are investigated, apart from cognitive and regulatory processes and performance measures, the influence of motives needs to be taken into account. This is one main general objective of this thesis.

This thesis aims to understand *which* motivational factors are relevant and *how* they are related to each other and whether the interplay between these relevant variables has the potential to influence driver behaviour. Inspired by the theory of planned behaviour and its extended versions, it is aimed to develop a theoretical model of factors that determine the engagement in secondary activities while taking actual DAS use experience into account. In order to understand the potential influence of DAS use on motivational factors and answer the question whether it induces secondary (distracting) activities like using the mobile phone while driving, this work considers the actual experience with DAS as an external variable that influences several motivational variables that have to be identified. In order to gain an in-depth-view into the interplay between these motivational variables, a qualitative approach will be applied (see Chapter 2).

As underlined previously, qualitative methods are strong and effective when developing hypothesis of unknown contexts. They follow the heuristic assumption that logic is flowing "from specific to the general" (Johnson & Onwuegbuzie, 2004, p. 14). In contrast, qualitative approaches are weak in gaining information that can be used to conclude representative statements. In order to derive more discrete and general statements and to be able to obtain representative conclusions, the results that will be gained based on the qualitative approach (introduced in Chapter 2), will be tested quantitatively (see Chapter 3). Thus, this work aims first to develop a theory that core assumptions will be analysed quantitatively then.

As also underlined previously, that DAS are able to contribute to traffic safety is depending on drivers' willingness to use DAS. If the driver does not have a positive opinion about DAS, he/she will not use the system. Thus, it is important to understand which factors may influence driver attitudes towards DAS. This is also important in order to derive effective implementations that lead to positive changes in driver attitudes towards DAS. So, this work has the objective to gain a better understanding about influencing variables on driver attitudes towards DAS.

When drivers are supported by DAS, they have to perform different forms of the same driving task part in comparison as if they are not assisted by DAS. This is based on the fact that in one case drivers are supported by the DAS which simplifies the relevant task or takes control over completely and in the other case drivers are not supported and have to perform all tasks on the respective level independently. This difference might have an effect on driver motivation and decisions that are reflected on certain levels (e.g. the strategic level, according to Michon, 1985, or the goals and context of living, according to Hatakka, 1998, 2000). The idea behind the majority of hierarchical approaches is that any features and events on higher levels may have an influence on lower levels. When drivers use for instance a navigation system while driving on unfamiliar route, they are relieved on the operational, tactical and strategic level of driving. The drivers do not need to spend the same amount of attention and energy on the orientation- and trip-planning tasks as drivers who use the printed instruction to 'find' the destination. Thus, one major objective of this thesis is to investigate whether the use of DAS may influence driver motivational processes, and consequently, driver cognitive processes (distraction, see Chapter 2, 3 and 5).

In summary, the main general objectives of this thesis are as follows:

- to identify motivational factors that are relevant when the effects of DAS on driver behaviour are investigated (Chapter 1, 2, 3, 4, 5 & 6);
- to identify the role of *actual* DAS use experience when the effects of DAS are investigated (Chapter 2, 3, 4, 5 & 6);
- to gain a better understanding of variables that influence driver attitudes towards DAS (Chapter 2, 3, 4 & 6); and
- to gain a better understanding of the effects of motivational processes on cognitive processes in response to DAS use (Chapter 5 & 6).

In order to achieve the reported general objectives, three studies were conducted that are introduced in the following. In the coming chapters, the specific research issues and its resulting decisive objectives will be explained in detail.

2. Study I - On the interplay of actual DAS use experience and motivational factors determining drivers' engagement in secondary activities – a theoretical model

"Look deep into nature, and then you will understand everything better."

(Albert Einstein, 1879-1955)

2.1. *Introduction*

Secondary activities distract drivers because attention resources that are decisive for driving in a safe manner are allocated to activities that are irrelevant for a safe performance of the driving task (Lee, Young & Regan, 2009). Examples of secondary activities are operating the radio or using the mobile phone while driving. These are activities that are not related to the immediate driving task, but demand driving-safety-relevant resources. Referring to the first example, the driver turns the eyes away from the road in order to operate the radio: safety-relevant visual attention is allocated to a safety-irrelevant activity.

As presented in Chapter 1, DAS were introduced in order to improve driving safety and to enhance comfort by supporting the driver in fulfilling the driving task safely. However, once a system has proven to fulfil its technical functionality that may contribute to an increased traffic safety, unintended aspects of driver behavioural adaptation need to be considered (Huth, Bueno, Fort & Brusque, 2013). Recent studies underlined that it is relevant to take this traffic safety endangering behavioural adaptation into account. For instance, focus group studies with experienced users of Adaptive Cruise Control have revealed that assisted driving can promote non-driving related activities like using the mobile phone (Bianchi Piccinini, Simoes & Rodrigues al., 2012; Lancelle, Hugot, Brusque & Bonnard, 2012). Thus, the use of DAS while driving is associated with being motivated to carry out secondary activities while driving and consequently being distracted.

Three psychological theories may help explaining the unintended effects of DAS use leading to distracted behaviour while driving. (1.) According to Wickens' multiple resources theory (1984, 2002), drivers dispose of a certain amount of cognitive resources, that can be allocated to the performance of different tasks. Those tasks that require resources on the same cognitive level interfere with each other. The use of DAS frees resources, which can be reallocated to other activities including the execution of secondary activities while driving. (2.) As presented in Chapter 1, the risk compensation theory (Wilde, 1982, 1994) postulates that individuals have a stable subjective level of risk that they accept and seek to maintain. So, if drivers perceive a change of the risk level due to any changes in the traffic system, they will compensate these changes by adapting their behaviour. Thus, a decrease in perceived risk provoked by the use of DAS might induce drivers to engage in secondary activities while driving. Similarly, (3.) Fuller's task-capability interface model (2005; Fuller et al., 2008) assumes that drivers try to keep task difficulty (i.e. the interaction between the task demands and the driver capabilities) within a preferred range. In order to determine their subjective risk threshold, driver use their knowledge on a range of traffic situations that they evaluate as safe. As soon as this threshold is surpassed, drivers adapt their behaviour in order to get back within the accepted boundaries. The experience of DAS support might lead to an enhanced safety evaluation of certain traffic situations and a correspondingly higher risk threshold.

A study by Dotzauer, Caljouw, de Waard and Brouwer (2013) provides evidence for the emergence of habitual behaviour following DAS use. Even when the participants were not assisted by the system anymore, their behaviour was found to be affected by a long-term carry-over effect of DAS use. In line with Wickens' multiple resources theory (1984, 2002) and the motivational theories of Wilde (1982, 1994) and Fuller (2005; Fuller et al. 2008), and the found carry-over effect, it is a basic assumption of this work that drivers who are more used to be assisted while driving are more used to have free resources while driving in general and are used to have a higher risk threshold respectively perceive a reduced risk in general in comparison to drivers who are not used to be assisted by DAS. Consequently, drivers who are used to DAS support may be more likely to carry out secondary activities like using the mobile phone while driving because they judge the current task difficulty as safer and perceive more free resources as those drivers who are not used to DAS support. Referring to this basic assumption concluded from well established theories and to the reasons introduced in Chapter 1, it is important to take actual DAS use experience into account when the effects of DAS use on driver behaviour are investigated.

The majority of studies that investigated if DAS use may lead to unintended negative behavioural adaptation deal with cognitive processes to explain driver performance (e.g. Popken, 2009; Wege, 2014; Dotzauer, 2015). However as highlighted in Chapter 1, hierarchical approaches of driver behaviour (e.g. Hatakka, Keskinen, Gregersen, Glad & Hernetkoski, 2002) underline the importance of motivational aspects influencing driving performance. So, what are the motivational factors influencing if drivers carry out secondary activities like using the mobile phone while driving related to their actual DAS use experience? Motivation is determined by internal factors like individual drives and wishes, risk perceptions, personal benefits and assessments of different situations on the one hand, and external factors like interactions with other people (social pressure, opinions of important others) and environmental factors on the other hand. Accounting for the reported multidimensionality of motivation as well as the process of behavioural motivational change over time, the reduced external validity of experimental studies (see Chapter 1) and the relevance of the carry over effect of DAS use, the present study focuses on actual DAS use experience in contrast to the use of a specific DAS over a limited period of time. As introduced previously in Chapter 1, actual DAS use experience in this work is defined as the interplay of the use duration of one or more systems, the current frequency of driving with the support of these systems, and the subjective familiarity with them.

Still, the question 'What are the motivational factors influencing if drivers carry out secondary activities like using the mobile phone while driving related to their actual DAS use experience?' could not be answered yet by basic psychological theories and studies that investigated the effect of DAS use on driver behaviour. Thus, the objectives of this qualitative study are first to identify *which* motivational aspects are effected by actual DAS use experience, second to identify *how* these motivational aspects are influenced by actual DAS use experience and third to understand how the influence of actual DAS use experience on motivational factors effects the driver's conscious willingness to carry out secondary activities while driving. To sum up, this study aims at developing a theoretical model of motivational factors that determine the engagement in secondary activities while taking actual DAS use experience into account.

2.2. *Methods*

2.2.1. *Focus group discussions.*

Exploring motives and intentions by means of focus group discussions delivers particularly rich and deep data (Rabiée, 2004). Focus group interviews are group discussions where the participants share their thoughts and experiences, encourage each other and enhance efforts to think, to remember and to argue (Morgan & Spanish, 1984). A moderator guides the group in order to stimulate discussion that will offer insights in to the motivations that underlie the behaviour of interest (Maykut & Morehouse, 1994; Greenbaum, 2000; Hyden & Bulow, 2003), and group-dynamic effects (e.g., like building a consensus or standing up for the own point of view, see Littig & Wallace, 1997, Breiling, 2000) allow a wider range of important aspects to emerge than it would be possible in one-to-one interviews.

In the present study, focus group discussions were the method of choice in order to identify relevant motivational factors associated to actual DAS use experience and secondary activity engagement. A further advantage of this method is that it allows detecting the mechanisms of the interplay of these factors. This is possible because participants in focus groups usually explain why they act the way they do which allows to identify interplays between factors. Additionally, the moderator can ask for explanations actively. Thus, focus groups are an appropriate method establishing a theoretical model accordingly. The qualitative data obtained in this exploratory study builds a basis for systematic testing in subsequent quantitative studies.

2.2.2. *Participants.*

The participants were recruited directly from a test person pool of the FACTUM OG Research Institute for Social and Traffic Analyses and via online calls. They participated on a voluntary basis and were remunerated 20 € each. Twenty drivers

(14 males, 6 females) aged between 21 and 68 years (*M* = 39.15, *SD* = 15.87) took part in the study. All participants indicated to drive at least 5,000 km per year, with a total driving experience of over 10,000 km.

Given that the study aimed at exploring the influence of actual DAS use experience on motivational factors, a demographic online questionnaire administered prior to the study included three questions on actual DAS use experience: (1.) *Have you ever used this system? If so, since when?* (2.) *How often do you currently drive with this system activated?* and (3.) *How familiar do you feel with this system?* The questions were asked for 24 systems (see Table 5, p.52) that are currently on the market, providing the participants with a short description of the system (e.g. Emergency brake assist: a system that provides the necessary pedal pressure in a braking action; or: Intelligent Speed Adaptation: a system that supports the driver in keeping the current speed limit of the momentarily driven road section). The selection of the systems was based on the results of an expert discussion that addressed this issue involving the views of seven experts from the field. A summative index was calculated from the participants' answers on five-point ordinal scales, which was used to identify low, medium or high DAS use experience. According to this level of actual DAS use experience, participants were invited to particular focus group discussions. The first focus group discussion was attended by highly experienced DAS users, the second one was conducted with drivers who had low experience in using DAS, whereas participants with varying degrees of DAS use experience attended the last two focus group discussions. Table 4 (p.51) shows the demographic data of the participants in the different focus group discussions.

Table 4. *Demographic data of the participants in the focus groups.*

Description of the participants of the different focus groups	**Mixed DAS experience**	**Low DAS experience**	**High DAS experience**
Number of focus groups	2	1	1
Number of participants	8	7	5
Male	7 (87,5%)	3 (43%)	4 (80%)
Female	1 (12,5%)	4 (57%)	1 (20%)
Age	*M* = 48.75 (*SD* = 18.07)	*M* = 34.57 (*SD* = 13.16)	*M* = 30.2 (*SD* = 6.61)
DAS experience: high	3 (37,5%)	/	5 (100%)
DAS experience: medium	3 (37,5%)	/	/
DAS experience: low	2 (25)	7 (100%)	/

M = Mean value; *SD* = Standard Deviation

2.2.3. *Procedure.*

Prior to their participation in the focus group discussions, the participants were asked to fill in an online questionnaire asking for demographic information and their level of DAS experience. The latter was determined by the three main questions introduced in the previous section. The response format was a five-point Likert-scale. An index was built for each person, which represents their DAS experience. A cut-off-value served to distinct the DAS use experience in low experience, medium experience and high experience. According to the experience with DAS participants were invited for the particular focus group discussions.

Table 5. *List of DAS.*

Name	Description
Anti-lock braking system (ABS)	system that reduces the brake pressure in case of a hard braking situation in order to avoid a possible blockade of the wheels
Traction control system (**TCS**), also known as **anti-slip regulation** (**ASR**)	a system that prevents wheels from spinning when the driver accelerates
Electronic stability control (**ESC**)	(also includes traction control) a system that counteracts the break out of the vehicle by the specific breaking of the single wheels
Automatic headlamps	a system that automatically switches the headlight on and off
Curve light	a system that adapts the lighting direction of the headlights in a curve situation according to the curve direction
Advanced front-lighting system (AFS)	adaptive bright-darkness-threshold; a system that illuminates the road scene depending on the traffic situation
Automatic beam switching	a system that automatically fades in and dims the high beam
Automotive night vision	an optical system that provides the driver a higher sight in dark environment conditions
Rain sensor	a system that automatically switches the wipers on and off
Head-up-Display (HUD)	a display in the drivers glance direction; a front-view-display; a display that projects important information in the drivers visual field of view
Emergency brake assist	a system that provides the necessary pedal pressure in a braking action
Precrash system	a system that in case of danger initiates an automatical emergency brake when recognizing critical situations
Hill-holder	a system, that avoids rolling back while hill-starting
Hill Descent Control	a system that provides driving stability while driving downhill
Cruise control	speed regulation system; a system that keeps the speed set by the driver
Adaptive Cruise Control (ACC)	a system that automatically keeps the distance to the lead vehicle respectively in case no lead vehicle is present that keeps the speed set by the driver
Navigation system	a system, that provides route guide information to the driver in consideration of desired criteria
Blind spot monitor	a system that warns the driver of a threatening collision while lane changing

Name	Description
Lane departure warning system (LDW)	a system that warns the driver of an unintended lane change
Intelligent Speed Adaption (ISA)	a system that supports the driver in keeping the current speed limit of the momentarily driven road section
Car-to-Car communication	describes the exchange of information and data between vehicles by following the objective to inform the driver in time of critical / hazardous situations
Tire-pressure monitoring system	a system that serves to observe the vehicle's tire pressure in order to avoid accidents that are induced by brokentires
Parking sensors	a system that supports parking
Traffic Sign Recognition	a system that identifies traffic signs of the driven road and displays this information on an in-vehicle- or head-up-display

Participants were informed about the anonymous treatment of the data they would provide during the study. Four focus group discussions that lasted about 2 hours were conducted in September 2011 and February 2012. Two experienced researchers managed the discussions, one moderating the discussion and the other documenting the proceedings. In addition, all focus group discussions were audio-taped.

After an introduction to the procedure and the objectives of the focus group discussions, the moderator started the discussion process following a topic guide. This guide had been developed specifically for the study, in accordance with the theoretical approach (Krueger & Casey, 2000; Newman, 2002). The discussion was initiated by an opening statement that encouraged the participants to get involved in the discussion. The moderator then placed transition questions in order to guide the participants without directly questioning them and to stimulate discussions on relevant topics (Hughes & DuMont, 1993; Morgan, 1997; Massey, 2011). These topics included perceptions and attitudes related to driving, DAS use and secondary activities while driving. Whenever necessary, further key questions, which were related to statements of the participants, were added in order to prompt more detailed discussions. At the end a question asking for final comments, was used to close the discussions. This semi-structured pattern had proven to allow the discussions to naturally flow and to trigger the emergence of themes that are not previously defined (Krueger & Casey, 2000; Newman, 2002; Massey, 2011).

The focus group discussion process followed the principle of saturation (Mason, 2010), according to which the systematic, data driven procedure is continued until no new information emerges any more. It can be assumed that the data gathered in this cumulative sampling is relevant to a wider range of DAS users.

*2.2.4. **Data analysis.***

The data analysis followed a systematic, inductive procedure based on grounded theory (Glaser & Strauss, 1967). The goal of grounded theory is to generate theory emerging from the data with no preconceived hypotheses and, this way, to capture the complexity and movement of the real world (Strauss & Corbin, 1996). Thus, the theory derived by the researcher is grounded in the views of the participants in a study (Creswell, 2009), which makes it an effective approach to understand new phenomena.

The analysis of qualitative data according to grounded theory starts with open coding of the data. This form of content analysis detects and conceptualizes the underlying issues in the data by scrutinizing data segments for commonalities that reflect categories. In a second step, the data are coded axially, that is the relations among the categories are explored and the data is reorganized and grouped correspondingly. The third analytic level is selective coding, in which the data included in the categories are considered in detail and assigned to the generated theoretical concept, constructing a set of relational statements. Finally, a logic paradigm or a visual picture of the generated theory is developed (Strauss & Corbin, 1998).

This analysis procedure was applied in the present study, with the aim to identify relevant motivational aspects (categories) and to derive a theoretical model on the interplay between motivational factors associated to the engagement in secondary activities while driving that considers the influence of actual DAS use experience.

The analysis was carried out based on notes and audio records taken during the focus group discussions. Three researchers carried out the three analysis steps independently on the entire data set. Following the completion of each step, the researchers met to discuss and to interpret the results. Eventually, the theoretical model that had emerged from the step-wise analysis of categories and their relations was completed and discussed.

2.3. *Findings and Model Development*

The analysis finally resulted in the identification of four motivational categories that were related to drivers' DAS use experience and drivers' engagement in secondary activities. These categories are: perceived risk, perceived behavioural control, safety-related beliefs concerning DAS and safety-related beliefs concerning carrying out secondary activities. In the following, the findings are reported in detail, grouped into categories and considering their relation to DAS use experience and secondary activity engagement as well as their inter-relatedness. The identified categories and their detected relations progressively lead to the developed theoretical model.

2.3.1. *Perceived risk while driving.*

Perceived risk emerged as a relevant category when talking about driving and about DAS use while driving. Perceived risk as identified in the focus groups reflects the participants' evaluation how safe they feel while driving and how hazardous they assess driving. In general, drivers reported that they feel safe on the road, e.g. *"I feel pretty safe on the road, also if it's frightening."* The focus group discussions revealed that the use of DAS is acknowledged as contributing to a perceived decreased risk while driving but is also considered to bear the risk of impairing driving safety. Some participants perceived DAS as reducing risks, e.g. *"I feel safer because I simply* *think that the car has much more control, for example in braking situations."* This type of statement was however qualified by somewhat critical views, e.g. *"But if you rely too much on it, for example in risky situations, you might recognize problems too late while driving a car equipped with DAS."* In this regard, experienced DAS users within the focus group discussions expressed to be more aware of their own limitations and the risks on the road than drivers with less experience.

Several changes in driver state and behaviour due to DAS use were seen as being risk increasing. On the one hand, potential negative effects of DAS use were attributed to alterations of driver workload resulting in (a) distraction, e.g. *"The more the car does independently the more you are distracted from driving. If then a special situation occurs you are not prepared.";* (b) driver overload e.g. *"Resources are reduced by the complexity of the systems in the cars and they are not there when it is necessary"* (c) inattention, e.g. *"There are some good systems, but most of them are not that good because the drivers' responsibility is withdrawn and he consequently becomes less attentive."*; or (d) boredom, e.g. *"I get terribly bored and then I do other things alongside driving."*

On the other hand, the participants pointed out that DAS use seemed to imply a delegation of responsibility to the system that was associated to (a) over-reliance on the system, e.g. *"DAS are too much a technique on which everyone relies. If they do not work, unexpectedly, an accident may happen."*; (b) loss of driving skills, e.g. *"Then, nobody is able to drive anymore, for example to perform counter-steering or cadence breaking.";* and (c) misconception of system functions, e.g. *"Things that can be misunderstood should be considered with caution [...]. People do not deal with physics, instead they buy a new car and just drive."*.

Finally, the participants were also aware of possible risk compensation behaviour that could be promoted by DAS use. It included (a) speed behaviour, e.g. *"You feel safer when you use DAS and then you are driving faster and the safety effect is reduced again."* or (b) getting involved in secondary activities, e.g. *"There's no need anymore to concentrate on driving because the systems do everything. Caused by this you are seduced to do other things while driving."*

Thus, the findings revealed a relation between DAS use and perceived risk while driving. In this context, especially secondary activity engagement was considered as a relevant risk factor.

2.3.2. *Perceived behavioural control.*

A further motivational factor that was identified to be affected by actual DAS use experience and related to secondary activity engagement was perceived behavioural control. According to the focus groups findings, perceived behavioural control reflects participants assessment of their own ability to handle driving in a safe manner. This factor turned out to be a central influencing variable of drivers' perceived level of risk. In general, participants reported a stable feeling of control while driving, declaring that they perceive a wide range of driving situations as manageable and consequently as safe. According to the participants, DAS use may lead to a reduced feeling of control while driving. Some participants were concerned that a wrong action by the system could lead to an accident (e.g. *"I'm afraid an accident could happen due to a system. I think it should be possible to switch off active systems."*). Thus, statements like this given by the participants suggest that an increased risk perception may result from a reduced perception of behavioural control in potential hazardous situations that are induced by a DAS.

On the other hand, some participants pointed out that using DAS may result in an increased perceived control, e.g. *"But I feel safer when I use DAS, because I think the car has much more control, for instance when breaking."* Participants explained this increased perceived control while driving by the support they experience due to the tasks that DAS take over reliably and they affirmed that this sensation is accompanied with feelings of enhanced driving safety.

Hence, both the reduction and the increase of perceived behavioural control during DAS use were associated to a change in perceived risk. Correspondingly, in the theoretical model DAS use experience affects drivers' level of perceived behavioural control and consequently leads to changes in drivers' perceived level of risk (see Figure 7, p.59).

Beside DAS use experience, several external variables were found to influence drivers' perceived behavioural control. These include the state and type of car, the traffic situation, other road users, weather conditions and the road type. The effect of these variables on perceived control and on perceived risk is enhanced by a certain lack of driver control over these variables and by the perception that those variables are perceived as risky, e.g. *"Cyclists are the greatest risk for me. All of them. Things I can influence don't bother me that much but cyclists represent the greatest risk".* The participants reported that they can influence these external factors only to a very limited extent, e.g. *"On the highway you have higher speed but you have more control. In the city it is exhausting with all those confusing intersections. There you have less control. Someone might run across the road for the tram, you can do everything right but still crash."* Accordingly, these external variables are added to the model as influencing drivers' perceived behavioural control and perceived risk (see Figure 7, p.59).

Participants, who admitted to sometimes engage in secondary activities while driving, justified this behaviour with specific strategies, e.g. *"Sometimes I make a call, but only at red traffic lights."* Depending on the degree of control they feel over the driving situation, they decide if it is appropriate and safe to carry out secondary activities. This decision takes into consideration that participants perceive reduced behavioural control when they carry out secondary activities while driving, e.g. *"When I use my mobile while driving, I have the feeling to have less control."* Only if the demands of the driving task combined with the secondary activity allow them to stay in their acceptable range of control, drivers would actually carry out the secondary activity. These findings underline the mutual influence of perceived behavioural control and drivers' engagement in secondary activities. Hence, this mutually determining relation was included in the theoretical model (see Figure 7, p.59).

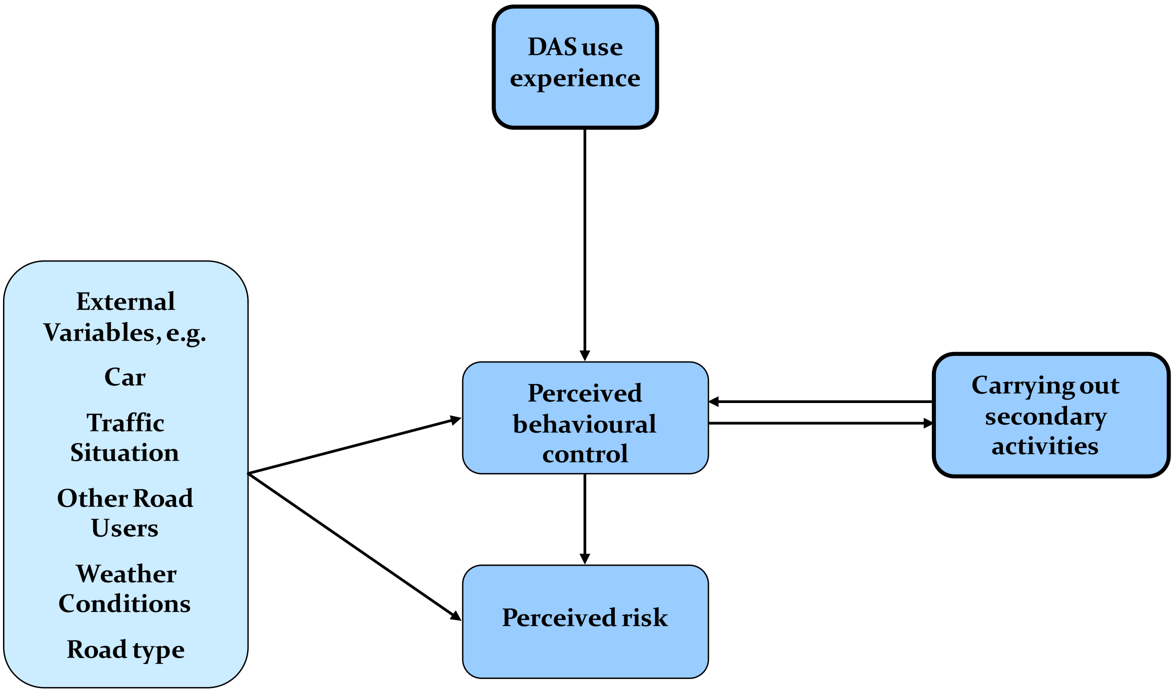


Figure 7. Relations between DAS use experience, perceived behavioual control, perceived risk, external variables and the decision to carry out secondary activities while driving.

2.3.3. *Safety-related beliefs concerning DAS: attitudes towards-, and norms concerning-, DAS.*

A further factor that was detected as a relevant motivational factor being affected by DAS use experience consists in safety-related attitudes towards DAS. These attitudes ranged from moderately positive to highly negative in the present study. While both experienced and less experienced DAS users associated DAS use with positive as well as negative aspects, experienced DAS seemed to find it easier to express detailed views and were generally more active in the discussion of DAS compared to those with less experience.

Participants had a more positive opinion regarding systems that are on the market for longer periods of time and that are already implemented in many vehicles, compared to more recent systems, e.g. *"ABS is quite useful and contributes to safety [...], the speed limiter is annoying [...] and the lane keeping assistance is senseless."* Thus, familiarity with a system was linked to drivers' safety-related attitudes towards DAS (see Figure 8, p.62). This relation is strengthened by the fact that experienced DAS users showed to have stronger opinions concerning DAS.

Whenever participants judged it as safe to use DAS, they reported a higher degree of perceived control. In contrast, negative safety-related attitudes towards DAS were explained by decreased feelings of behavioural control, e.g. *"Actually, the speed-limiter is also dangerous in hazardous situations since it has the control over the speed."*. Hence, safety-related attitudes towards DAS were identified to determine drivers' level of perceived behavioural control while driving. This relation was added to the theoretical model (see Figure 8, p.62).

In the discussions, participants often expressed their views and opinion concerning DAS by using normative phrasing, reflecting their perception of what one should do with respect to DAS use. Thus, norms concerning DAS could be identified as a relevant motivational factor that on the one hand is affected by DAS use experience and on the other hand strongly represents safety-related judgements of DAS.

The generally predominating norm within the focus group discussions that it is supported to use DAS conflicted with several negative aspects that were brought to light during the discussions. Participants expressed that DAS should be used only under certain conditions, i.e. it should be possible to switch the systems off (e.g. *"Active systems that intervene should provide the possibility to be switched off.")*; drivers should not over-rely on the systems and monitor their functioning (e.g.*"You should not rely too much on the systems. You should observe the systems pretty well for the case a system breaks down.")* and the systems should work reliably (e.g. *"As long as they function well, they should be used.")*.

As illustrated previously, attitudes towards DAS and norms concerning DAS showed to be highly interwoven constructs. When participants reported their norms on DAS, they reflected their attitudes towards DAS and consequently emitted a judgement on DAS, e.g. *"In the future, every car should be equipped with DAS because this would be good to calm down traffic."* Hence, it was identified that norms concerning DAS and safety-related attitudes towards DAS can be considered as one category, strongly reflecting drivers' safety-related evaluation of DAS. Thus, the two categories were added to the theoretical model as *one* motivational category 'safety related beliefs concerning DAS' that is directly affected by DAS use experience (see Figure 8). Therefore safety-related beliefs concerning DAS reflected participants' assessments of DAS as either good, neutral or bad for traffic safety and their opinion if DAS should be used (in order to increase traffic safety).

Further, situational factors determined by external variables were identified to potentially affect drivers' judgement of DAS, e.g. *"Cruise Control supports while driving on the highway."* Consequentially, the relation of external variables to attitudes (and norms) towards DAS was added to the model (see Figure 8, p.62).

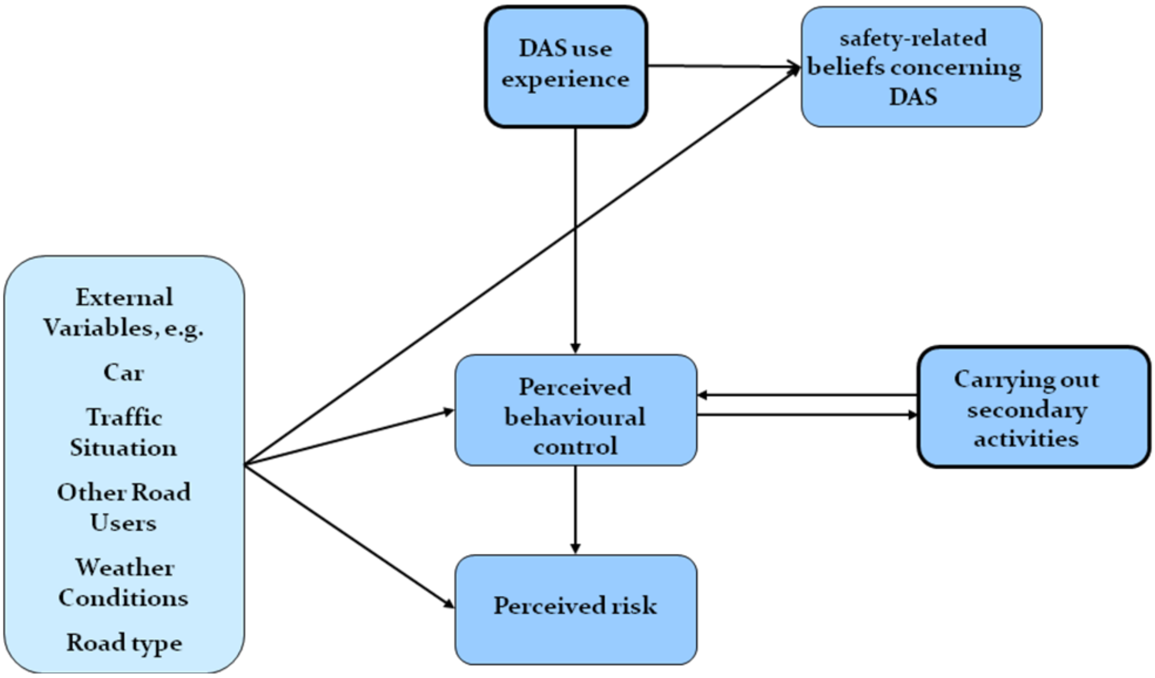


Figure 8. Role of safety-related beliefs concerning DAS in the relations between DAS use experience, perceived behavioual control, perceived risk, external variables and carrying out secondary activities while driving.

2.3.4. *Safety-related beliefs concerning carrying out secondary activities: attitudes towards-, and norms concerning-, carrying out secondary activities while driving.*

Finally, safety-related attitudes and norms concerning secondary activities were identified as two relevant motivational elements determining drivers' engagement in secondary activities. Norms and attitudes concerning the carrying out of secondary activities while driving were interconnected since both reflected the drivers' judgement on carrying out secondary activities while driving. Analogously to the relation between attitudes and norms concerning DAS, the focus group discussions revealed that driver attitudes towards secondary activities were reflected in driver norms concerning secondary activities while driving. Thus, as with safety-related beliefs concerning DAS, it was decided to treat these two identified factors as one category representing drivers' assessment regarding the risks connected to carrying out secondary activities and their opinion of whether secondary activities should be forbidden (due to the increased risk). The most salient beliefs concerning carrying out secondary activities referred to the avoidance of secondary activities while driving because they are judged as too risky, e.g. *"Smoking should be forbidden because the cigarette may fall down. It's not necessary and dangerous. There should exist an uniform regulation for such things."* This relation was added to the model (see Figure 9, p.64).

Drivers' approval or disapproval of secondary activity engagement proved to be directly linked to their control beliefs. In situations of high perceived control the participants considered the carrying out of secondary activities while driving as acceptable and safe. By the same token, when participants attributed an increased risk to limited control over the driving activity in a certain situation, they deemed secondary activities as inappropriate and would accordingly not be willing to carry them out, e.g., *"Calling while driving is risky. When I use my mobile phone, I have the feeling to have reduced control while driving"* and *"I call using hands-free equipment. But only when the situation is appropriate."* As a consequence of this finding, the previously identified direct link between carrying out secondary activities depending on the level of perceived behavioural control was modified into an indirect relation in the model. Hence, the carrying out of secondary activities is directly affected by the safety-related beliefs concerning this behaviour, e.g. *"I never call while driving. Calling while driving in my opinion is an endangerment of the situation that is not justifiable."* These beliefs, in turn, are built depending on the level of perceived behavioural control, e.g. *"It's depending on the situation, if you can control it, unimportant calls are okay. So sometimes I conduct a conversation while driving but I know my limitations."* The other way round, beliefs concerning carrying out secondary activities while driving also have a direct influence on perceived behavioural control (Figure 9, p.64). While the level of perceived behavioural control has already been identified as influencing drivers' level of perceived risk (see 2.3.2, Figure 8, p.62), data on beliefs concerning secondary activities uncover that this level of perceived risk also directly determines the drivers' approval or disapproval of secondary activity engagement, e.g. *"Calling, it doesn't matter if hands-free or using the mobile is distracting and thus, dangerous"* (see Figure 9). The influence of external variables inducing the situational point of view in drivers judgement of carrying out secondary activities and also in the decision to be engaged in secondary activities while driving was also added to the model (see Figure 9).

Given that no obvious differences in reported secondary activities while driving between the drivers with different degrees of DAS use experience appeared during the focus group discussions, no direct link was included in the model.

Figure 9 illustrates the final theoretical model resulting from the step-by-step analysis of the data: the STADIUM Model - *S*econdary Ac*T*ivity Eng*A*gement *D*epending on the *I*nfl*U*ence of experience on *M*otivational factors.

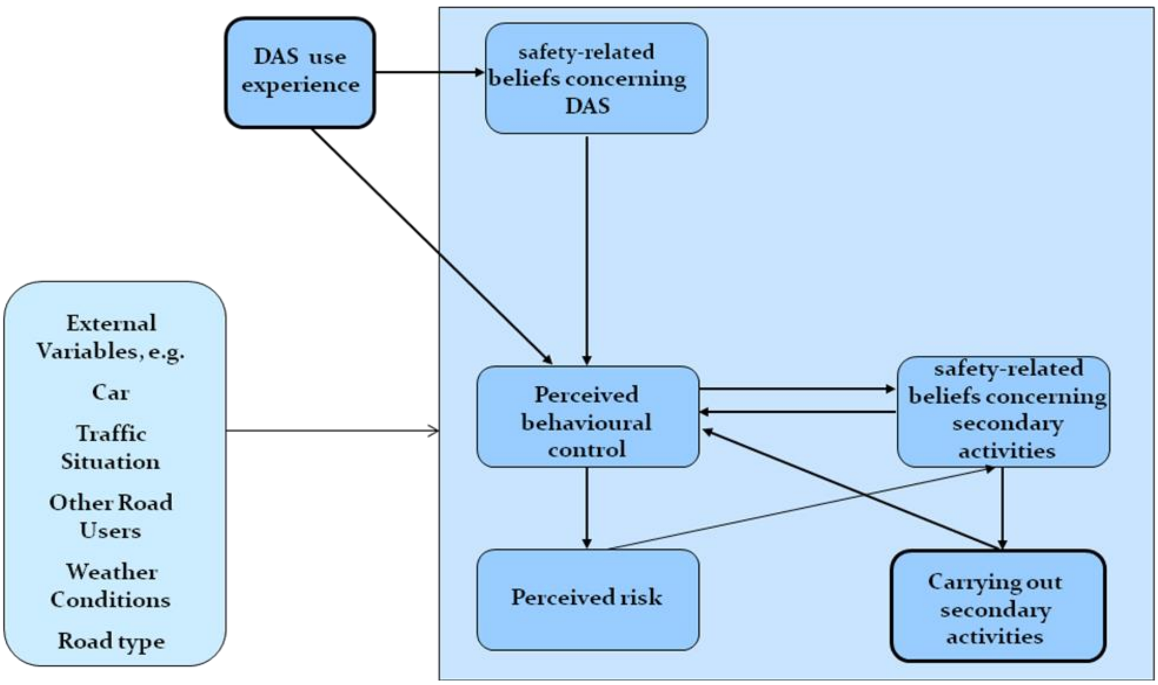


Figure 9. The STADIUM model: *S*econdary Ac*T*ivity Eng*A*gement *D*epending on the *I*nfl*U*ence of experience on *M*otivational factors

2.4. *Discussion*

The main goal of this study was to identify which motivational aspects are affected by drivers' actual DAS experience and how the interplay of those motivational factors influences drivers' engagement in secondary activities. Focus group discussions were conducted and results were analysed by applying elements of grounded theory.

2.4.1. *The STADIUM model.*

Based on the relations between the variables extracted from the participants' statements and reflections, the STADIUM model (*S*econdary Ac*T*ivity Eng*A*gement *D*epending on the *I*nfl*U*ence of experience on *M*otivational factors) shown in Figure 9 (p.64) was derived.

It includes all relevant motivational categories that have been identified in the analysis of the focus group discussions as being related to DAS use experience and secondary activity engagement: perceived risk, perceived behavioural control, safety-related beliefs concerning DAS, safety-related beliefs concerning carrying out secondary activities (included in the box). Additionally, several non-motivational external variables (like the traffic situation, other road users, etc., see Figure 9, p.64) were identified as relevant with regard to secondary activity engagement.

The STADIUM model states that DAS use experience directly affects drivers' safety-related beliefs concerning DAS and drivers' perceived behavioural control. Perceived behavioural control is additionally hypothesized to be influenced by safety-related beliefs concerning DAS, by safety-related beliefs concerning secondary activities and to actually carrying them out. Thereby, perceived behavioural control is expected to affect both perceived risk and drivers' beliefs concerning secondary activities, which in turn determines the actual engagement in this behaviour. The included interplay of motivational factors is assumed to be affected by a number of other external variables (beside DAS use experience) like the type/state of the vehicle, the traffic situation, other road users etc.

The STADIUM model helps to better understand how a number of motivational factors relate to the execution of secondary activities while driving and how these are affected by DAS use experience. It offers a framework to structure research data and to interpret obtained results. The model can be used to derive relevant research questions and to generate specific hypotheses. For instance, the direct relation between driver safety-related beliefs concerning secondary activities and drivers' engagement in secondary activities suggests that awareness about secondary activities has a more powerful impact on secondary activity engagement than drivers' actual DAS use experience, which is indirectly related to drivers' engagement carrying out secondary activities. By consequence, road safety measures targeting one or several motivational factors can be derived on the basis of the model, e.g. awareness raising campaigns on secondary activities.

In conclusion, the STADIUM model considers the influence of motivational factors on road traffic behaviour and related safety issues. It explains that motivation determines to a high degree whether drivers engage in secondary activities while driving. The model shows that actual DAS use experience does not have a direct major influence on carrying out secondary activities. However, it considers that actual DAS use experience determines these motivational factors which in turn influence whether drivers are engaged in carrying out secondary activities while driving. This underlines the relevance of motivational factors for the development and implementation of traffic safety measures.

2.4.2. *Strengths and limitations.*

A particularity of the present study lies in the concept of actual DAS use experience. It was defined as interplay of the use, and its duration, of the particular systems, the current frequency of driving with the particular systems activated, and the subjective familiarity with them. Technical systems that support the driver can be quite different in their functioning and in their level of support (informing, warning, assisting). Furthermore they refer to different elements of the driving task, which may require different levels of driver attention and physical activity. The present study makes the implicit assumption that higher scores in the built DAS index indicate higher familiarity with assisted driving. As systems are heterogeneous, the proposed way of determining DAS use experience can be biased. Still, this index was used as the best available approximate value of actual DAS experience and a closer inspection of the data showed that different levels of DAS use experience were tied to a characteristic set of DAS. Participants with high DAS use experience were typically familiar with ACC, Cruise Control, Navigation Systems and less advanced assistance systems, whereas drivers with low DAS experience usually reported to be familiar with ABS and Navigation Systems.

According to its exploratory goal and the nature of its research questions, the present study adopted a qualitative approach. The aim of this study was to explore motivational factors of secondary activity engagement related to DAS use experience. The qualitative approach allowed determining which motivational factors are influenced by DAS use experience, how they are influenced and how the factors relate to each other. Based on the data which were gathered in the focus group discussions, it was possible to develop a theoretical model describing the inter-relatedness and influence of these relevant elements.

However, the qualitative data do not permit making general statements on the degree DAS use experience influences the motivational variables of interest, neither does it reveal the representativeness of the detected influence of DAS use experience and the relation between the motivational factors for secondary activity engagement. Qualitative researchers “contend […] that logic flows from specific to general” (Johnson & Onwuegbuzie, 2004, p. 14). The present study shed light on the specific, which may serve as hypothesis for quantitative studies that are able to conclude on the general. The qualitative approach was used to derive the theoretical model and to gather information that can be taken into account in future studies. Standardised and representative questionnaire studies may serve to investigate the derived interplay more quantitatively, to make more discrete statements, and to measure how much variance of driver intentions to carry out secondary activities while driving can be explained by the variables of interest. The study introduced in the following Chapter 3 takes this issue into account.

3. Study IIa – The STADIUM Model: *S*econdary AcTivity EngAgement *D*epending on the *I*nfl*U*ence of DAS use experience on *M*otivational factors

"A theory can be proved by experiment but no path leads from experiment to the birth of a theory."

(Albert Einstein, 1879-1955)

3.1. Introduction

The number of vehicles equipped with Driver Assistance Systems (DAS) that aim to improve traffic safety has substantially increased in recent years and this number is still on the rise (see Bengler et al., 2014). In addition to its safety-enhancing effect, the use of DAS may engender behavioural adaptation that is neutral or even negative with regard to traffic safety (Wege, Pereira, Victor & Krems, 2013). Given that DAS tend to simplify the driving task by providing relevant information to the driver or by taking over parts of the vehicle control, the driver has spare resources which might lead to increased engagement in secondary activities like for instance using the mobile phone or sending text messages while driving while driving (Bianchi Piccinini, Simoes & Rodrigues, 2012; Lancelle, Hugot, Brusque & Bonnard, 2012). Since carrying out of secondary activities was found to be a common crash causation factor (e.g. Stutts, Reinfurt, Staplin & Rodgman, 2001; Klauer, Dingus, Neale, Sudweeks & Ramsey, 2006 and McEvoy, Stevenson & Woodward, 2007), the present study focuses on this matter of concern.

The qualitative study introduced in the previous Chapter 2 developed a theoretical model explaining the interplay between DAS use experience and motivational variables, and their influence on drivers' decisions to engage in secondary activities while driving. This model, named STADIUM model (*S*econdary Ac*T*ivity Eng*A*gement *D*epending on the *I*nfl*U*ence of experience on *M*otivational factors, Figure 9, p.64) was developed by analysing focus group data following grounded theory (Glaser & Strauss, 1967). DAS use experience was defined as the synergy of the use duration of one or more systems, the current frequency of driving with the support of these systems, and the subjective familiarity with them (see Chapter 1 & 2, Haupt, Kahvedžić-Seljubac & Risser, 2015). Four relevant motivational factors were identified in the STADIUM model whose interplay affects drivers' engagement in secondary activities depending on DAS use experience: perceived risk, perceived behavioural control, safety-related beliefs concerning DAS, and safety-related beliefs concerning carrying out secondary activities while driving. As an additional influencing factor on these motivational variables and consequently on drivers' engagement in carrying out secondary activities, a set of external variables is also considered in the model (see Figure 9, p.64, previous Chapter 2).

The model shows commonalities with, and differences from, the Theory of Planned Behaviour (Ajzen, 1991, Ajzen & Fishbein, 2005) that states that behavioural intentions are determined by attitudes towards the targeted behaviour, subjective norms and perceived behavioural control. Both models have in common that attitudes towards the targeted behaviour affect (the intention to show) the target behaviour. However, the STADIUM model postulates a more complex interplay of four motivational factors. It suggests that DAS use experience directly determines drivers' safety-related beliefs concerning DAS and drivers' perceived behavioural control. Perceived behavioural control is additionally expected to be influenced by safety-related beliefs concerning DAS, by safety-related beliefs concerning carrying out secondary activities and by actually carrying out secondary activities. Thereby, perceived behavioural control is hypothesized to affect drivers perceived risk (that is directly linked to safety-related beliefs concerning secondary activities) and drivers safety-related beliefs concerning carrying out secondary activities, which in turn determines the actual engagement in secondary activities. The included interplay of motivational factors is assumed to be affected by a set of external variables (beside DAS use experience), including the type/state of the vehicle, the traffic situation, other road users, etc.

While qualitative methods are strong and effective in developing theories and hypotheses of unknown contexts, these approaches are weak in gaining representative information. Once a context is explored qualitatively, its hypotheses need to be tested with quantitative methods. The present study aims at testing the core assumptions of the STADIUM model quantitatively. These assumptions are grouped into two sets of relations. The first set refers to the stated direct and indirect relations between DAS use experience and motivational variables:

- DAS use experience has a direct effect on safety-related beliefs concerning DAS.
- DAS use experience has a direct effect on perceived behavioural control.

- DAS use experience also has an indirect effect on perceived behavioural control.
- DAS use experience has an indirect effect on perceived risk.
- DAS use experience has an indirect effect on safety-related beliefs concerning secondary activities.

The second set describes the expected influence of the motivational variables on drivers' engagement in carrying out secondary activities (like using the mobile phone for example) while driving:

- Secondary activity engagement is directly affected by safety-related beliefs concerning secondary activities.
- Secondary activity engagement is indirectly affected by general perceived risk while driving.
- Secondary activity engagement is indirectly affected by perceived behavioural control.
- Secondary activity engagement is indirectly affected by safety-related beliefs concerning DAS.

Beyond these sets of assumptions, it was ultimately of interest to conclude on the relation between the main independent variable of the STADIUM model, actual DAS use experience, and the main independent variable, drivers' engagement in secondary activities while driving.

3.2. Methods

3.2.1. Participants.

Two hundred and eleven drivers (91 females, 120 males) aged between 19 and 78 years (M=40.01; SD = 14.19) participated in the study. Most drivers (n = 198) had a total driving experience of over 10,000 km (n = 141 have had more than 100,000 km in total). The participants were recruited either from a participant pool of the Chemnitz University of Technology (Germany) via online call or personally from a BMW car dealership in Vienna (Austria). The response rate of the participants recruited at the BMW car dealership was 100% since participants were recruited during their waiting time when BMW changed the wheels on their vehicles. For these participating drivers, the costs of the wheel changing and storage were covered. The response rate of drivers recruited from a participant pool of CUT is unknown. All students studying psychology received an email with the request to ask relatives to participate in the online study in order to get a well-distributed sample covering a wide age range, balanced in gender and varying in DAS use experience. For the participation, students were credited one hour of research time required as part of their studies for each complete questionnaire.

3.2.2. ***Questionnaire.***

A questionnaire was compiled based on participant statements of the focus group study introduced in the previous Chapter 2, a literature search and an iterative process including ten experts from the transport research domain. The questionnaire covered the variables of the '*S*econdary Ac*T*tivity Eng*A*gement *D*epending on the *I*nfl*U*ence of experience on *M*otivational factors' (STADIUM) model (see Figure 9, p.64, Chapter 2). Thus, it included items asking for participants' actual DAS use experience and items referring to the motivational constructs: perceived risk, perceived behavioural control, safety-related beliefs regarding DAS, safety-related beliefs concerning secondary activities, and intentions to carry out secondary activities while driving.

Whenever participants answered a question on a particular DAS they received a short information regarding the functionality of the DAS (i.e., Traction control system (TCS), also known as anti-slip regulation (ASR): a system that prevents wheels from spinning when the driver accelerates).

Participants recruited from the car dealership could choose between an online and a printed version. Participants recruited from the university received a link to the online version of the questionnaire.

3.2.2.1. DAS use experience

DAS use experience was investigated as introduced in Chapter 2 (see p.46) by three items. The questions were asked for 29 systems that are currently available on the market. The list of DAS taken into account was updated based on the results (see Table 5, Chapter 2, p.52). On the one hand, systems that were mentioned during the focus group discussions were added to the list, e.g. auto transmission was stated to be clearly perceived as being of assistance while driving. On the other hand, different versions of systems that have entered the market or whose market penetration has increased were added, e.g. distinguishing between an active parking system that automatically steers the vehicle in the parking space and a warning systems that provides an alarm signal when the vehicle gets too close to a particular object. Thus, following assistances were added to the previous, first list: auto transmission, the active warning parking system, the active intelligent speed adaption, the active lane keeping assistance and the braking assistance system. As in the previous introduced focus group study, a summative index representing actual DAS use experience was calculated for each participant. This index is assumed to reflect drivers' familiarity with all levels of assistance, including informative support (e.g., route guidance information), warning support (e.g. lane change warning) and active/intervening support (e.g. automated headway control). Thus, it is expected that different levels of DAS use experience are not tied to the use of specific types of support technologies but to a generalized degree of familiarity with assisted driving.

3.2.2.2. *Motivational factors*

Participants indicated their agreement with given statements or answered questions referring to the four motivational factors on a seven-point[3] Likert scale with verbal anchors. The respective items are listed in Table 6.

Table 6. *Questionnaire items on motivational factors.*

Factor	Item	Verbal anchors
Beliefs concerning DAS	*The activation of this system so that it can inform, warn or intervene if necessary is dangerous.* *When a child is a passenger in the car, this system should be activated in order to be able to inform, warn or intervene if necessary.* (both items asked for the 29 systems)	totally disagree - totally agree
Perceived behavioural control	Driving more than 110 km/h on a dry rural road is… Driving more than 110 km/h on a we rural road is…	definitely within my abilities- definitely beyond my abilities
Perceived risk	*How risky do you consider driving in general?*	not risky at all - very risky
	How likely is it that you will be involved in an accident in the next five years? *In comparison to other drivers, how likely is it that you will be involved in an accident in the next five years?*	not likely at all - very likely
	Other road users are a risk on the road.	totally disagree - totally agree

[3] Seven-point-scale in this case was used in order to provide the participants more freedom to point out their point of views. In contrast to using the five-point-Likert scale when asking for drivers' experience in using DAS which included a precise point-information for each of the five points. According to Dawes (2008) both scale formats are appropriate and can be compared or transformed easily without distorting the results.

Factor	Item	Verbal anchors
Beliefs concerning secondary activities	*In general it is dangerous to <carry out secondary activities> while driving.* (item asked for a set of secondary activities, e.g. eating, phone use, talking to passengers, etc.) *In general, it should be forbidden to carry out other activities while driving.*	totally disagree - totally agree

3.2.2.3. *Target behaviour: Intentions to carry out secondary activities while driving*

In accordance with the Theory of Planned Behaviour (Ajzen, 1991), behavioural intentions were measured as the best predictor of actual behaviour. Participants were provided with statements on their intention to carry out secondary activities while driving (e.g. *I intend to eat while driving.*). The intentions were questioned for the same set of activities used when participants were asked for their beliefs concerning secondary activities. Participants indicated their agreement with each statement on a seven-point Likert scale with verbal anchors (totally disagree-totally agree).

3.2.3. ***Data analysis.***

In the first place, analyses were conducted on the participants' DAS use experience so as to test the assumption that the index used in this study reflects general DAS use experience rather than the use a specific category of systems. According to their score in the DAS use experience index value participants were assigned to one of three groups of DAS use experience: low, medium or high. Contingency tables were created crossing this DAS use experience with the participants' answers to the three questions (first use, current use frequency and subjective familiarity) for each system, and corresponding Chi squares and correlations were calculated.

Item analyses were calculated for the motivational factors in order to obtain an indicator of the internal consistency of the scales. Cronbach's Alpha values of >.80 represent good reliability (Bortz & Döring, 2006), and lower values between .60 and .70 can still be considered acceptable (Bagozzi & Yi, 1988). Then, correlations and partial correlations between the variables of interest were calculated so as to provide an initial insight into the relations stated in the model.

In order to test stated core assumptions of the STADIUM model, the data were analysed by path analysis (based on Wright, 1921, 1934, 1960). The objective of this analysis was to investigate the hypothesized direct and indirect effects of DAS use experience on motivational variables, as well as the direct and indirect of motivational variables and DAS use experience on drivers' intentions to carry out secondary activities.

Path analysis is a statistical method that is applied to examine complex relationships. It is mainly used to proof models of stated direct relations (see Seibel & Nygreen, 1972). Within a path analysis a (complex) model of relations that are illustrated by arrows between independent and dependent variables is analysed. Every arrow represents a path between two variables. For every path a standardised path coefficient (*ß*) is calculated that represents the strength of a relationship between two variables by controlling the influence of the other variables that are included in the analysis. Additionally, for every included variable a residual path is calculated that included the information of all variables that are not explained (see Seibel & Nygreen, 1972).

SPSS AMOS 22 was used for the path analysis with *Chi-square*, *Normed fit Index* (*NFI*) and *Steigers Root Square Error of Approximation* (*RMSEA*) serving as interpretation values for the investigation of whether the model fits the data. A non-significant *Chi-square* indicates a close fit between the data and the tested theoretical model (Specht, 1975; Browne & Cludeck, 1993), a significant *Chi-square* indicates that the data does *not* fit the tested model (see Schumacker & Lomax, 2010; Bollen 1989, Loehlin 1998). The *NFI* tests the hypothesized model against a reasonable baseline model and should ideally be 1.0. According to Loehlin (1998), a *RMSEA* value of < .1 can be evaluated as "good" and < .05 as "very good". Path significance was evaluated based on the critical ratio (*CR*) with a CR > 2 in absolute value indicating significance on a alpha-level of .05 (Arbuckle 1997). A Stability Index (η) was calculated for the model, with values of > 1.0 indicating an unstable model (Bentler & Freeman 1983).

3.3. Results

3.3.1. DAS use experience: Chi-Squares and correlations.

Significant positive correlations ($p < .01$) were found between DAS use experience and first system use for each DAS. Chi-square tests confirmed that increased general DAS use experience is associated to earlier use of the respective systems. Similar results were obtained regarding general DAS use experience and current system use. Positive significant correlations ($p < .05$) and chi-square tests indicate that participants with higher DAS use experience also used the respective systems more often. Finally, all tested chi-squares and correlations between DAS use experience and subjective familiarity with the respective system were found to be significant ($p < .01$). These results reveal that higher general DAS use experience is linked to a higher subjective familiarity with using the respective individual systems.

3.3.2. Item analysis.

Item analyses for the four motivational factors confirmed internal consistency for all scales (cf. Bagozzi & Yo, 1988; Bortz & Döring, 2006). The scales of safety-related beliefs concerning DAS and safety-related beliefs concerning secondary activities showed good reliability with alpha values of α=.943 and α=.838 respectively. Acceptable reliability was detected for the scales of perceived behavioural control (α=.786) and perceived risk (α=.649).

3.3.3. Correlations and Partial correlations.

As shown by significant correlations and partial correlations, the central independent variable of the model, actual DAS use experience, is related to safety-related beliefs concerning DAS (r = .265, p = .000; $r_{x.yz}$ = .289, p = .000) and perceived behavioural control (r = .239, p = .000; $r_{x.yz}$ = .210, p = .001). The analysis revealed, the more DAS use experience the participants have, the more positively they judge DAS with regard to safety. In addition, these participants report increased behavioural control while driving. However, no significant correlation, nor partial correlation were found between DAS use experience on perceived risk (r = -.019, p = .390; $r_{x.yz}$ = -.041, p = .271). Marginal significance (on an Alpha level <.10) was reached for the correlation between DAS use experience and safety-related beliefs concerning secondary activities (r = -.107, p = .061), but not for their partial correlation ($r_{x.yz}$ = -.071, p = .154). There seems to be a trend that drivers judge secondary activities while driving more positively the more DAS use experience they have. Supporting the expected indirect relation between DAS use experience and the intention to carry out secondary activities were given by a significant positive correlation (r = .139, p = .022). Driver intention to carry out secondary activities increases with DAS use experience. However, partial correlations between these variables were not significant ($r_{x.yz}$ = .024, p = .367).

Regarding the central dependant variable of the model, the intention to carry out secondary activities, the analysis give first insights supporting the assumed direct relation with beliefs concerning secondary activities both by the detected significant correlation (r = -.393, p = .000) and significant partial correlation ($r_{x.yz}$ = -.401, p = .000). Corresponding with the direct relation between the intention to carry out secondary activities and perceived behavioural control, a significant correlation (r = .264, p = .000) and partial correlation ($r_{x.yz}$ = .197, p = .002) were found for these variables. Participants who reported more behavioural control also indicated a stronger intention to engage in secondary activities. Drivers indicate higher intentions to carry out secondary activities the more control they perceive while driving.

Significant correlations and partial correlations were also detected between perceived risk and the intention to carry out secondary activities (r = .131, p = .028; $r_{x.yz}$ = .238, p = .000). According to the data of the present study, drivers show a higher intention to carry out secondary activities the more risk they perceive.

For the hypothesized indirect relation between safety-related beliefs concerning DAS and the intention to carry out secondary activities, neither a significant correlation (r = -.020, p = .388) nor a significant partial correlation ($r_{x.yz}$ = .038, p = .292) were found.

3.3.4. ***The path analysis****.*

Path analysis calculations for the core of the STADIUM model revealed an acceptable stability index of η =.429, reflecting a stable model (Bentler & Freeman, 1983; Loehlin, 1998; Arbuckle, 1997). Figure 10 (p.81) shows the path diagram with respective standardised path coefficients of the calculated model. Five of the nine hypothesized paths were significant on an Alpha level of 5% and had a CR value higher than |2|. A further two path coefficients were found to be marginally significant (α<.10).

However, the model as a whole did not fit the data (*Chi-square* = 19.314, p = .004, *NFI* = .827, *RMSEA* = .103). The path analysis showed, that the considered variables of interest and their hypothesized interplay: DAS use experience, safety-related beliefs concerning DAS, perceived behavioural control, perceived risk and safety-related beliefs concerning carrying out secondary activities while driving explain 12.2% of the variance in drivers' intention to carry out secondary activities while driving.

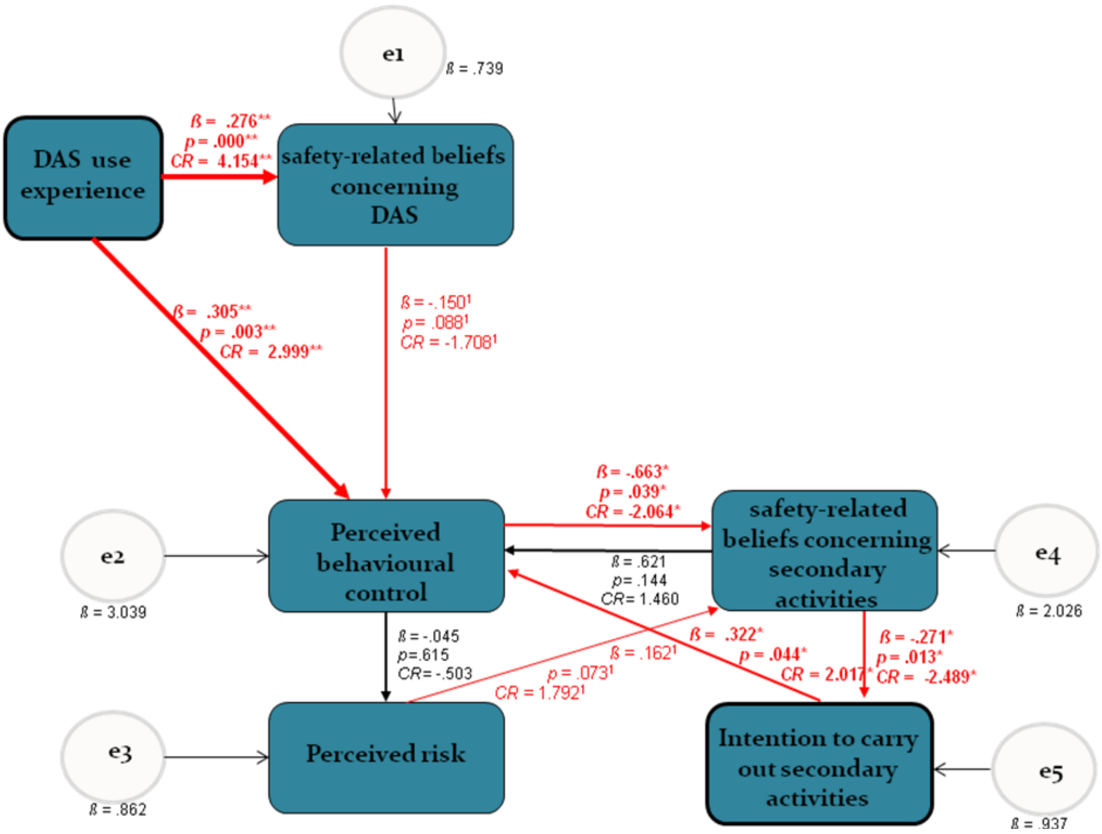


Figure 10. Standardised path coefficients between the factors determining the drivers' engagement in secondary activities while driving. The STADIUM model: *S*econdary Ac*T*ivity Eng*A*gement *D*epending on the *I*nfl*U*ence of experience on *M*otivational factors

Note: [1] – significant on an Alpha level 0f .10; * - significant on an Alpha level of .05; ** - significant on an Alpha level of .01

As hypothesized, DAS use experience has a direct effect on beliefs concerning DAS (*ß* =.276) and on perceived behavioural control (*ß* =.305). The direct path from beliefs concerning DAS to perceived behavioural control was marginally significant (p <.10, *ß* =-.150). In addition to the direct effect, DAS use experience was found to indirectly affect perceived behavioural control (*ß* = -.111) and safety-related beliefs concerning secondary activities (*ß* = -.130). The expected path from perceived behavioural control to perceived risk was not found to be significant (*ß* =-.045) and correspondingly, the standardized indirect effect of DAS use experience on perceived risk was minimal ($ß$ = -.009).

As expected, intentions to carry out secondary activities were directly affected by beliefs concerning secondary activities ($ß$ = -.271) and indirectly affected by perceived behavioural control ($ß$ = .134).

Standardised indirect effects were found to be $ß < |.100|$ for the assumed indirect effects of beliefs concerning DAS ($ß$ = -.020) and perceived risk ($ß$ = -.032) on drivers' intention to carry out secondary activities. However, the paths constituting one of the indirect relations between beliefs concerning DAS to the intention to carry out secondary activities (from beliefs concerning DAS to perceived behavioural control to beliefs concerning secondary activities to the intention to carry out secondary activities) were all found to be significant or marginally significant (see Figure 10, p.81). Likewise, the paths building the indirect relation from perceived risk to the intention to carry out secondary activities (from perceived risk to beliefs concerning carrying out secondary activities to the intention to carry out secondary activities) were found to be marginally (on an Alpha level of $\alpha < .10$) significant and significant (see Figure 10, p.81).

The hypothesis of an indirect effect of DAS use experience on the intention to carry out secondary activities while driving was supported by significant paths from DAS use experience to perceived behavioural control, from perceived behavioural control to beliefs concerning secondary activities and from beliefs concerning secondary activities to drivers' intention to carry out secondary activities (Figure 10, p.81). The corresponding standardised indirect effect was $ß$ = .035.

3.4. *Discussion*

The study presented in this Chapter 3 was performed in order to quantitatively test the stated relations within the STADIUM model. The focus should be on how DAS use experience directly and indirectly influences beliefs concerning DAS, perceived behavioural control, perceived risk, beliefs concerning carrying out secondary activities and how these motivational variables and DAS use experience affect drivers' intention to carry out secondary activities. The model (see Figure 9, p.64 Chapter 2) was developed based on data collected from focus group discussions (see Chapter 2). A questionnaire survey was conducted to gather participants' DAS use experience, safety-related beliefs concerning DAS, perceived risk on the road, perceived behavioural control while driving, safety-related beliefs concerning carrying out secondary activities while driving, and intentions to carry out secondary activities.

DAS use experience in this study was defined as the synergy between drivers' first use, drivers' frequency of current use and drivers' perceived familiarity with the use of the particular system. The results of this study show that higher DAS use experience reflects earlier use of diverse support systems, higher use frequency of any type of DAS and higher familiarity with being assisted by any DAS. Thus, DAS use experience as defined in this and the previously in Chapter 2 introduced study reflects a general familiarity with the use of diverse support systems. It can be excluded that participants in this study who had low experience in DAS use in general had more experience with some of the systems considered. Considering actual DAS use experience, on the one hand it can be concluded as strength of this study that external validity of this study can be evaluated as high. On the other hand, it is still possible that actual DAS use experience is determined by variables that were not considered in this study and that could not be controlled. The high value of the related residual variable underlines that unknown influence factors might determine the subjective level of drivers' DAS use experience. The participants within this study were heterogeneous. In order to exclude potential determining unknown variables, a suggestion would be to investigate a more homogeneous group like employees of a company (with different affiliation time) that drive DAS-equipped cars.

The outcomes of the study confirm the hypothesized direct effects of DAS use experience on beliefs concerning DAS and on perceived behavioural control. Thereby, results showed that participants judge DAS more positively the more experience they have with using such systems. On the one hand, as drivers gain more experience with DAS they are likely to improve their knowledge of DAS functionality and their awareness of its potential benefits. Initial scepticism towards DAS might be explained by a lack of awareness of the benefits that the systems offer (Molin & Marchau, 2004). On the other hand, drivers generally consider those DAS that have been on the market for longer periods of time as being better than more recent systems (see Chapter 4; Haupt, Kahvedžić-Seljubac & Risser, 2015). This finding hints towards a positive influence of familiarity with a system on the attitude towards it. In social psychology, the mere exposure effect states that repeated exposure to a stimulus provokes more positive ratings of this stimulus compared to unknown ones (Fechner, 1876, Zajonc, 2001).

The results of the present study also confirm the direct and indirect effect of DAS use experience on perceived behavioural control as stated in the STADIUM model. While the results of the focus group study conducted to develop the model (Chapter 2) suggested that DAS use experience could lead to both a reduced and an increased feeling of control while driving. The present data support that drivers perceive more control while driving the more experienced they are in using DAS. Experiencing the assistance of DAS that take over parts of the driving task reliably seems to lead to a general enhancement of perceived control (in line with the results presented in Chapter 2).

The expected indirect effect of DAS use experience on perceived risk was not identifiable in this study, due to the absent effect of perceived behavioural control on perceived risk. This could be due to some limitations (as follows and see 3.4.1, p.87) of this study. The complete STADIUM model also takes external variables as relevant influencing variables into account (see Figure 9, p.64 Chapter 2), but the focus of the questionnaire study was to look at the influence only of DAS use experience on motivational factors. External factors determining situational conditions like weather, road type etc. were not considered. However asking for a general view on perceived risk and control while driving or on perceived risk and control in a certain situation (determined by external variables) might make a difference. It can be assumed that drivers who are experienced with DAS and with particular driving situations in which they are used to be supported by DAS (i.e. by being warned of a hazard that was not expected; by assistance in keeping the lane in curves, etc.) perceive different levels of risk and control in certain situations. The reason why the hypothesized effects that are suggested by the STADIUM model were not found may be due to this. This is a research issue that should be considered in detail in future studies.

The study provides evidence that actual DAS use experience is indirectly affecting safety-related beliefs concerning secondary activities while driving. As stated in the STADIUM model, this indirect effect results from the linkage of two direct effects connected by perceived behavioural control. The more DAS use experience drivers have the less dangerous they judge it to carry out secondary activities while driving, probably as a result of an increased perceived behavioural control. Thus, it could be shown that actual DAS use experience plays a significant role in affecting driver beliefs concerning carrying out secondary activities which was confirmed to be the most important variable influencing drivers' actual intention to carry out secondary activities while driving.

The present study also reveals that the intention to carry out secondary activities while driving is directly affected by safety-related beliefs concerning secondary activities. The safer drivers consider secondary activities while driving, the more they intend to carry out such activities. This result is in line both with the STADIUM model and with the Theory of Planned Behaviour which considers attitudes and norms regarding the target behaviour as a relevant predictor of the intention to carry out the target behaviour (Ajzen, 1991; Aizen & Fishbein, 2005).

In accordance with the STADIUM model, perceived behavioural control was found to indirectly affect the intention to carry out secondary activities by influencing beliefs concerning secondary activities. By contrast, the Theory of Planned Behaviour (Ajzen, 1991; Aizen & Fishbein, 2005) states a direct effect of perceived behavioural control on behavioural intentions. The results of this study underline that the perception of control while driving determines if it is judged as appropriate and safe to carry out secondary activities while driving or not, which influences if a driver shows the intention to carry out secondary activities while driving or not. Neglecting this indirect relation may also induce an (artificial) direct effect between perceived behavioural control and the intention to carry out secondary activities while driving. However as suggested by the STADIUM model and according to the results of this study, perceived control is a decisive variable affecting driver beliefs concerning carrying out secondary activities and as a consequence indirectly affecting drivers' decisions to carry out secondary activities while driving or not.

In the present study participants with a stronger intention to carry out secondary activities while driving were also those who perceived more risk on the road. This result contradicts the assumptions of risk compensation theories (e.g., Wilde 1982, 1994). In line with the risk compensation theory, it would be assumed that higher perceived risk tends to limit the inclinations to carry out secondary activities. Perceived risk in this study was recorded by asking for participants' perception of risk during driving in general; the perceived probability to be involved in an accident in the next five years; the likelihood to be involved in an accident in the next five years when compared to other drivers and how risky other road users are perceived. As this result might seem contra-intuitive at the first sight, a viable explanation could be that drivers have a realistic self-perception: when they carry out secondary activities during driving they are distracted, and consequently the risk of being involved in an accident which they are aware of increases. Thus, this result may in fact be based on a correct assessment of the risks they run in traffic due to their own behaviour that probably includes engaging in secondary tasks. As suggested earlier, future research needs to consider each involved variable in a more situation-related and less general view.

Although the hypothesized indirect effect of safety-related beliefs concerning DAS on the intention to carry out secondary activities while driving could not be confirmed in the present study, its individual paths were all (at least marginally, on a Alpha level of $\alpha<.10$) significant. This strengthens the hypothesized paths in the STADIUM model even if the tested part of the model did not fit the data as a whole.

3.4.1. *Strengths and limitations.*

This study was performed in order to quantitatively test the stated relations respecting the motivational factors within the STADIUM model. In conclusion, results of this study underpin the influence of actual DAS use experience on motivational variables, the effect of the motivational variables on drivers' intention to carry out secondary activities and the role of DAS use experience on the intention to carry out secondary activities. Seven of nine hypotheses stated in the STADIUM model could be confirmed. However, the tested core of the STADIUM model could not be confirmed by this study as a whole. Within the questionnaire, general driver views regarding the motivational variables of interest were collected, but no situational aspects were taken up. In contrast, the initial STADIUM model considers external variables that are expected to provide a more situational view of the motivational variables of interest. However, due to the limitations of a questionnaire study and to the aim to focus on the motivational factors and on their role determining drivers' engagement in secondary activities, these external variables were not taken into account in this questionnaire study. Thus, a possible reason why the model could not be confirmed as a whole with the data from the questionnaire study is that the views of drivers on the variables were inherent in the two studies. In the focus group study during the discussions drivers may have had a more situational view of driving situations while discussing whereas in the questionnaire study, drivers were asked for a more general position. This could also be an explanation for why the residual variables of the dependent (endogenous) variables tested in the model were relatively high. Including exogenous variables as proposed by the STADIUM model is assumed to explain these variances and to strengthen the consistency of the model. Consequently, future research should specify external variables in the questions, e.g. "when it is raining…" and administer several items with different contexts per variable. It is expected that taking external variables into account when asking for the factors within the STADIUM model would reflect the outcomes of the focus group study much better, and would also increase the explanatory value of the involved variables.

However, although not all hypothesized relations within the model were found to fit the particular data, interesting significant expected path coefficients, partial correlations and correlations were received that support the relevance of the STADIUM model.

4. Study IIb – The role of driver assistance experience, system functionality, gender, age and sensation seeking in attitudes towards the safety of driver assistance systems

(A previous version of this Chapter 4 was published as: Haupt, J., Kahvedžić-Seljubac, A., Risser, R.(2015). The role of driver assistance experience, system functionality, gender, age and sensation seeking in attitudes towards the safety of driver assistance systems. *IET Journal of Engineering, 9*(7), 716-726. doi: 10.1049/iet-its.2014.0199)

"Knowledge of what is does not open the door directly to what should be."
Albert Einstein (1879-1955)

4.1. *Introduction*

The study presented in the previous Chapter 3 highlighted the relevance of attitudes towards DAS. As underlined before, driver assistance systems (DAS) mainly follow the aim to improve traffic safety. However, DAS may only contribute to increased traffic safety when drivers have a positive attitude towards the particular DAS and consequently are willing to use DAS. Attitudes may influence human behaviour (see Ajzen & Fishbein, 2005). This notion can be applied to the use of DAS; it can be assumed that drivers only actively decide to use when they are adjusted positively towards DAS. Thus, attitudes towards DAS are a main factor contributing to the potential positive influence of DAS on traffic safety. Therefore, it is important to understand what determines driver attitudes towards DAS.

The Automation Acceptance Model (AAM, see Figure 11, p.93, Ghazizadeh, Lee & Boyle, 2012) illustrates that *external variables* influence several variables (compatibility, trust, perceived usefulness and perceived ease of use). Their interplay affects driver attitudes towards DAS use which determines driver intentions to use DAS and consequently behaviour. Within a literature research introduced below, following external variables were identified as important to be investigated in detail concerning their potential influence on driver attitudes towards DAS: system functionality/characteristics of DAS and driver characteristics such as DAS usage experience, gender and driver level of sensation seeking.

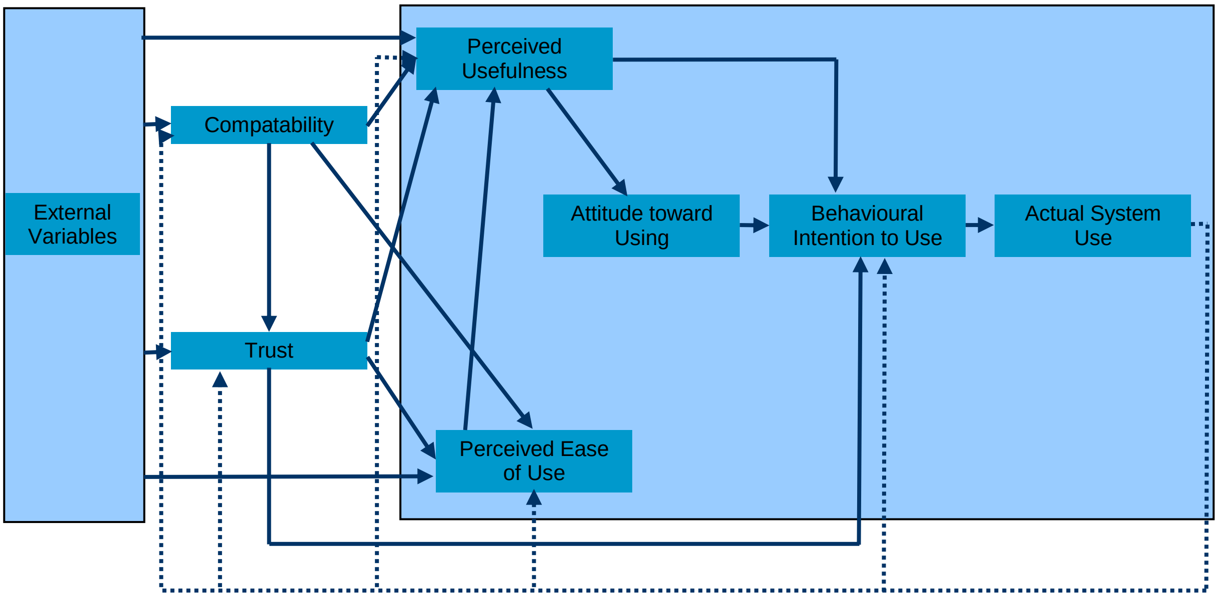


Figure 11. The Automation Acceptance Model (see Ghazizadeh, Lee & Boyle, 2012).

However, literature also reveals that research on *how* those variables affect driver attitudes towards DAS is lacking. Consequently, this study focuses on the impacts of the external variables: system functionality/characteristics of DAS, actual DAS use experience, gender and driver level of sensation seeking on drivers' safety-related attitudes towards DAS.

4.1.1. ***System functionality.***

As the AAM (see Figure 11, Ghazizadeh, Lee & Boyle, 2012) states that perceived usefulness of a system is a relevant factor that influences driver attitudes towards DAS it can be assumed that different system functionalities are perceived differently with respect to their usefulness. As already described in the first chapter of this work, the Introduction, there is a wide variety of system functionalities.

The introduction of DAS can be considered as the partial giving up of the direct control over the vehicle, and drivers are generally not in favour of systems that reduce their control by monitoring activities and invading their privacy (Brookhuis, de Waard & Janssen, 2001; Regan, Mitsopoulos, Haworth & Young, 2002).

In a long-term study, Marell and Westin (1999) investigated how the use of an information system was accepted whereby drivers indicated a high level of acceptance. The system used in the aforementioned study was an assistance system that provides information to the driver. So, how do drivers accept systems that not only provide information but also warn the driver of potential hazards or even intervene actively?

Research on the introduction of DAS in vehicles concludes that perceived changes in safety and comfort affect the preferences of DAS and that most importantly, fuel consumption has the least impact. Drivers believe for instance that DAS designed to warn of possible rear-end collisions may contribute more to safe and comfortable driving than DAS that automatically take over driving tasks (Molin & Marchau, 2004; Marchau, Wiethoff, Penttinen & Molin, 2001). Päätalo, Peltola and Kallio (2001) for example found that drivers accept the Intelligent Speed Adaptation that intervenes in the driving task and actively controls vehicle speed and that it is less accepted than systems that just provide information regarding the speed limit even if the active system was found to be more effective regarding safety.

However, the majority of research that has been carried out so far on this topic considered only a limited amount of systems, comparing two or three different versions of one system or two different systems (e.g. Päätalo, Peltola & Kallio, 2001). In order to take this lack of research into account, this study will consider a wide range of systems that are already available on the market.

4.1.2. *Driver characteristics.*

4.1.2.1. *Actual DAS use experience*

Experience with DAS may result in a higher acceptance level (Katteler, 2005). Katteler (2005) focused on the intelligent speed adaptation system. However, considering actual use of DAS that is supposed to reflect driver safety-related attitudes towards DAS, a study of driver behaviour in terms of the Adaptive Cruise Control (ACC) system shows that previous ACC driver experience has no effect on

ACC use (Rajaonah, Tricot, Anceaux & Millot, 2007). However, a literature review shows that research on DAS use experience in relation to driver attitudes is sparse (e.g. Marell & Westin, 1999; Jamson, Lai, Carsten, 2007; Wallen Warner & Aberg, 2008; Adell, 2009). Furthermore, research on the effects of DAS may drift from actual DAS use experience.

Studies on the use of DAS and the associated effects on driver behaviour often follow a specific experimental design (e.g. Buld & Krüger, 2003; Brouwer & Hoedemaeker, 2006; Popken, 2009). Briefly, experimental groups are built which make a comparison between driving with a deactivated and with an activated system possible. Most of the studies that have been carried out have investigated the effect of one DAS only (e.g. Vadeby, Wiklund & Forward, 2011; Wallen Warner & Aberg, 2008) with only a select number considering how driver behaviour is influenced by the use of more than one DAS simultaneously (e.g. Brouwer & Hoedemaeker, 2006). However, is this a realistic approach? First DAS were introduced on the market decades ago. In practice, it is difficult to find any passenger car that is not equipped with at least one DAS. The Anti-lock braking system (ABS), for instance, can be found as standard equipment in every European car built after June 2004 (POEL TEC, 2013). In addition, it is difficult to find persons who have never driven without the support of DAS. Furthermore, there are no active drivers who have *no* experience with other DAS while being familiar with an ACC, i.e. drivers who use an ACC are also familiar with e.g. Navigation System, Cruise Control, Head-up Display etc.

Changes in driver safety-related attitudes require time. Internal factors such as internal drives and wishes, risk perceptions, the benefits of behaviour for oneself, and assessments of different situations as well as external factors such as interactions with other people (social pressure, opinions of close related persons) and environmental factors determine motivational factors like attitude formation. While "internal factors are the basis for change, external factors are the conditions for change" (Miller, 1999). For instance, driving one hour in a driving simulator cannot simulate motivational change because not all relevant influence factors can be taken into account. Furthermore, investigating only one system in a strictly experimental design does not reflect reality. Internal validity of studies that follow a strictly experimental design or that focus only on the effects of one to three DAS on driver behaviour can be evaluated as high. But when taking real experience with using DAS into account external validity of those studies is rather low and neglects the *actual* DAS experience that may already have induced effects especially on motivational factors such as driver attitudes towards DAS.

Concluding, actual DAS use experience was identified as a relevant variable that may affect driver attitudes towards DAS. Therefore, it was decided that it is necessary to analyse the actual DAS use experience that drivers have by not only considering one, two or three systems, but the majority of the usual DAS that are currently on the market. Based on these considerations, actual DAS experience in this research issue is defined, as in the previous Chapters 1, 2 & 3, as interplay between the use, and the duration of use, of the particular systems, the current frequency of driving with the particular systems activated, and the subjective familiarity with them.

4.1.2.2. Gender

A survey of the literature suggests that very little research has been carried out on the difference in male and female driver attitudes towards DAS (Rajaonah, Tricot, Anceaux, Millot, 2007; Rudin-Brown & Parker, 2004; Jamson, Lai & Carsten, 2007; Höltl & Trommer, 2013). A study of the behaviour of drivers using ACC suggests that personal variables such as gender have no effect on dependent variables such as ACC use, trust in ACC, self-confidence, effort required, decrease in vigilance, risk of collision or risk taken by using the device (Rajaonah et al., 2007). In comparison, however, another study of ACC in terms of behavioural adaptation proposes that gender can play a significant role in driver attitudes towards such systems. The test-track study demonstrates that when drivers were assessed for “sensation seeking” while using ACC, men were more likely to display higher sensation seeking tendencies than women (Rudin-Brown & Parker, 2004). A number of studies reveal that men score higher in sensation seeking than women. So, the level of driver sensation seeking that is also highlighted as a potential external influencing variable by Gazizadeh, Lee and Ng Boyle (2012) is a factor that should also be taken into account. However, considering studies that investigate differences in the general acceptance of technology, men are generally more interested in new technologies than women. In addition, men are more affected by their perceptions of usefulness, whereas women are more affected by perceptions of ease of use (Venkatesh & Morris, 2000; Broos, 2005).

However, considering research on the differences in motivational factors in general, gender has been found to be a relevant variable that affects human motivations (Yagil, 1998). Consequently, it was identified as potential external variable that may influence driver attitudes towards DAS, which this study will examine.

4.1.2.3. Sensation seeking & age

Past research has shown that sensation seeking, a personal characteristic, is related to a person's attitude. A lot of research has been carried out on a person's level of sensation seeking and attitudes towards consuming mind-altering substances (e.g. Hoyle, Stephenson, Palmgreen, Lorch & Donohew, 2002). Thereby, a higher score in sensation seeking is always associated with less negative attitudes towards mind-altering substances. So, how does the level of driver sensation seeking influence safety-related attitudes towards systems that aim at improving traffic safety? Again, there is a lack of research on this topic. No study was found that focuses on this research issue. However, a number of studies have shown that individuals that score high in sensation seeking appear to be attracted by risky activities such as reckless or drunk driving (e.g. Arnett, 1990; Jonah, 1997; Heino, van der Molen & Wilde, 1996). Whissel and Bigelow (2003) found that attitudes towards speeding correlate to young drivers' scores in sensation seeking. Age has been found to negatively correlate to adventure- and thrill-seeking (Bekhor & Albert, 2014). Subsequently, age may be also a contributing factor influencing driver attitudes. Concluding, sensation seeking and age were added as relevant to be investigated if they affect driver attitudes towards DAS.

4.1.3. ***Objectives & hypotheses.***

A questionnaire study is conducted in order to gain information on *how* the variables of interest - DAS use experience, level of driver sensation seeking, gender and age - affect driver safety-related attitudes towards DAS.

Referring to the reported literature research it is expected that

- drivers judge systems differently; thereby, it is assumed that drivers judge systems more positively the less automation the system provides
- female drivers judge DAS differently from male drivers
- the higher drivers score on sensation seeking the less positive they judge DAS in terms of safety
- the younger the age of the driver, the less positive the judgement of DAS is in terms of safety
- driver experience in DAS use positively influences driver safety-related attitudes towards DAS.

4.2. ***Methods***

4.2.1. ***Participants.***

The 211 (91 ♀, 120 ♂) participants answered the here addressed items within the framework of the previously in Chapter 3 introduced questionnaire study. For a detailed description of the participants characteristics see Chapter 3, p.67f).

4.2.2. *Questionnaire.*

A questionnaire was compiled based on the results of an antecedent focus group study (introduced in Chapter 2), a literature search and on an iterative communication process with 10 experts from the transport research domain. The questionnaire included, additionally to the items introduced in Chapter 3, items asking for the participants' safety-related attitudes towards DAS and their level of sensation seeking (SSS, see Hoyle, Stephenson., Palmgreen, Lorch & Donohew, 2002).

4.2.2.1. *DAS use experience*

DAS use experience was assessed as in Chapter 2 and 3. Within the questionnaire, *DAS use experience* was determined by the three main questions*: (1.) Did you - and if yes, when did you first - used the particular system*? *(2.) How often do you currently drive with the particular system activated? (3.) How familiar do you feel with the particular DAS?* The questions were asked for the systems listed in Table 5, p.52, Chapter 2 and supplemented in Chapter 3 (p.69).

4.2.2.2. *Attitudes towards DAS*

Since persons perceive an extensive need to generally feel safe and especially in traffic (SWOV, 2012), in this study safety-related attitudes towards DAS will be considered. The questions that served to assess driver safety-related attitudes towards DAS and that should be answered on a 7-steps-Likert-scale, were as follows:

> *"Would you wish that closely related persons (parents, children, partner, friends) use the respective system?" (asked for each system listed in Table 5, p.52 and the supplemented systems, see Chapter 3, p.69)* (answering mode ranging from 1 'no, not at all' to 7 'yes, absolutely')

“When a child is a passenger in the car, the respective system should be activated in order to be able to inform, warn or intervene if necessary.” (asked for each system listed Table 5, p.52 and the supplemented systems, see Chapter 3, p.69) (answering mode ranging from 1 ‘absolutely not agree’ to 7 ‘absolutely agree’)

“The activation of the respective system so that it can inform, warn or intervene if necessary is dangerous.” (asked for each system listed in Table 5, p.52 and the supplemented systems, see Chapter 3, p.69) (answering mode ranging from 1 ‘absolutely not agree’ to 7 ‘absolutely agree’)

An item analysis was calculated for this ‘safety-related attitudes towards DAS’-scale. Including the first two items, Cronbach’s alpha was always (for each system) >0.7. Cronbach’s alpha decreased when the third item was included in the scale. Thus, the first two items served as ‘indirect safety-related attitudes towards DAS’ and the third as ‘general attitude towards DAS’. For a better understanding and interpretation of the results, the item *“The activation of the respective system so that it can inform, warn or intervene if necessary is dangerous.”* was polarised in the same direction as the other two items.

*4.2.3. **Data analysis.***

In order to identify general differences in the safety-related attitudes towards DAS between the several DAS, a one-way ANOVA with repeated measures was calculated. Partial Eta square η_p^2 was computed as effect size. According to Rasch, Friese, Hofmann & Naumann (2006), a value of .01 can be interpreted as a small effect, .06 as medium and >= .14 as a large effect. In order to gain the information about the differences between the safety-related attitudes towards the particular systems, Bonferroni post hoc analyses were calculated. Spearman correlations were reckoned to consider the influence of driver DAS use experience and level of sensation seeking on safety-related attitudes towards DAS. The gender effect was analysed by applying the independent t-test. Additionally, *Cohen’s d (d)* was calculated in order to gain information about the strength of the effects. Cohen

(1988) stated the following cut-off values: a *d* of .20 can be interpreted as a small effect, .50 as medium and >= .80 as large effect.

The data analysis was calculated with PASW Statistics 18. A *p*-value of smaller than .05 was chosen as a threshold of significance.

4.3. Results

The general safety-related attitudes towards DAS differed between the systems significantly, $F(28,1) = 23.145$, $p = .000$, $\eta_p^2 = .099$. A significant difference was also found for the indirect judgement of the DAS safety potential, $F(28,1) = 70.7$, $p = .000$ with an effect of $\eta_p^2 = .252$. Table 7 gives an overview of how safe the participants judged the particular DAS. The DAS are arranged from the DAS perceived as being less safe to the ones perceived as being most safe.

Table 7. *Arranged list of participants' general and indirect safety-related attitudes towards DAS (answers from 1 'not safe' to 7 'safe')*

Name	*Mean* 'general attitudes towards DAS'	*SD* 'attitudes towards DAS'	Name	*Mean* 'indirect attitudes towards DAS'	*SD* 'attitudes towards DAS'
Emergency brake assist	5.185	1.836	**Auto transmission**	3.768	1.841
Head-up-Display (HUD)	5.455	1.789	**Parking system (active)**	3.834	1.772
Lane Keeping assistance (active)	5.531	1.640	**Head-up-Display (HUD)**	3.834	1.686
Intelligent Speed Adaptation (active)	5.569	1.659	**Car-to-Car communication**	3.853	1.739
Cruise control	5.763	1.583	**Hill Descent Control**	3.955	1.808
Navigation system	5.768	1.624	**Traffic Sign Recognition**	4.033	1.712
Car-to-Car communicatio n	5.810	1.634	**Intelligent Speed Adaptation (active)**	4.133	1.689
Parking system (active)	5.863	1.456	**Hill-holder**	4.225	1.788

Name	*Mean* 'general attitudes towards DAS'	*SD* 'attitudes towards DAS'
Adaptive Cruise Control (ACC)	5.877	1.459
Traffic Sign Recognition	5.943	1.479
Braking Assistance System (BAS)	5.967	1.526
Intelligent Speed Adaptation (passive)	6.033	1.488
Blind spot monitor	6.100	1.419
Lane Keeping assistance (warning)	6.104	1.397
Pre-crash warning system	6.137	1.439
Hill Descent Control	6.199	1.397
Tire-pressure monitoring system	6.251	1.404
Hill-holder	6.256	1.367
Advanced front-lighting system (AFS)	6.289	1.326
Automotive night vision	6.294	1.313
Automatic beam switching	6.133	1.477
Electronic stability control (ESC)	6.313	1.453
Parking system (warning)	6.332	1.375
Rain sensor	6.332	1.292
Traction control system (TCS), also known as anti-slip	6.346	1.390

Name	*Mean* 'indirect attitudes towards DAS'	*SD* 'attitudes towards DAS'
Cruise control	4.261	1.651
Lane Keeping assistance (active)	4.332	1.626
Intelligent Speed Adaptation (passive)	4.474	1.695
Automatic beam switching	4.536	1.702
Adaptive Cruise Control (ACC)	4.559	1.624
Advanced front-lighting system (AFS)	4.630	1.566
Lane Keeping assistance (warning)	4.780	1.527
Rain sensor	4.808	1.717
Curve light	4.848	1.501
Blind spot monitor	4.884	1.579
Automotive night vision	4.901	1.603
Automatic headlamps	4.946	1.616
Emergency brake assist	4.953	1.671
Navigation system	5.026	1.617
Tire-pressure monitoring system	5.043	1.641
Pre-crash warning system	5.194	1.448
Parking system (warning)	5.201	1.567

Name	*Mean* 'general attitudes towards DAS'	*SD* 'attitudes towards DAS'
regulation (**ASR**)		
Auto transmission	6.351	1.227
Automatic headlamps	6.360	1.292
Anti-lock braking system (ABS)	6.365	1.442
Curve light	6.408	1.248

Name	*Mean* 'indirect attitudes towards DAS'	*SD* 'attitudes towards DAS'
Braking Assistance System (BAS)	5.372	1.455
Traction control system (**TCS**), also known as **anti-slip regulation** (**ASR**)	5.654	1.452
Electronic stability control (**ESC**)	6.187	1.135
Anti-lock braking system (ABS)	6.574	0.916

Note: According to Eskandarian (2012, see Chapter 1,Table 1, p.16.):
marked systems were classified as 'Informational'
marked systems were classified as 'Informational' / 'Warning-alerting'
marked systems were classified as 'Warning-alerting'
marked systems were classified as 'Partial (semi) control', and
marked systems were classified as 'Automatic (full) control"

Table 8 (p.104) and Table 9 (p.105) show the results of the post hoc analysis and how the systems were judged differently.

Table 8. *Results of the post hoc analysis differences in general attitudes towards DAS.*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1		1	1	1	1	1	1	1	1	.000	.002	.000	1	1	1	.000	.001	.000	1	.000	1	.000	.400	.002	1	.002	1	.032	1
2			1	1	1	1	1	1	1	.000	.002	.000	1	1	1	.000	.001	.000	1	.000	1	.000	.431	.002	1	.001	1	.023	1
3				1	1	1	1	1	1	.000	.018	.000	1	1	1	.000	.005	.001	1	.000	1	.000	1	.009	1	.005	1	.113	1
4					1	1	.279	1	1	.000	.000	.000	1	1	1	.000	.000	.000	.676	.000	.703	.000	.071	.000	1	.000	1	.001	1
5						.987	.015	1	1	.000	.000	.000	.123	1	1	.000	.000	.000	.016	.000	.029	.000	.002	.000	1	.000	1	.000	1
6							1	1	1	.000	.060	.000	.1	1	1	.000	.000	.000	1	.000	1	.000	.654	.001	1	.001	1	.025	1
7								1	1	.000	1	.000	.1	1	1	.157	.988	.486	1	.000	1	.000	1	.680	1	1	1	1	1
8									1	.000	.018	.000	.1	1	1	.000	.000	.000	1	.000	1	.000	.329	.000	1	.001	1	.008	1
9										.000	.013	.000	.1	1	1	.000	.001	.000	1	.000	1	.000	.353	.002	1	.000	1	.008	1
10											.034	1	.000	.000	.000	1	.249	1	.000	1	.000	1	.000	.747	.000	.674	.000	.002	.000
11												.000	1	.217	1	1	1	1	1	.006	1	.041	1	1	1	1	.062	1	.145
12													.000	.000	.000	.002	.000	.013	.000	.041	.000	.033	.000	.000	.000	.000	.000	.000	.000
13														1	1	.137	.224	.448	1	.000	1	.000	1	.049	1	1	1	1	1
14															1	.000	.001	..004	.1	.000	1	.000	.352	.001	1	.010	1	.213	1
15																.008	.013	.050	1	.000	1	.000	1	.006	1	.080	1	1	1
16																	1	1	.341	1	.225	1	1	1	.003	1	.000	1	.000
17																		1	1	.013	1	.043	1	1	.046	1	.003	1	.001
18																			.802	1	1	1	1	1	.022	1	.000	1	.000
19																				.000	1	.000	1	.153	1	1	1	1	1
20																					.000	1	.000	1	.000	.422	.000	.022	.000
21																						.000	1	.079	1	1	1	1	1
22																							.000	1	.000	1	.000	.145	.000
23																								.551	1	1	.353	1	.594
24																									.008	1	.002	1	.001
25																										.080	1	.598	1
26																											.000	1	.001
27																												.009	1
28																													.009
29																													

Note: 1= Anti-lock breaking system; 2= Anti-slip regulation; 3= Electronic stability control; 4= Automatic headlamps; 5= Curve light; 6= Advanced front-lighting system; 7= Automatic beam switching; 8= Automotive night vision; 9= Rain sensor; 10= Head-up-Display; 11= Braking Assistance System; 12= Emergency brake assist; 13= Pre-crash warning system; 14= Hill-holder; 15= Hill Descent Control; 16= Cruise control; 17= Adaptive Cruise Control; 18= Navigation system; 19= Blind spot monitor; 20= Lane Keeping assistance (active); 21= Lane Keeping assistance (warning); 22= Intelligent Speed Adaptation (active); 23= Intelligent Speed Adaptation (passive); 24= Car-to-Car communication; 25= Tire-pressure monitoring system; 26= Parking system (active); 27= Parking system (warning); 28= Traffic Sign Recognition; 29= Auto transmission

x significant on an Alpha Level of .05

x significant on an Alpha Level of .01

Table 9. *Results of the post hoc analysis differences in indirect attitudes towards DAS.*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
2			.000	.000	.000	.000	.000	.000	.000	.000	1	.000	.000	.000	.000	.000	.000	.002	.000	.000	.000	.000	.000	.000	.000	.000	.088	.000	.000
3				.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
4					1	.110	.001	1	1	.000	.050	1	1	.000	.000	.000	.407	1	1	.000	1	.000	.056	.000	1	.000	1	.000	.000
5						.060	.007	1	1	.000	.000	1	.444	.000	.000	.001	1	1	1	.000	1	.000		.000	1	.000	1	.000	.000
6							1	.009	1	.000	.000	1	.000	**.043**	.000	.811	1	.919	1	.831	1	.001	1	.000	.184	.000	.001	.001	.000
7								.001	1	.000	.000	.118	.000	1	.000	1	1	.070	.911	1	1	.069	1	.000	**.032**	.000	.000	**.039**	.001
8									1	.000	.001	1	1	.000	.000	.000	.669	1	1	.000	1	.000	**.020**	.000	1	.000	1	.000	.000
9										.000	.001	1	.1	.000	.000	.000	1	1	1	.139	1	.000	1	.000	1	.000	.147	.000	.000
10											.000	.000	.000	.201	1	.377	.000	.000	.000	.003	.000	1	.000	1	.000	1	.000	1	1
11												.005	1	.000	.000	.000	.000	1	.001	.000	.000	.000	.000	.000	1	.000	1	.000	.000
12													1	.000	.000	.000	**.015**	1	1	.000	1	.000	**.011**	.000	1	.000	1	.000	.000
13														.000	.000	.000	.000	1	.127	.000	.000	.000	.000	.000	1	.000	1	.000	.000
14															**.013**	1	1	.000	.000	1	.000	1	1	1	.000	.425	.000	1	.422
15																1	.000	.000	.000	.289	.000	1	.000	1	.000	1	.000	1	1
16																	1	.000	.000	1	**.011**	1	1	.959	.000	.063	.000	1	**.023**
17																		.182	.335	1	1	.000	1	.000	**.042**	.000	.000	.000	.000
18																			1	.000	1	.000	**.019**	.000	1	.000	1	.000	.000
19																				.000	1	.000	.000	.000	1	.000	1	.000	.000
20																					.000	1	1	.000	.000	.005	.000	1	.081
21																						.000	.000	.000	1	.000	.109	.000	.000
22																							.000	.587	.000	1	.000	1	1
23																								.000	.001	.000	.000	.001	.002
24																									.000	1	.000	1	1
25																										.000	1	.000	.000
26																											.000	1	1
27																												.000	.000
28																													1
29																													

Note: 1= Anti-lock breaking system; 2= Anti-slip regulation; 3= Electronic stability control; 4= Automatic headlamps; 5= Curve light; 6= Advanced front-lighting system; 7= Automatic beam switching; 8= Automotive night vision; 9= Rain sensor; 10= Head-up-Display; 11= Braking Assistance System; 12= Emergency brake assist; 13= Pre-crash warning system; 14= Hill-holder; 15= Hill Descent Control; 16= Cruise control; 17= Adaptive Cruise Control; 18= Navigation system; 19= Blind spot monitor; 20= Lane Keeping assistance (active); 21= Lane Keeping assistance (warning); 22= Intelligent Speed Adaptation (active); 23= Intelligent Speed Adaptation (passive); 24= Car-to-Car communication; 25= Tire-pressure monitoring system; 26= Parking system (active); 27= Parking system (warning); 28= Traffic Sign Recognition; 29= Auto transmission

x significant on an Alpha Level of .05

x significant on an Alpha Level of .01

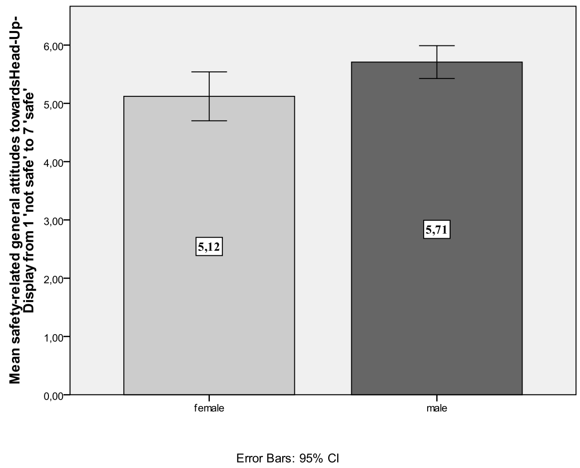
4.3.1. ***Gender differences.***

General safety-related attitudes towards DAS: Significant gender differences in participant *general* safety-related attitudes towards DAS were found for the *Head Up Display* (t(164.475) = -2.306, p = .011, d = .360), the *Tire-pressure monitoring System* (t(159.524) = -2.196, p = .015, d = .348) and the *warning Parking System* (t(143.885) = -2.039, p = .022, d = .340). Male participants considered these systems safer in comparison to female participants. No gender differences were found for the other 26 systems.

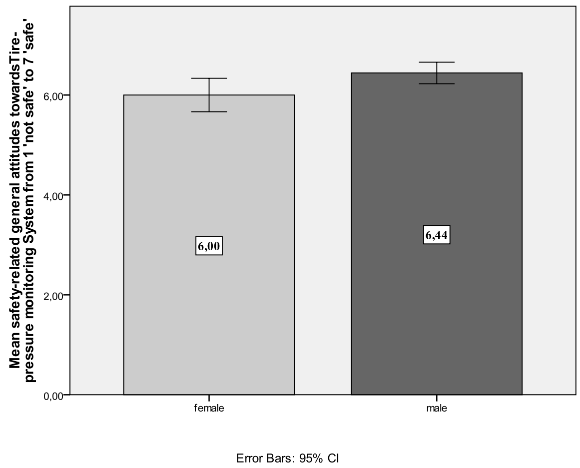
Indirect safety-related attitudes towards DAS: Female participants indirectly judged the *Electronic stability control System* (t(173.055) = -1.745, p = .042, d = .265) and the *Hill Descent Control* (t(209) = -1.692, p = .046, d = .234) as being less safe compared to the male participants' assessments. No gender differences were found for the other 27 considered systems.

Figure 12 (p.107) illustrates the differences in participant general and indirect safety-related attitudes towards the mentioned systems with respect to gender differences.

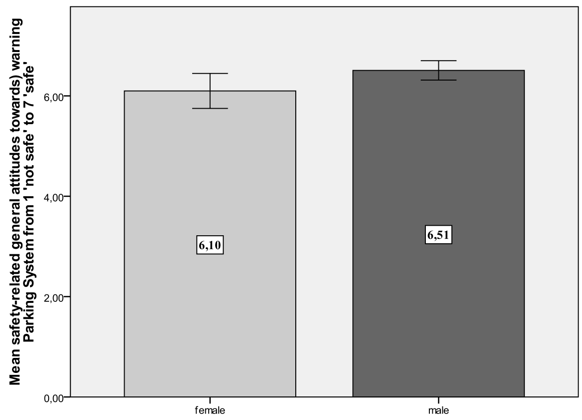
(a) Head Up Display – General safety-related attitudes towards DAS



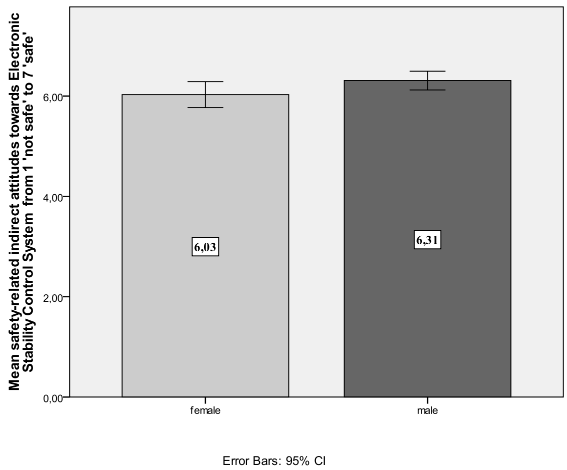
(b) Tire-pressure monitoring System – General safety-related attitudes towards DAS



(c) warning Parking System – General safety-related attitudes towards DAS



(d) Electronic stability control System – Indirect safety-related attitudes towards DAS



(e) Hill Descent Control System – Indirect safety-related attitudes towards DAS

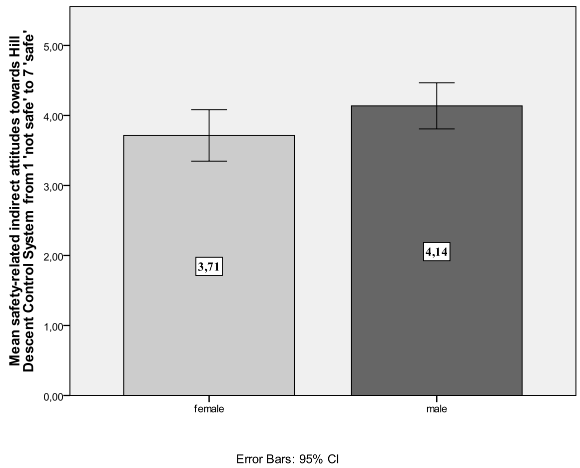


Figure 12. Gender differences in participants attitudes towards DAS.

4.3.2. **Sensation seeking.**

General safety-related attitudes towards DAS: One small significant correlation was found for the effect of the driver's level of sensation seeking on general safety-related attitudes towards a specific DAS. The higher the participants scored in 'sensation seeking', the safer they judged the *Electronic stability control System*, r = -.128, p = .032. No further correlations were found for the other 28 considered systems.

Indirect safety-related attitudes towards DAS: The level of participant sensation seeking correlated significantly with participant indirect safety-related attitudes towards *Traffic Sign Recognition System*, r = .153, p = .013. The correlation can be interpreted as being small. No further correlations were found for the other 28 considered systems.

4.3.3. **Age.**

General safety-related attitudes towards DAS significantly correlated positively with age for the *Cruise Control System* (r = .170, p = .007) and the *Navigation System* (r = .195, p = .002). The small correlations reflect that the older participants were, the more positive they judged the two systems in terms of safety. No further significant correlations were found.

Indirect safety-related attitudes towards DAS did *not* significantly correlate with age for the *active Intelligent Speed Adaptation System* (r = 0.100, p = .074), the *warning Intelligent Speed Adaptation System* (r = .097, p = .080) and the *Traffic Sign Recognition System* (r = .058, p = .200). Significant correlations between age and the indirect safety-related attitudes towards DAS are illustrated in Table 10 (p.109).

Table 10. *Correlation between age and indirect safety-related attitudes towards DAS.*

Name	Correlation	Name	Correlation
Advanced front-lighting system (AFS)	.330** *p* = .006	**Hill-holder**	.193** *p* = .002
Automatic beam switching	.308** *p* = .006	**Tire-pressure monitoring system**	.179** *p* = .005
Automotive night vision	.298** *p* = .092	**Parking system (warning)**	.177** *p* = .005
Hill Descent Control	.294** *p* = .000	**Precrash warning system**	.174** *p* = .006
Rain sensor	.285** *p* = .000	**Adaptive Cruise Control (ACC)**	.173* *p* = .006
Curve light	.250** *p* = .000	**Car-to-Car communication**	.164** *p* = .009
Cruise control	.236** *p* = .000	**Emergency brake assist**	.163** *p* = .009
Navigation system	.234* *p* = .000	**Anti-lock braking system (ABS)**	.157* *p* = .011
Auto transmission	.233** *p* = .000	**Traction control system (TCS)**, also known as **anti-slip regulation** (ASR)	.151* *p* = .014
Automatic headlamps	.225** *p* = .000	**Head-up-Display (HUD)**	.150* *p* = .015
Parking system (active)	.223** *p* = .001	**Lane Keeping assistance (warning)**	.149* *p* = .015
Braking Assistance System (BAS)	.213** *p* = .001	**Electronic stability control (ESC)**	.132* *p* = .028
Lane Keeping assistance (active)	.193** *p* = .002	**Lane Keeping assistance (warning)**	.149* *p* = .015

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level

4.3.4. *Actual DAS use experience.*

Table 11 shows the correlations found between the actual DAS use experience and the safety-related attitudes towards the particular systems. All found correlations were positive, thus, the more experienced participants were in using DAS, the higher they judged DAS concerning safety. The found correlations can be interpreted as being small.

Table 11. *Arranged list of correlation between safety-related attitudes towards DAS and DAS experience.*

General safety-related attitudes towards DAS		Indirect safety-related attitudes towards DAS	
Name	**Correlation**	**Name**	**Correlation**
Curve light	.242** p = .000	**Auto transmission**	.316** p = .000
Braking Assistance System (BAS)	.229** p = .000	**Automatic headlamps**	.247** p = .000
Blind spot monitor	.229** p = .000	**Electronic stability control (ESC)**	.245** p = .000
Head-up-Display (HUD)	.228** p = .000	**Rain sensor**	.243** p = .000
Rain sensor	.225** p = .000	**Anti-lock braking system (ABS)**	.232** p = .000
Parking system (warning)	206** p = .001	**Parking system (warning)**	.218** p = .001
Tire-pressure monitoring system	.201** p = .002	**Braking Assistance System (BAS)**	.214** p = .001
Lane Keeping assistance (warning)	.195** p = .002	**Hill Descent Control**	.207** p = .001
Traction control system (TCS), also known as **anti-slip regulation (ASR)**	.183** p = .004	**Tire-pressure monitoring system**	.194** p = .002
Hill-holder	.176** p = .005	**Traction control system (TCS)**, also known as **anti-slip regulation (ASR)**	.176** p = .005
Auto transmission	.176** p = .005	**Hill-holder**	.168** p = .007
Intelligent Speed	.174**	**Head-up-Display**	.153*

General safety-related attitudes towards DAS		Indirect safety-related attitudes towards DAS	
Name	**Correlation**	**Name**	**Correlation**
Adaptation (warning)	p = .006	**(HUD)**	p = .013
Traffic Sign Recognition	.173** p = .006	**Advanced front-lighting system (AFS)**	.145* p = .017
Hill Descent Control	.164** p = .009	**Automatic beam switching**	.143* p = .019
Automatic headlamps	.163** p = .009	**Cruise control**	.134** p = .026
Cruise control	.158* p = .011	**Lane Keeping assistance (warning)**	.133* p = .027
Electronic stability control (ESC)	.156* p = .012	**Curve light**	.115* p = .048
Navigation system	.155* p = .012	**Emergency brake assist**	.111 p = .053
Car-to-Car communication	.143* p = .019	**Navigation system**	.108 p = .060

** Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level

4.4. *Discussion*

The main goal of this study was to gain information on how the variables DAS use experience, level of driver sensation seeking, gender, and age affect driver safety-related attitudes towards DAS. In order to investigate this research question, a questionnaire survey was carried out. The hypotheses were that (1.) drivers would judge systems differently, thereby it was expected that drivers would judge systems more positively the less automation the systems provide. Further, it was expected that (2.) women judge DAS in terms of safety differently from men. It was also expected that both, the level of driver sensation seeking and age were related to driver safety-related attitudes towards DAS. Therefore, it was assumed that (3.) the higher drivers score on sensation seeking, the less positive they judge DAS in terms of safety and that (4.) age is positively correlated to driver safety-related attitudes. Additionally, it was hypothesized (5.) that the more DAS use experience drivers have, the more positively they judge DAS in terms of safety. Hypotheses (1.), (4.) and (5.) were confirmed by the results of this study.

The results show that, in terms of safety, there is great variation in safety-related attitudes towards the 29 systems. Some were valued positively, others rather negatively. When participants were questioned on safety with regard to a system that is available as a 'warning'-version and as 'active' intervening version (e.g. lane keeping assistance, ISA), participants evaluated the warning versions as being safer in comparison to the active ones. This supports our hypothesis (1.) and the results of previous studies (Molin & Marchau, 2004; Marchau, Wiethoff, Penttinen & Molin, 2001). The result may be explained such that different systems induce different perceived usefulness due to their various functionalities. According to the AAM (see Figure 11, p.93, Ghazizadeh, Lee & Boyle, 2012) perceived usefulness directly influences driver attitudes towards DAS. Thus, the results confirm this stated relation of the AAM model. A further explanation is that drivers do not trust automation as much as they trust themselves as drivers. Another explanation is that drivers are generally not in favour of systems that reduce their control by monitoring activities, as several past studies found (Brookhuis, de Waard & Janssen, 2001, Regan, Mitsopoulos, Haworth & Young, 2002). The ABS, ESC and ASR systems were considered the safest. Considering the ranking of the DAS, a potential influencing factor on the safety-related attitudes of drivers towards the safety of a DAS could be the length of time a system is available on the market and to which extent the system is implemented in licensed cars. This issue should be further investigated in future research.

When participants were directly asked how dangerous they judge the particular activated system, it was found that the Curve Light System, the ABS and the Automatic Headlamps were evaluated as least dangerous when activated. A possible explanation for this outcome goes in line with the previous one: the ABS was one of the first introduced systems on the market and is at current state serially installed in regular passenger vehicles. The Curve Light System and the Automatic Headlamps are both systems that are assigned to the fourth category of Eskandarian's (2012) classification and are classified as automatic (full) control systems. Both systems automatically take over their respective task. However, providing light automatically cannot be seen as an active part of the driver's primary driving task but rather as a natural function of the vehicle, like a wheel. Drivers may perceive this as not intervening in the primary driving task.

However, the fact that drivers judge DAS so differently underlines that system functionality plays an important role in the perceived safety of DAS. Potential influencing factors on the safety-related attitudes of drivers towards the safety of DAS raised in the questionnaire survey were gender, driver level of sensation seeking, age, and drivers experience in using DAS.

Gender differences in participant judgements on DAS were found for five of the 29 systems: ESC, HuD, Hill Descent Control, Tire-Pressure Monitoring System and the warning Parking System. Male participants consistently evaluated these systems as being safer in comparison to female participants. The effect was highest for the Head-up-Display. The results do not, however, confirm the hypothesis (2.) that women judge DAS better than men. This was assumed because men score higher in sensation seeking than women, and consequently judge safe measurements such as DAS as being less positive. As for the majority of considered systems (24 of 29) no gender differences were found. Hence, it can be concluded that gender is not a decisive factor in influencing whether a system is perceived as being safe or not. This supports the findings of Rajaonah, Tricot, Anceaux and Millot (2007).

The same can be concluded for the level of sensation seeking. Only two correlations were found for the effect of the participants' level of sensation seeking on safety-related attitudes towards a specific DAS. The effects were found for the Traffic Sign Recognition System and the Electronic Stability Control System. The results do not confirm the expectations (3.) in that drivers would judge DAS less positively when scoring higher in sensation seeking. The hypothesis was derived from evidence that revealed that the higher drivers score in sensation seeking, the less safe they behave in traffic (e.g. Arnett, 1990; Jonah, 1997; Heino, van der Molen & Wilde, 1996) and the more positively reckless driving (such as speeding) is judged (see Whissell & Bigelow, 2003).

According to research that has shown that age and adventure- and thrill-seeking are negatively correlated (Bekhor & Albert, 2014) and that sensation seeking was expected to be related to more negative attitudes towards safety (hypothesis 3., see previous paragraph), hypothesis 4 was derived that predicted that the older drivers are the more positive they judge DAS in terms of safety. As illustrated, the third hypothesis could not be confirmed in this study. However, although no general relation between the level of driver sensation seeking and safety-related attitudes towards DAS was found, the results show that when drivers were asked indirectly for their attitudes towards DAS for the majority (26 of 29) of the systems, a positive correlation to age was found. In the search for a justification of this result and one that indeed confirms the hypothesis (4.) but not the derivation, it was concluded that one reason might be a relation between age and DAS experience. In fact, a positive correlation (r = .193, p = .002) between age and DAS experience was found. Consequently, a partial correlation was calculated by controlling the variable 'DAS experience' and found 22 significant correlations between age and attitudes towards DAS. No significant correlations were found for the Anti-lock Braking System, the Anti-Slip Regulation System, the Electronic Stability Control System, the Blind Spot Monitor System, the active and the warning Intelligent Speed Adaptation System and the Traffic Sign Recognition System. However, quite generally it can be concluded that age contributes to driver attitudes towards DAS.

In contrast, for the majority of considered systems (24 of 29), significant correlations with participant DAS experience were found. No significant correlations were found for the active Lane Keeping Assistance System, the active ISA, the warning ISA, the active Parking System and the Pre-Crash Warning System. The significant correlations found were consistently positive: the more DAS experience the participants had, the safer they judged the systems. Thus, experiencing DAS and its functionality seems to have a positive influence on how drivers judge the safety relevance of DAS. This result confirms the hypothesis and supports the study results of Katteler (2005). The availability of DAS and the ability to afford DAS might contribute to a higher DAS experience in the general public and consequently to a more broadly distributed positive view on DAS.

It is important to note that different results were obtained when participants were either asked directly or indirectly about their attitudes towards DAS. The results indicate that more significant effects were found when asking for the indirect attitudes towards DAS. Indirect measurements of attitudes have a high convergent and predictive validity (see Jonas, Stroebe & Hewstone, 2007), while one may assume that measurements not only reflect attitudes but also social desirability. Indeed, indirect measurements may be more of a reflection of the 'real' attitudes. This should be taken into account in future research on attitudes towards DAS.

It should be highlighted that participants were genuine DAS users. As discussed earlier (in studies in Chapter 2 and 3), this can be considered both a strength and a limitation of the study. The related issues (see Chapter 2 & 3, p.62ff.) should be taken into account in future research.

5. Study III – Look where you have to go! A field study comparing glance behaviour at urban intersections using a navigation system or a printed route instruction

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"Truth is what stands the test of experience."

(Albert Einstein, 1879-1955)

5.1. *Introduction*

The previously presented studies (see Chapter 2, 3 and 4) could underline the relevance of motivational factors that are influenced by the use of DAS. Taking the navigation system as a DAS-example, the study introduced in this chapter will show how the effects of DAS use and its influence on internal motivational factors are reflected in observable driver behaviour.

A navigation system aims to support the driver in the driving task by providing dedicated and timed route instructions. The system guides the driver verbally and/or visually through the quickest or shortest route to the chosen destination. This support aims to reduce the effort the driver has to make in order to navigate the vehicle and allows the driver to spend additional resources on the performance of the driving task. Previous research shows that the use of a navigation device is more efficient for reaching a destination compared to when a map is used (e.g. Dingus, 1995, Lee & Cheng, 2008). A navigation system provides a more efficient and convenient way to reach the destination and also saves time and fuel.

The navigation system for passenger cars was introduced to the market over 30 years ago. Therefore it is not surprising that quite a substantial amount of research has already been done on this topic. A thorough literature search shows that the existing research on the use of navigation systems has focussed on two main questions:

1. How should a navigation system be designed? (e.g. Parkes & Coleman, 1990; Srinivasan, 1999; Burnett, 2000; Lin, Wu & Chien, 2010; Lee, Forlizzi & Hudson, 2008).

2. How does operating the system (e.g. typing in new destinations) while driving affect driver behaviour? (e.g. Dingus, Atin, Hulse & Wierwille, 1989; Lee, Caven, Haake & Brown, 2001, McCall, Achler & Trivedi, 2004).

5.1.1. Behavioural effects of navigation system use.

When considering the research domain on operating the system (e.g. typing in new destinations) while driving and the effects on driver behaviour, Wickens' (1984, 2002) multiple resources theory must be taken into account. Wickens aimed to predict to which extent the two concurrently performed tasks (e.g. driving and navigating) interfere with each other. He categorised four dimensions that are important when considering time-sharing tasks: (1.) stages; (2.) modalities; (3.) codes and; (4.) visual channels, each of which are further divided into different levels (see Figure 13).

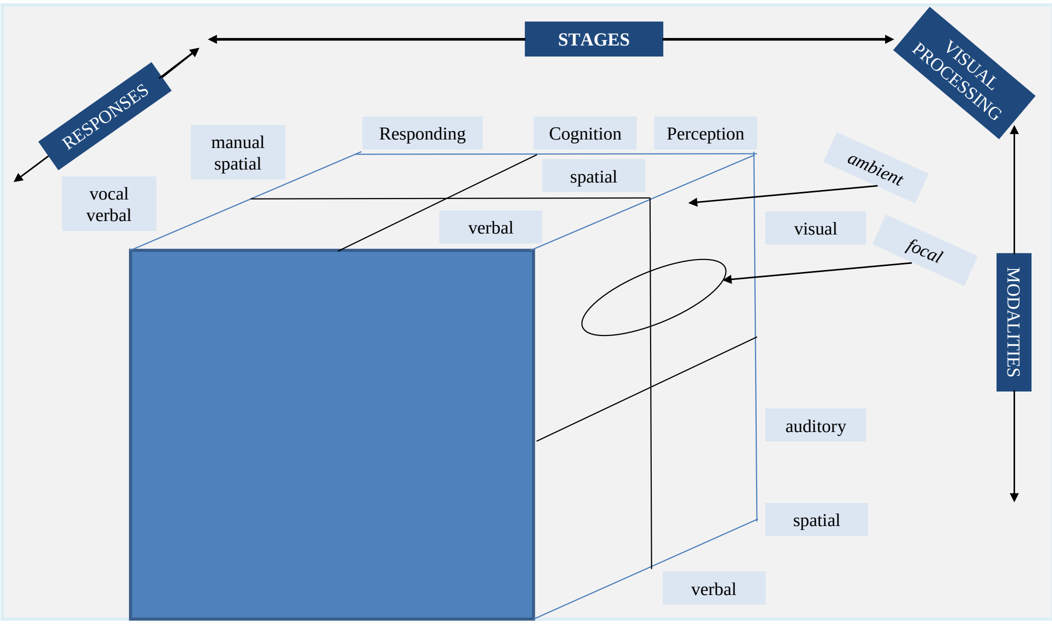


Figure 13. Multiple resources theory model representing three dimensions of humans' resources. The fourth visual processing dimension is embedded within visual resources. (see Wickens, 2002).

The active operation of a navigation system while driving may cause higher levels of distraction (e.g. Maciej & Vollrath, 2009) since the driver must perform two tasks simultaneously: driving and the operation of the system. This manual-interaction with the system mainly requires the drivers' visual attention and consequently may distract the driver while driving (e.g. Dingus, Atin, Hulse & Wierwille, 1989, Maciej & Vollrath, 2009). Chiang, Brooks and Weir (2004) conducted a field study in order to investigate the distraction level of a drivers' visual attention in response to entering destinations while driving. They interpreted that the visual distraction caused by entering the destination while driving is 'acceptable'. In their driving simulator study, Maciej and Vollrath (2009) found distraction to be higher when entering a destination (speech based or manually) than in the baseline driving condition.

Some studies have investigated the effects of route guidance on driver behaviour while driving (e.g. Lee & Cheng, 2008; Kun, Paek, Medinica, Oppelaar & Palinko, 2009). In a field experiment, Lee and Cheng (2008) found that the level of route guidance significantly affected the mean driving speed. In urban areas, on average drivers drove 2.72 km/h faster when they used a portable navigation device for navigation support compared to when a printed route instruction was provided. In addition, the drivers who used the navigation system deviated less in driving lanes and had on average a lower yaw rate than the printed route instruction users. In a driving simulator study, Kun et al. (2009) investigated drivers' visual attention and driving performance when using a map in comparison to using a navigation system. They found that drivers who used a map had poorer visual attention and displayed poorer driving performance compared to when using a navigation system. A recent study by Christoph, van Nes and Wesseling (2012) considered the effects of voice instructions on eye glance behaviour on motorways. They found that drivers tend to look more often and longer at the navigation system just after an instruction. Drivers seem to appreciate visual information in order to interpret the auditory instruction. In summary, when drivers use navigation systems, three factors play an important role: the drivers' visual attention, level of workload, and resources. All three factors are related to Wickens' (1984, 2002) multiple resources theory and to traffic safety issues.

5.1.2. *Errors in visual attention allocation: The looked but failed to see phenomenon.*

Visual attention is not only relevant when a navigation system is employed, rather it is also required for the successful performance of the driving task: the environment has to be observed, the road scene has to be scanned for potential hazards and any relevant information (traffic signs, infrastructural information, other road users) has to be gathered. One main factor causing fatal accidents, which is linked to attention and glance behaviour, is the *"looked but failed to see"* phenomenon. In 2005, Brown discussed the 'looked but failed to see' (LKFTS) phenomenon by referring to past studies and accident literature. It was found to be a very important factor contributing to road accidents. Interestingly, the phenomenon applies mostly in situations that are expected to be well visible and clear such as mini roundabouts and during daylight conditions. Werneke and Vollrath (2012) found a similar result in which accidents in different intersection situations mostly happened in the least complex intersection situations. In their driving simulator study, they investigated if the presence or absence of pedestrians and a pedestrian crossing in intersection situations had an influence on driver glance behaviour. Further, the number of cars present was varied. Werneke and Vollrath found that drivers had more accidents when there were no pedestrians present. They interpreted this interesting outcome in terms of driver attention allocation that was valued as inadequate. A theory that was used to explain this phenomenon was the SEEV model of Wickens et al. (Wickens, Helleberg, Goh, Xu & Horrey, 2001; Wickens, McCarley, Steelman-Allen, Sebok & Bzostek 2009). The model considers visual attention allocation with regard to top-down (knowledge-driven) and bottom-up (environment-driven) processes. Thus, the drivers' *expectations* as part of top-down processes were found to play an important role in influencing the drivers' attention allocation in intersection situations.

5.1.3. The navigation task and hierarchical models of driver behaviour.

The comparison of driver behaviour when a navigation system or a printed route instruction is used requires the understanding of the differences in tasks for these different conditions. In fact, the driver must perform different tasks or different levels of the same tasks. To understand the components of driver behaviour, the hierarchical models of driver behaviour that were already introduced in Chapter 1 are useful (e.g. Michon, 1985, Hatakka, 1998, 2001). Driving is characterised by automatic and controlled behaviours (Schneider and Shiffrin 1977; Shiffrin and Schneider 1977). Michon's (1985) driver behaviour model distinguishes three levels of driving: the operational, manoeuvre (tactical level) and the strategic levels (navigation). The driving task at the operational level mainly includes the skills required for handling the vehicle: knowledge of how the vehicle works; its initiation, steering; operation of the clutch, gas and breaking pedal and switches (e.g. the indicator); speed control; and determination of the direction and position of the vehicle. The behaviour performed on this level is automated. Driving behaviour on the manoeuvre (tactical) level mainly represents the driver's reaction to certain driving situations such as: stopping the car at red lights, reducing speed in an urban area or giving pedestrians priority at zebra crossings. Performance on this level is mainly determined by the environmental situation and is mainly automatic but underlies a certain control since the driver must react to the particular traffic situation. This level of driver behaviour requires the driver's situation awareness, the appropriate observation of the environment in order to be able to react to certain situations and the detection of potential hazards. Driver behaviour on the strategic level includes decision-making processes such as planning of the route in order to reach the trip destination. The performance on this level is mainly memory-driven and controlled. Rasmussen (1987, as also introduced in Chapter 1) also distinguishes three levels in order to explain driver behaviour: (1.) skill-based, (2.) rule-based, and (3.) knowledge-based driver behaviour. Behaviour on the skill-based level is automatic and highly experienced (e.g., stepping on the gas) and requires almost no effort to be performed. Rule-based driving behaviour requires a certain control from the driver. The driver has to react to the environment and must implement learned rules (giving priority to a car that is on the main road). Rule-based behaviour may become automatic with increased driving experience. In case a situation is unexpected and new or rare to the driver, the driver has to apply his/her knowledge-based behaviour in order to handle the (new) situation. Performance on this level is highly controlled and memory-based. Figure 14 illustrates a hierarchical model of driver behaviour according to Rasmussen and Michon.

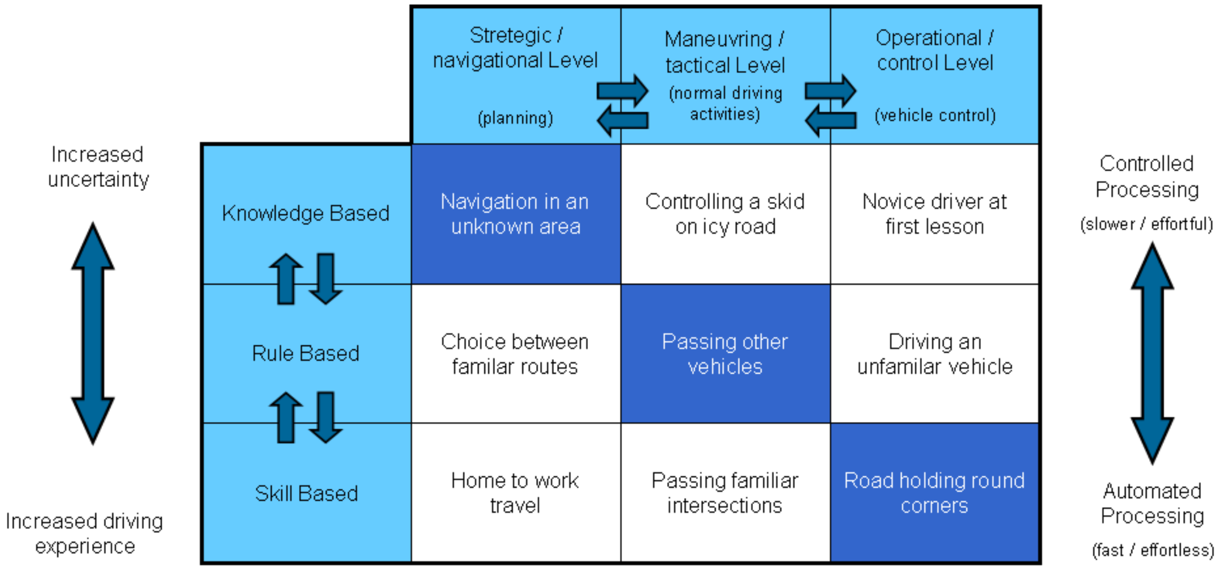


Figure 14. A model of driving behaviour according to Rasmussen (1987) and Michon (1985).

The navigation task is represented on the strategic level of driving and is predominantly knowledge-based and memory-driven. Varying route guidance supports influence the navigation task of the driver and thus may affect behaviour on the strategic level of driving. Approaches including different levels of driver behaviour are based on the idea that any changes in driver behaviour at one of the levels may lead to changes to behaviour on the other levels. Overall, it is obvious that when using a navigation device *or* printed route instruction, and therefore having different preconditions on a higher level of driver behaviour, the type of route guidance is expected to be an important factor in influencing driver behaviour in at intersection situations.

5.1.4. *Objectives.*

So far, most of the research on navigation systems has focused on the driver's manual interaction with the system, as this is considered the riskiest factor. A recent naturalistic driving study showed that manual interaction with the navigation system accounts for approximately 1% of total driving time (Christoph, Van Nes & Knapper, 2013). According to Green (1999), it takes 1 to 2.5 min to enter a destination. In their study, Chiang, Brooks and Weir (2004) found total entering task times to be 32 to 37s. A literature search shows that there is a lack of research studies concerning the remaining trip time and the investigation of whether there are any effects of navigation system use on the driving behaviour while not operating with the system. This was identified as a relevant next step. It would be interesting to investigate whether the use of a navigation system affects general driver behaviour, aside from the operation itself. Does the navigation system affect the speed or eye glance behaviour of drivers?

The aim of this study is to investigate whether there is a difference in driving behaviour between two different types of route guidance: a printed route instruction including a map (in the following called 'printed instruction') versus a navigation system. The focus of this study is to investigate whether the navigation system affects driver speed and glance behaviour at intersections in real traffic situations.

5.1.5. *Hypotheses.*

Driving is a complex dynamic control-task (Rouse, 1981). In addition to the operating and tactical tasks, drivers in the two different conditions (navigation system vs. printed instruction) in this study must be able to perform a different orientation-task and consequently, a different navigation. This may have an effect on the drivers' *motivation* and decision-making that relate to the third (strategic) level of driver behaviour. Further, fulfilling the guidance/navigation tasks is linked to the driver's planning abilities that are also associated with the strategic level of driving. This level considers planning abilities and decisions. The idea behind hierarchical approaches is that any features and events on higher levels may have an influence on the lower levels. When the driver uses a navigation system to drive an unfamiliar route, the driver is relieved in the operational, tactical and also on the strategic levels of driving. The driver does not have to dedicate the same amount of resources towards the orientation- and trip-planning tasks as a driver who uses a printed instruction to 'find' the destination. According to Nilsson (2005), the driving task includes the continuous monitoring of the environment, the knowledge of where and when to look, the selection of relevant information, and the ability to recognise which information is important, handle unexpected events, revise planned actions and alter them according to the situation at hand. In order to steer the vehicle safely, the driver has to pay visual attention to the driving scene. Wickens' (1984, 2002) multiple resources theory states that tasks that comprise the same cognitive level (in the case of this study: visual attention) interfere with each other. Based on this theory, it would be expected that drivers look longer at the printed instruction than at the navigation system since the latter also provides auditory information in addition to the visual information that would reduce the drivers' workload on the visual processing dimension.

Other theories that were already introduced previously in Chapter 1 and that should be taken into consideration when investigating the driving task are the risk compensation theory (Wilde, 1982, 1994) and the risk threshold models (e.g. Fuller, 2011). Wilde's basic assumption is that people have a stable, subjectively perceived, level of risk that they accept. If the perceived risk changes due to any variation in the traffic system, the driver will attempt to level out the perceived risk with other tasks. Risk-threshold-models (e.g. Fuller, 2011) consider risk from two perspectives: from the (1) subjective and from the assumed (2) objective point of view. The statement is that drivers strive to keep subjective and (assumed) objective risk in balance – they want to perceive control. It is also assumed that drivers are aware of a range of traffic situations that they perceive as being safe. The upper limit of this safety margins serves as a threshold. In the case of the threshold limit being exceeded, the situation is perceived as being risky and the behaviour is adapted in order to return to accepted levels of 'risk limits'. Drivers that use the navigation system as route guidance do not have to share resources between the steering and orientation/navigation task and consequently can use resources to perform the operational and tactical tasks of driving. It is assumed that drivers perceive a reduced workload when they use a navigation system in comparison to using a printed instruction and that they do not feel a need to compensate a risky behaviour by for instance reducing speed when turning away to look at the printed instruction. In line with the multiple resources theory and with the risk threshold (Fuller, 2011) and risk compensation (Wilde, 1982, 1994) theories, it is hypothesized that drivers supported by the navigation system will drive faster compared to when using the printed instruction. Due to these additional tasks drivers using a printed instruction have to fulfil, it is also expected that they generally look for shorter periods of time at the road scene and its relevant areas of interest (front and side scene) as drivers are expected to do when they are supported by the navigation system.

To sum up, the following main hypotheses are put forward:

- When crossing an intersection, drivers look longer at the printed instruction than at the navigation system
- Average speed is lower when crossing the intersection with the printed instruction than with the navigation system
- When crossing an intersection, drivers spend less time looking at the road scene with the printed instruction than with the navigation system

5.2. Methods

In order to test the hypotheses, driver glance- and speed behaviour was investigated by analysing data of two test drives (one using a navigation system as route guidance and the other using a printed route instruction including a map). The two test rides were embedded in a running naturalistic driving study (NDS) that lasted for five weeks. Driver glance behaviour was analysed both, qualitatively and quantitatively. Speed behaviour was analysed quantitatively.

5.2.1. *Participants.*

In total, 20 participants (14 male, 6 female) participated in the study. They were between 27 and 59 years old (*SD* = 10.18 years) with a mean age of 37 and had a total driving experience of 25,000 kilometres or more. All drivers had prior experience in navigation system use and on average used it at least once a week.

The participants were recruited by means of an open call and were selected according to their driving and navigation system experience. They were awarded 60 € for participating in the test drives.

5.2.2. *Standardised test drives.*

The test drives were carried out in the Netherlands and the participants drove an equipped car within the five week naturalistic driving study. The car was equipped with a GPS and four cameras that recorded the forward scene, the driver in full view, the driver's face and the navigation system. The participants were asked to twice drive a given route of 7.2 kilometres. Two observers accompanied the participants during the test rides (as part of another research study). The first time the participants drove the route they were supported in their navigation by the TOMTOM GO LIVE 1005 navigation system. The second time the participants received a printed instruction of the route including a printed map (Google). The two journeys were at least 21 days apart. All test rides were between 10 am and 4 pm with low traffic density. Due to unexpected road works during the observation period, a small section of the route was altered for some participants. For this study *the type of route guidance* (Navigation System vs. Printed Instruction) was considered as an independent variable.

In naturalistic driving studies (NDS), the drivers' natural driving behaviour is observed unobtrusively in a natural setting (Dingus et al., 2006). The driver uses a car that is equipped with cameras and sensors to do his/her daily trips for a certain period of time. The equipment used in naturalistic driving studies that serves to record the drivers' behaviour is unobtrusively installed in the vehicle. One advantage to investigating driver behaviour in this way is that the driver behaves in his/her usual manner since the driver does not feel that he/she is being observed.

By embedding two drives of a route that was given to the participants in a period of a running NDS, this seemed an efficient method to gain reliable information concerning drivers' natural glance behaviours at intersections. On the one hand, the drivers are already familiar with the unobtrusive recording cameras installed in the equipped vehicle that increases the reliability of the gained results. On the other hand, the internal validity is improved since all participants drive a given route.

5.2.3. *Materials.*

Participants drove a Lancia Ypsilon or a Peugeot 207 as part of the study. The vehicle was instrumented with four cameras (illustrated in Figure 15, p.129) under the rear-view mirror directed at the driver's face; 2) on the right A-pillar (= the vertical support of the vehicle's right windscreen and the right side-window area) giving a full driver view; 3) behind the rear-view mirror recording the road ahead and 4) in front of the navigation system capturing the screen of the navigation system. The cameras recorded at a frame rate of 12.5 frames per second. A GPS sensor recorded location information and GPS derived measurements as speed and time. The navigation system provided to the participants was a TOMTOM GO LIVE 1005.

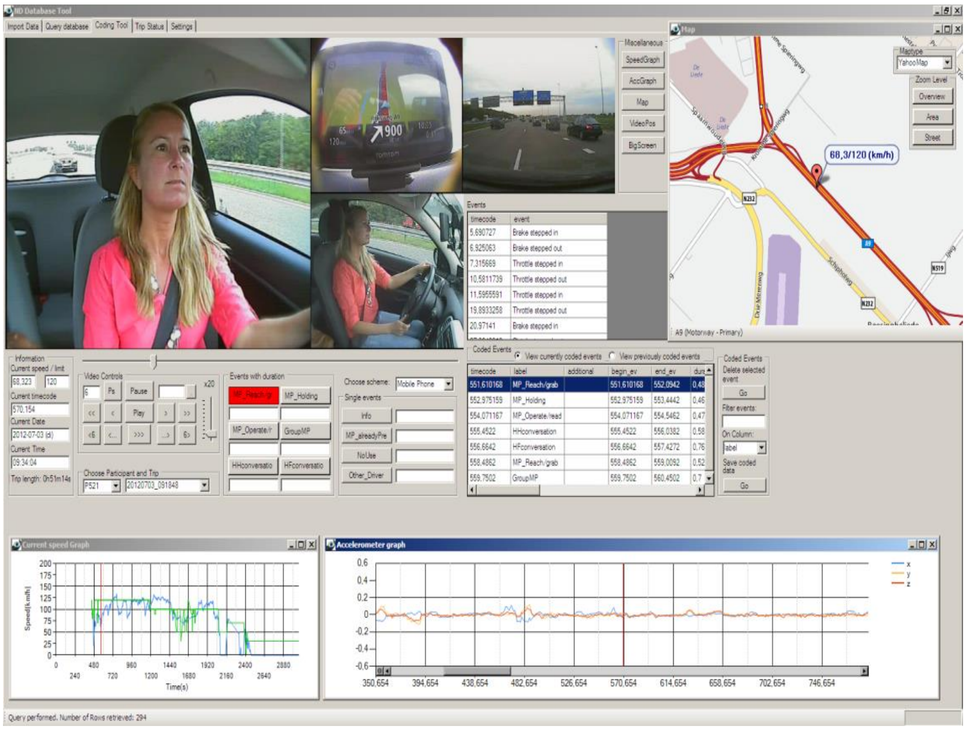


Figure 15. Illustration of the camera perspectives and data reduction software.

The navigation system was positioned in the bottom left corner of the windshield. There were no instructions regarding the use of the printed instruction (map); often the printed instruction was placed on the driver's lap or on the steering wheel and this varied during the test drive.

5.2.4. *Data analysis procedure.*

The analysis focused on un-signalised intersections that were passed straight. It included intersections with one side road, two side roads or a pedestrian crossing. The data analysis was divided into two parts: a qualitative and a quantitative analysis.

The qualitative observation analysis served to gain information about the drivers' glance patterns during different intersection situations and when supported by different types of route guidance. The qualitative analysis also served to generate the hypotheses for the quantitative part. In total, 911 relevant intersection situations were considered.

The qualitative video observation analysis (following Reichertz & Englert, 2010) consisted firstly of a detailed coding of the eye glances and an open coding. Thereby, different aspects, dimensions and elements were recorded that could potentially be relevant for the interpretation and the results. Second, the found aspects, dimensions and elements were interpreted. The researchers met several times to discuss the interpretations. From this, a notation scheme was build for the drivers' glance behaviour that made it possible to derive enriching statements based on a scientific approach. The duration of the process from the initial qualitative analysis to the finalisation of the written results was 10 weeks. All steps, interim results and interpretations were continuously discussed by all researchers involved.

The quantitative analysis was conducted in order to detect any differences between the glance deviation when the driver is supported in navigation by the navigation system or by the printed instruction (map).

For the quantitative eye glance analysis, situations where other road users disturbed the fluent driving (such as a pedestrian or cyclist crossing or a vehicle stopping or breaking in front) were excluded from the quantitative analysis. In addition, some situations could not be included because it was not possible to carry out the glance coding; cases where the driver wore sunglasses, the camera did not work or the quality was not appropriate, were excluded from the eye glance analyses. This resulted in a total of 811 intersection situations (428 in navigation system condition and 383 in printed instruction condition) to be used for the quantitative eye glance analyses. A balance between the conditions in situations when other disturbing road users occurred (such as vulnerable road users in parallel and driving vehicles) was confirmed. Since for some participants the data of only one of the two observation rides could be used, the quantitative analysis was done in a between subject design.

According to the coding scheme that was used in the 100-car study (see Dingus et al., 2006), the eye glance directions were modified and defined. Table 12 shows the defined eye glance directions. The eye glances were coded manually from the video data based on this scheme.

Table 12. *Coding scheme for the eye glance analysis based in Dingus et al. (2006).*

Eye glance location	Description
Forward	Glances at the forward road scene viz. to the direction of the driver Note that when a vulnerable road user was present in the observed scene, it was coded as additional information (for the qualitative analysis).
Right traffic scene	Glances at the right windshield, to the right window or to the right mirror Note that when a vulnerable road user was present in the observed scene, it was coded as additional information (for the qualitative analysis).
Left traffic scene	Glances at the left windshield, to the left window or to the left mirror Note that when a vulnerable road user was present in the observed scene, it was coded as additional information (for the qualitative analysis).
Rear-mirror	Glances at the rear mirror Note that glances at the rear mirror that were made in order to have a look at the passenger in the back seat were *not* included in this category.
Over the shoulder (right)	Glances over the right shoulder
Over the shoulder (left)	Glances over the left shoulder
Navigation system	Glances at the navigation system
Printed instruction	Glances at the printed instruction
Away from the traffic scene inside the vehicle	Glances at the inside of the vehicle Note that this category includes glances at the instruments and at the rear mirror in order to look at the passenger in the back seat and glances at the navigation guidance are *not* included in this category.
Away from the traffic scene outside the vehicle	Glances at the outside of the vehicle but not to the traffic scene (e.g. to advertisement, buildings etc.)
Eyes closed	Any time that the drivers eyes are closed

The detailed coding served mainly for the *qualitative observation analysis* in order to describe the glance behaviour of drivers in certain conditions. The *quantitative analysis* focused on the *(1.) Forward Scene* (including all glances coded "Forward"); *(2.) Side Scene* (including all glances at the right or left traffic scene, and shoulder glances); (3*.) Type of Navigation* (including all glances either at the navigation system or the printed instruction) and *(4.) Away from the forward and side scene* (including all glances at the rear-mirror, away from the traffic scene in- and outside the vehicle and when the eyes were closed).

5.3. ***Results***

5.3.1. ***Results from the descriptive, qualitative observation analysis.***

Having a comparative qualitative insight into driver glance behaviour when using a navigation system in contrast to a printed instruction, some interesting types of behaviours and conducts were found: when the drivers looked at the navigation system they just turned their glances away from the road scene but still had the peripheral view towards the road ahead. In contrast, when the drivers looked at the printed instruction they turned their heads completely away from the road in order to read the instructions. In addition, when assisted by the navigation system, drivers tended to check the scene ahead by only making eye movements when approaching an intersection (see Figure 16, p.133).

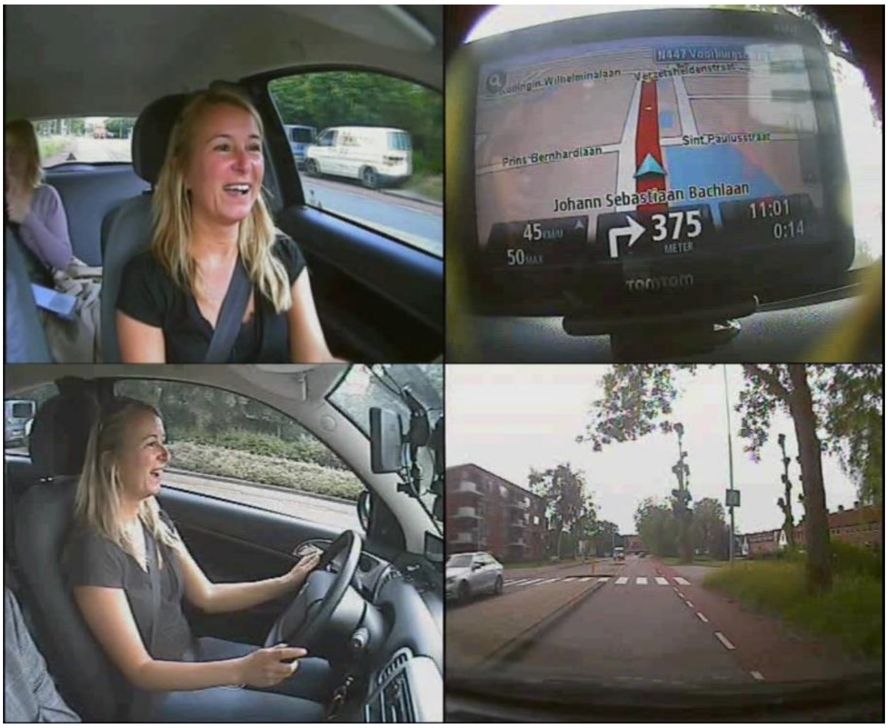


Figure 16. Drivers glances to the side scene when a navigation system was used.

When the drivers used the printed instruction for navigation assistance, they did not make eye movements only to look at the road side scene but instead used their "whole body", for instance by moving forward and turning the head completely to the right or left (as shown in Figure 17, p.134) or for instance by moving the complete torso forward and turning the head to the area of interest.

Figure 17. Drivers glances to the side scene when a printed instruction was used.

Taking the above observations into account, it can be concluded that when using a printed instruction for assistance, drivers spend more time looking at it and the side scene compared to when they are supported by a navigation system. These findings are in accordance with our expectations regarding the quantitative analysis.

Furthermore, when using a navigation system, drivers displayed a “stable” glance behaviour over the whole route which was checked continuously during the duration of the whole trip. In comparison, when a printed instruction was employed, drivers experienced instances (at the beginning and in the middle of the trip) where they looked very intensively at the printed route instruction for guidance and this was subsequently followed by phases where they did not use it for assistance. Interestingly, two drivers stopped their vehicles when using the printed instruction in order to have a more thorough look at the printed route instruction. This never happened when the drivers were supported by the navigation system. When the driver had to stop for some other reason (e.g. the vehicle in front stops or a pedestrian crosses the street) while using a navigation system, the time was used to engage in conversation with accompanying passengers whereas when they used a printed instruction the time was used to have a closer look at it for further guidance.

In order to decide which intersection situations to include in the quantitative analysis, the intersection situations were classified according to the presence of pedestrians and/or cyclists. It could be distinguished between five different types of intersection situations: (1.) no pedestrians or cyclists present; (2.) a pedestrian or cyclist moving in parallel; (3.) two or more pedestrians and/or cyclists moving in parallel; (4.) one or more pedestrians and/or cyclists intending to cross the road; and (5.) one or more pedestrians and/or cyclists crossing the road.

It was observed that pedestrians and/or cyclists approaching a crossing direction were rather noticed by navigation system users and that they rather reacted appropriately (stopped). Printed instructions users looked at the pedestrians and/or cyclists but did not react appropriately (drove). Due to the traffic safety relevance of this observation, this was added as a hypothesis to the quantitative analysis.

5.3.2. *Quantitative results.*

5.3.2.1. Drivers' reactions to pedestrians and/or cyclists who intend to cross

Qualitative analysis of the videos of the different intersection situations led to the observation that drivers using a printed instruction tend to look at the pedestrians and/or cyclists and continue to drive without stopping to let them cross in contrast to drivers using the navigation system. This was a fact that was valued as relevant to be checked in the data. In total, the data consisted of 32 intersection situations with one or more pedestrians and/or cyclists present intending to cross the street and where navigation support was available by either a printed instruction or the navigation system. When the navigation system was employed, drivers stopped in 50% of cases to allow the pedestrians and/or cyclists to cross while they did so only in 40.6% of the situations when they used the printed instruction (see Figure 18, p.136).

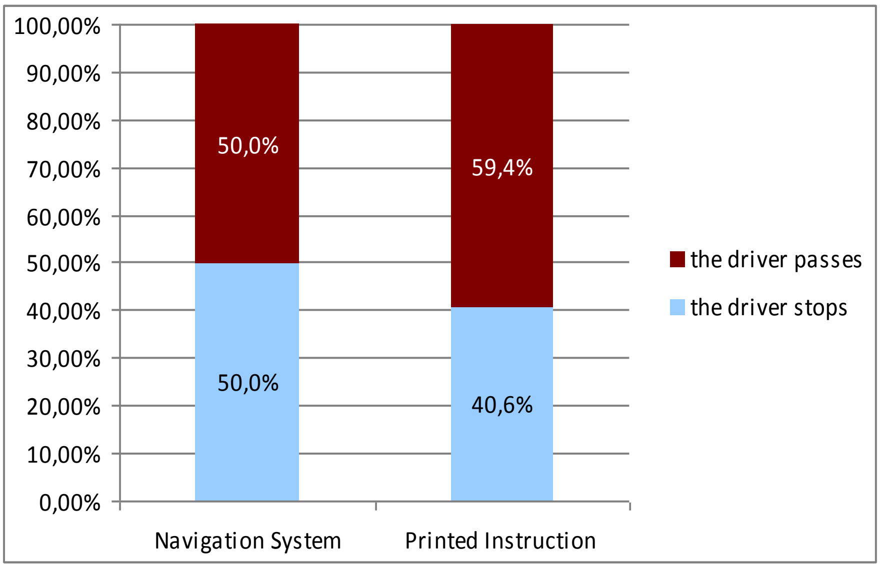


Figure 18. The percentage of drivers letting pedestrians and/or cyclists cross and those continuing driving when they encounter pedestrians and/or cyclists who intend to cross the road.

5.3.2.2. *Driving Speed*

The total time drivers required to pass the respective intersection was measured. As illustrated in Figure 19 (p.137), a significant difference in the passing duration and this depended on the kind of route guidance employed ($t(809) = -2.293$, $p = .011$, $d = .161$) was found.

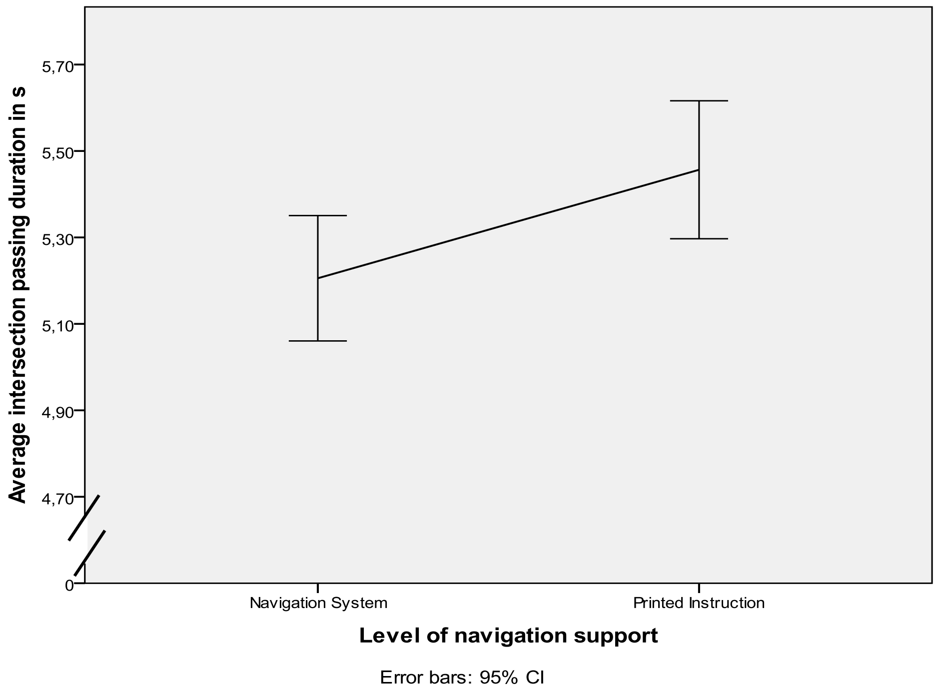
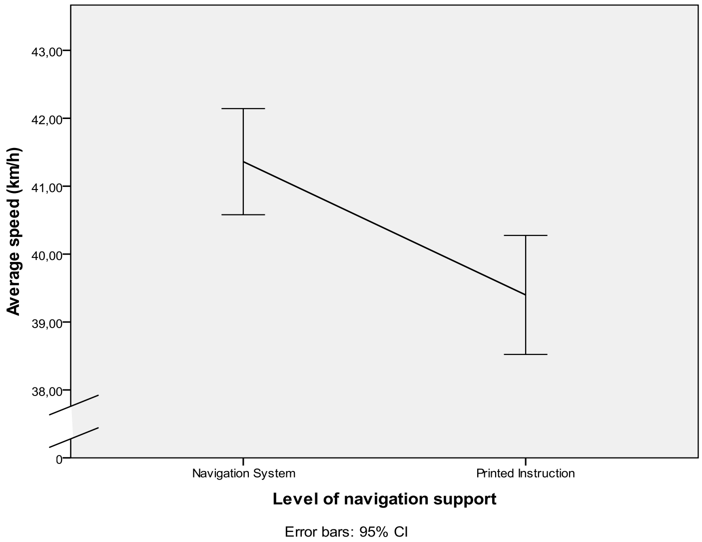


Figure 19. The average intersection passing duration .

On average drivers passed the intersection in *M* = 5.206s (*SD* = 1.526s) and *M* = 5.457s (*SD* = 1.588s) when assisted by the navigation system and the printed instruction respectively.

Average Speed. Taking into account the differences found in the time drivers required to pass the respective intersection and the fact that the intersections were equal in length, it was considered as necessary to evaluate average speed. Figure 20 (p.138) shows the significant effect of the type of route guidance on average speed, $t(1{,}772)^{a} = 3.292$, $p = .001$, $d = .237$.



	Navigation system		Printed instruction	
	M	***SD***	***M***	***SD***
	41.361	8.196	39.399	8.321

Figure 20. The average speed in km/h at the four types of intersection situations.[a]

[a]Note due to technical problems the GPS data of some intersection situations were not available. So for the calculation of the average speed in total 774 intersection situations could be considered.

The participants drove significantly slower when they used the printed instruction for navigation than when they were supported by the navigation system.

5.3.2.3. Number of Glances

5.3.2.3.1. Areas of interest

The quantitative analysis of how many glances were made at the different areas of interest *(1.) forward*, *(2.) side*, *(3.) type of navigation* and *(4.) away from the road scene* was done for 6,942 glances in 811 intersection situations.

Figure 21 illustrates how many glances drivers relatively made at the specific areas of interest.

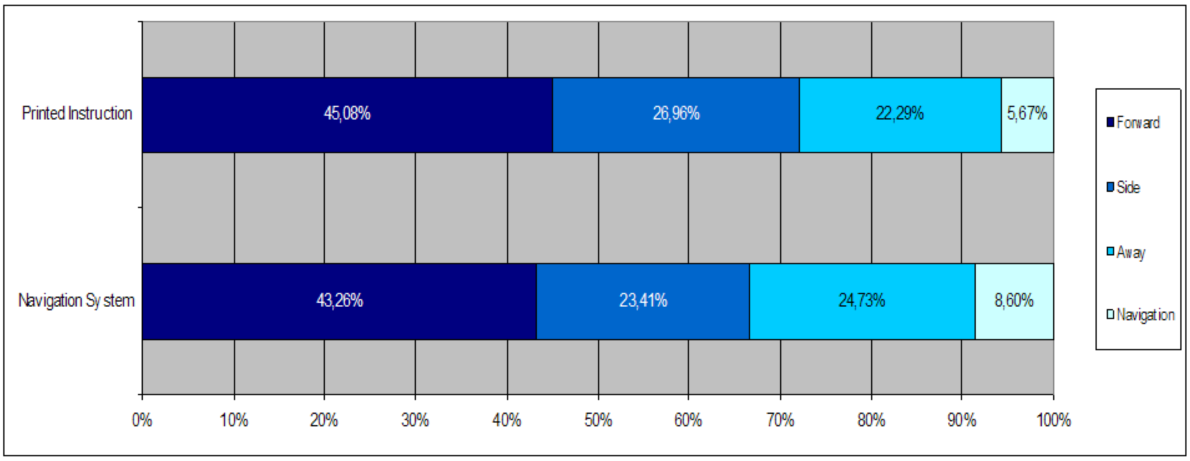


Figure 21. Glances to the different areas of interest for the two conditions.

As can be seen in Figure 21, most of the glances were towards the forward scene, followed by glances at the side scene, away from the road and at the route guidance. Comparing the average number of total glances during the different conditions, there was no significant effect of the level of route guidance ($t(809) = -.282$, $p = .389$, $d = .020$). Figure 22 (p.141) shows a detailed illustration of the average number of glances at the particular areas of interest.

The Forward Scene. No significant difference ($t(760.894) = -.857$, $p = .196$, $d = .062$) was found in terms of the average number of glances made straight ahead between the two navigation systems. When drivers used the printed instruction, they cast on average M = 3.83 (SD = 1.918) glances at the forward scene per intersection and when the navigation system was used, an average of M = 3.72 (SD = 1.663) glances were cast.

The Side Scene. The effect of the level of route guidance on drivers' glances to the side scene was significant, $t(769.885) = -2.169$, $p = .015$, $d = .156$). When the drivers were assisted by the navigation system they made on average significantly fewer glances at the side scene (M = 2.01, SD = 1.708) compared to when they used the printed instruction (M = 2.29, SD = 1.917).

The Navigation System or Printed Instruction. The type of navigation affected significantly the number of glances at the respective route guidance, $t(809) = 4.251$, $p = .000$, $d = .300$. Drivers cast on average more glances at the navigation system (M = .74, SD = .865) during an intersection situation than at the printed instruction (M = .49, SD = .856).

Away from the road scene. The type of system used to assist the driver during navigation showed a significant effect on the number of glances cast away from the road scene, $t(809) = 1.710$, $p = .044$, $d = .120$. Drivers on average looked 2.13 times (SD = 1.991) away from the road when they were assisted by the navigation system and 1.90 times (SD = 1.911) when using the printed instruction.

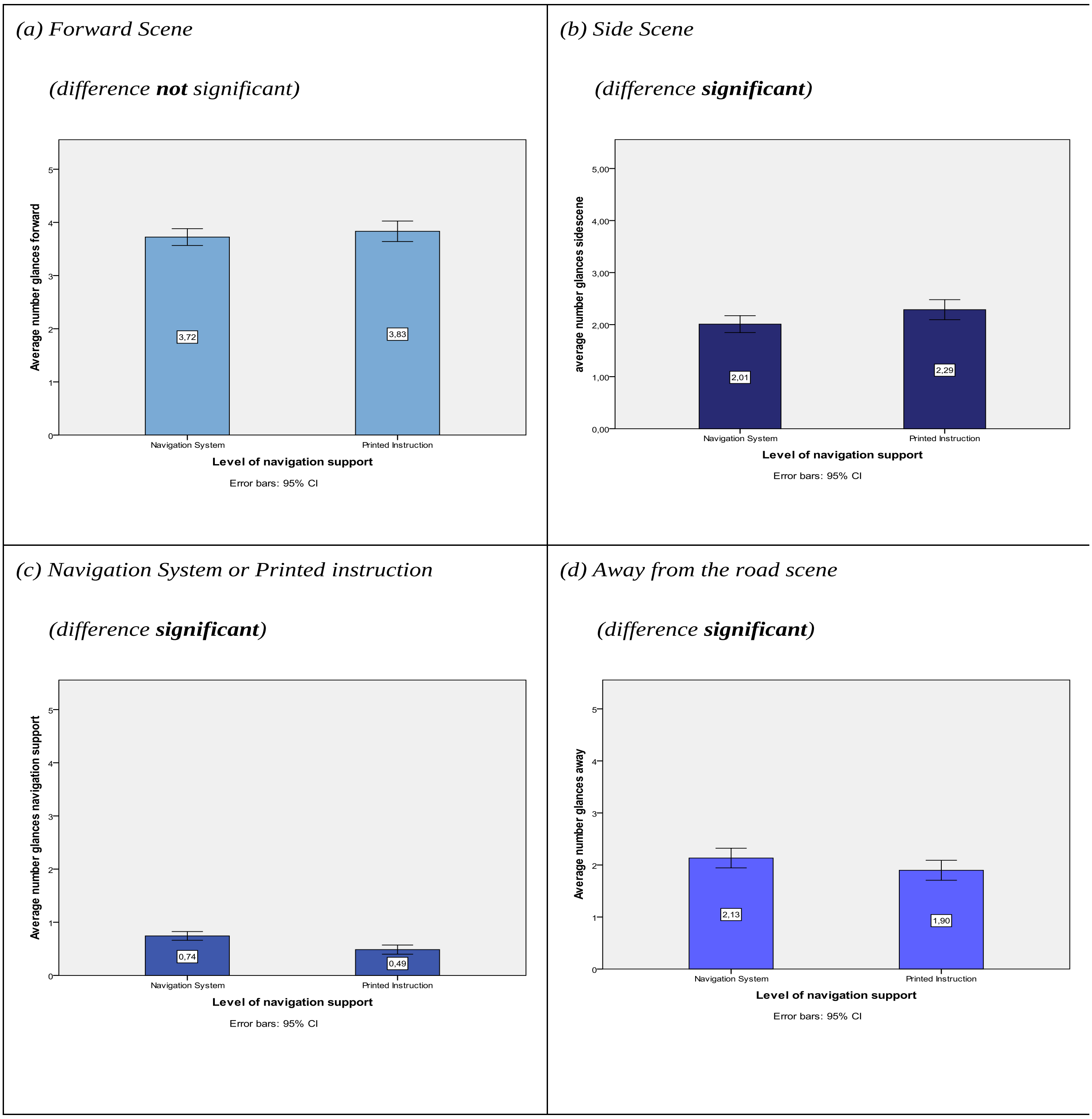


Figure 22. The average number of glances to (a) the forward scene, (b) the side scene, (c) the navigation system or printed instruction and (d) away from the road scene.

5.3.2.4. *Time looking to the areas of interest*

5.3.2.4.1. Areas of interest: distribution of glances

Analysis of the total time drivers spent in the respective intersection situations looking at the four areas of interest, shows that drivers spent the longest time observing the road ahead (forward scene) followed by the side scene. The areas they observed for the shortest time period were the route guidance and away from the road scene (see Figure 23).

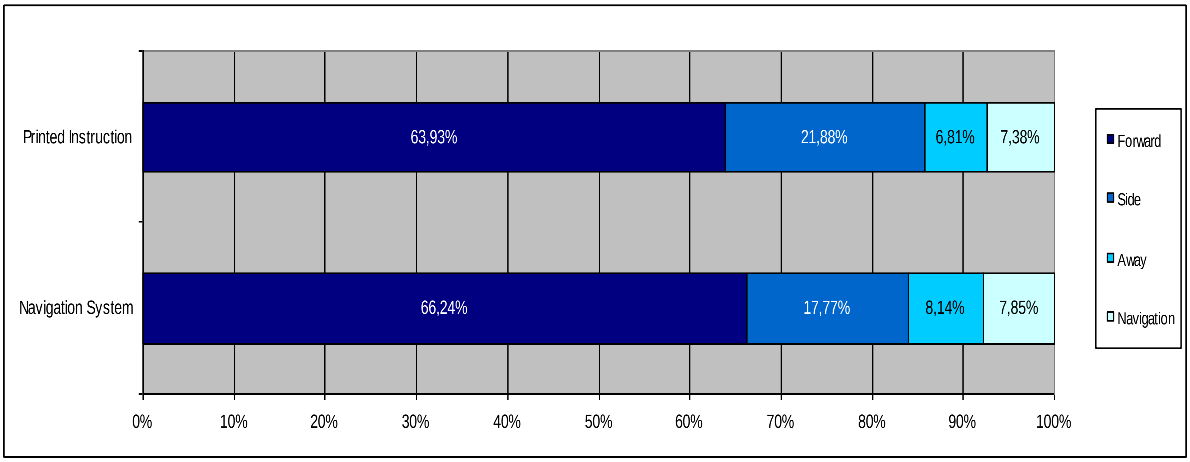


Figure 23. The proportion of all glance durations in total to the different areas of interest for the two conditions.

5.3.2.4.2. Proportionate time looking to the areas of interest related to intersection passing duration

As has been discussed above, this studies shows that drivers tend to pass intersections faster when supported by the navigation system compared to when the printed instruction is used. Therefore, it was considered as necessary to additionally calculate the difference in the proportion of time drivers spent looking at the particular areas of interest in relation to their intersection passing time.

Type of route guidance. The proportion of time spent looking t at the side scene in relation to the total intersection time was significantly affected by the kind of route guidance that was employed, $t(809) = -2.962$, $p = .002$, $d = .208$. When drivers used the printed instruction, they looked at the side scene longer ($M = 21.318$ %, $SD = 17.772\%$) than when they were supported by the navigation system, $M = 17.793$ % ($SD = 16.131\%$). The effect of the type of route guidance on the time drivers spent looking away from the road scene was significant, $t(809) = 1.721$, $p = .043$, $d = .121$. Drivers spent more time looking away from the road scene when they were supported by the navigation system ($M = 8.010$ %, $SD = 9.198\%$) than when they used the printed instruction, $M = 6.929$ % ($SD = 8.631\%$). Although not significant ($t(773.543) = 1.507$, $p = .066$), an effect size of $d = .108$ in direction was observed: drivers spent less time looking at the forward scene when they used the printed instruction longer ($M = 64.318$ %, $SD = 20.069\%$) than when they were supported by the navigation system, $M = 66.349$ % ($SD = 18.088\%$). No differences were found for the time drivers spent looking at the route guidance, $t(677.252) = .484$, $p = .315$, $d = .037$. Drivers spent on average 7.849 % ($SD = 9.795\%$) of the total intersection passing time looking at the navigation system and 7.435 % ($SD = 13.902\%$) at the printed instruction. Figure 24 (p.144) shows the results of the analysis of the proportional time spent looking at specific areas of interest.

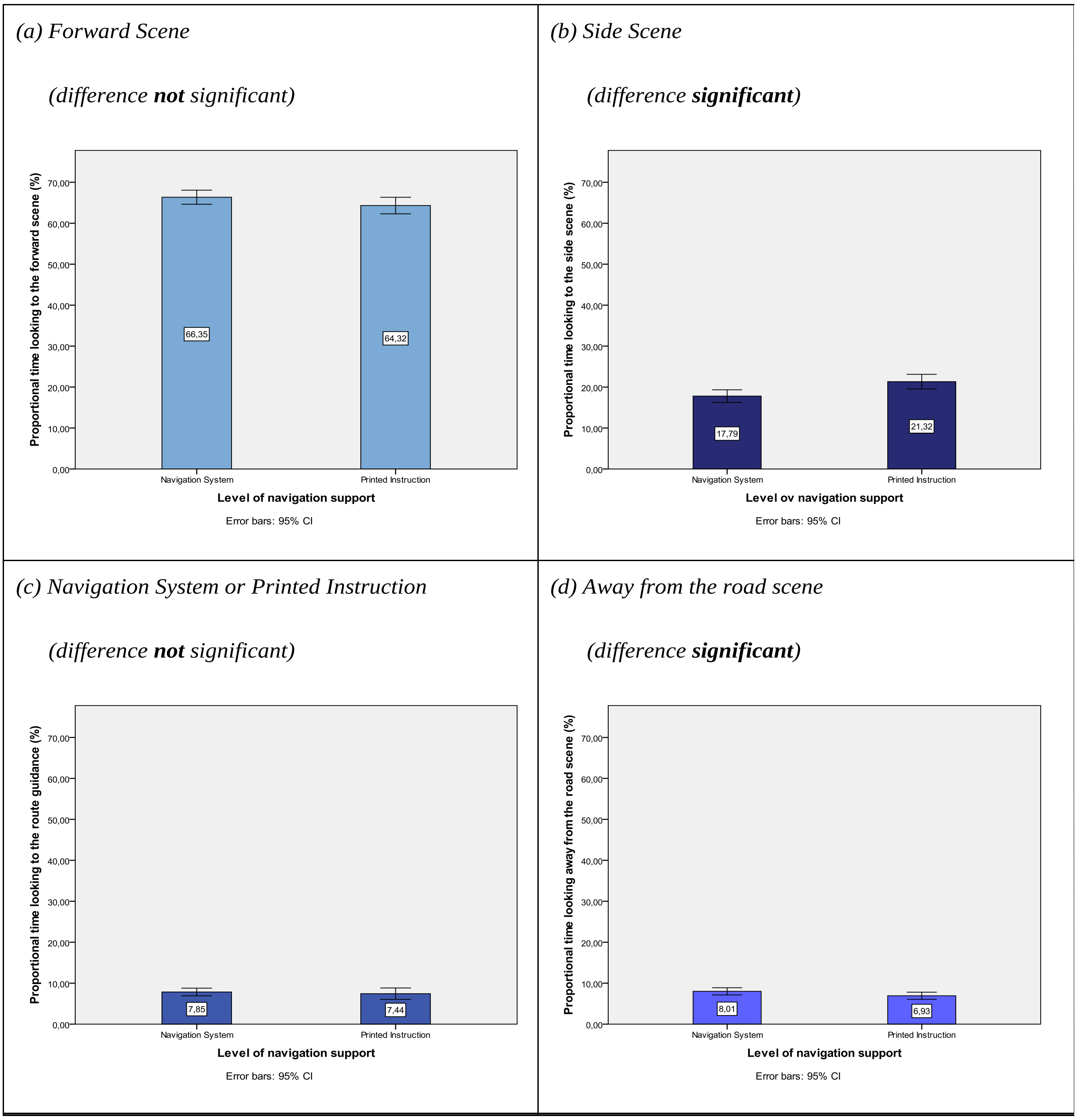


Figure 24. The average time looking at intersections to (a) the forward scene, (b) the side scene, (c) the navigation system or printed instruction and (d) away from the road scene.

5.3.3. *Summary of results from the qualitative and the quantitative analyses.*

Table 13 provides an overview of the main results of this study, comparing driving with a navigation system and driving with a printed instruction.

Table 13. *Summarised overview of the results: navigation system use vs. printed instruction.*

		Navigation system	Printed Instruction
Qualitative observation	**Glance behaviour to the type of navigation**	• Turned glances to the navigation system by eye movements • Small head movements to turn the glance to the navigation system • Road scene still in peripheral view	• Turned glances and head completely away from the road scene • No peripheral view to the road scene
	Glance behaviour to the side scene	• Checked the intersection scene by eye movements and small head movements in the direction of the glances	• Used their whole body: moved the torso forward, turned the head completely to the right or left
	Glance behaviour in general	• “Stable” glance behaviour • The route (on the navigation system) and the road scene were checked continuously	• “phase-progressed” glance behaviour • Phases when the drivers looked intensively, often and long to the printed instruction, and • Phases when drivers spent more time looking to the road scene

			Navigation system		Printed Instruction
Quantitative analysis	**Frequency, drivers stopped when a VRU intended to cross the road**		+	>	-
	Number of glances	**Forward Scene**		=	
		Side Scene	-	<	+
		Type of navigation	+	>	-
		Away from the road scene	+	>	-
	Average speed		+	>	-
	(proportional) Duration of glances	**Forward Scene**	-	< in direction	+
		Side Scene	-	<	+
		Type of navigation		=	
		Away from the road scene	+	>	-

5.4. Conclusion

The main goal of the study was to examine the effect of two different types of route guidance (printed instruction vs. navigation system) on driver glance behaviours at intersections. Additionally, driver speed behaviour and driver reactions to pedestrians and cyclists were investigated.

5.4.1. *Driving speed.*

The results of the study show that participants drove faster when they used the navigation system for assistance compared to when the printed instruction was employed. This confirms the findings of Lee and Cheng (2008). Nevertheless, the results also confirm the results of the 2008 study in which participants in both scenarios (driving with navigation vs. printed instruction) drove slower than the allowed speed limit of 50km/h. In order to look at a route guidance, the driver must divide his/her visual attention (Wickens, 1984) between the route guidance and the driving environment. The qualitative analysis showed that drivers tended to turn their heads completely away from the road scene when looking at the printed instruction whereas they maintained a peripheral view of the road scene when they using the navigation system. Drivers seem to need more visual resources to fulfil the orientation task when they use a printed instruction as a route guidance compared to when they use the navigation system. Results can be interpreted that, in order to compensate this risky behaviour (turning the head completely away from the road scene), participants reduced speed and consequently drove slower than when they used the navigation system as route guidance. This behaviour is in accordance with the risk threshold theory (Fuller, 2011) and risk compensation theory (Wilde, 1982, 1994).

5.4.2. *Glance behaviour*[4]

The results of this study suggest that drivers consciously decide that it is more appropriate to spend time looking at the printed instruction when the situation is judged as being suitable for looking away from the road scene.

[4] Note that glance behaviour as a measure in research is used to make conclusions about 'hidden' cognitive processes. However, as the *looked-but-failed-to-see-phenomenon* (see Brown, 2005) suggests, this measure may fail when the driver behaviour processes are examined.

A result supporting this explanation is the difference in variance of the proportional glance duration at the particular route guidance: when drivers used the printed instruction they had a deviation of *SD* = 13.902% whereas a smaller deviation *SD* = 9.795% was observed for the navigation system.

This outcome shows that drivers using the navigation system have a more continuous glance pattern with the route guidance than when using the printed instruction. This was also observed in the qualitative analysis of the videos. The following glance pattern and associated processes can be interpreted from the results: (1.) the driver decides consciously to look at the printed instruction in situations that are valued as appropriate for turning the head away from the road scene. (2.) The information is memorised for a certain period of time during which no further looks at the printed instruction are needed. (3.) When the driver needs to update the orientation-information and values the situation as appropriate, the driver looks again at the printed instruction. When the participants in the study used the navigation system, they showed a stable automated glance behaviour: the system was checked on a regular bases. Due to these different glance patterns, the variance of the proportional glance duration at the route guidance within the trip using the printed instruction is higher than when using the navigation system. All three steps of the drivers' glance patterns when using the printed instruction represent Rasmussens' (1987) knowledge-based behaviour of performing a strategy task on the third level of Michon's (1985) driver behaviour model. The driver's actions are memorised-based and controlled. In contrast, the driver acts highly automated when being supported by the navigation system and hence represents Rasmussens' (1987) rule of skill-based behaviour.

The type of route guidance had a significant influence on the amount and proportional duration of glances drivers made at the side scene. Participants looked more often and for longer periods of time at the side scene when using the printed instruction than when using the navigation system. Also, a different behaviour was observed when looking at the side scenes: when participants were assisted by the navigation system, they made small head- and eye movements in order to check this area of interest. In contrast, when participants used the printed instruction, they moved their entire bodies by for instance, moving their torso forward and turning their heads completely to the left or right. Such additional physical movement requires more time than the more subtle movements previously mentioned. From the video observations it can be interpreted that drivers using a printed instruction have different motivations to look to the right or to the left compared to drivers using the navigation system. When participants scanned the road scene by head- and eye-movements, they looked for potential hazards (vehicles, pedestrians, cyclists etc.). Alternatively, when drivers moved 'their entire bodies' when looking to the right or left, it was established that they looked for relevant information to orientate (street signs, public buildings such as churches) themselves. It should be noted that the participants were experienced navigation system users. Even if the route was unfamiliar, it can be assumed that using the navigation system means that performing the orientation task is rule-based and mainly automated (in line with Rasmussen, 1987): drivers scan the road scene and the navigation system automatically by making small head- and eye-movements and following the given route. There is no further need to think about a strategy for reaching the destination. The resources can be spent predominantly on the tactical and operational levels of the driving task, even glances at the navigation system were automated (in accordance with Rasmussen, 1987, Michon, 1985 and Wickens, 1984, 2002). When participants used the printed instruction, a strategic task (in line with Michon, 1985) was added: the participant had to think about how to reach the destination and how to share cognitive resources between the orientation task, the vehicle steering- and operational task. Upon performing this orientation task, the lower levels of driving are influenced: the participants drove slower and used their visual attention not only to perceive potential hazards but also to find relevant orientation information (such as street signs or public buildings). These findings are in line with the results of a study Ma and Kaber conducted in 2007. In their driving simulator study, they investigated the effects of different levels of navigation reliability on drivers' level of *situation awareness*. They found that 'perfect navigation' improves driver situation awareness. In this study, drivers did not receive 'wrong' navigation information, neither in the navigation nor in the printed instruction scenario. However, when using the printed instruction, participants did not passively obtain the required information and instead they had to actively retrieve it.

5.4.3. *Drivers' reactions to pedestrians and cyclists.*

Drivers stopped more often in situations in which a pedestrian showed the intention to cross the road when using the navigation system as opposed to the printed instruction. This finding supports also the conclusion that participants had different motives to look at the side scene with different types of route guidance. In addition, the qualitative analysis shows that participants looked at the side scene and towards the pedestrian or cyclists but regardless of this did not react appropriately (did not stop) when using the printed instruction. When participants were supported by the navigation system they were more likely to react in an appropriate manner by stopping in order to give way to the pedestrian or cyclists. The results from this observation can be interpreted that drivers have different intentions to look at the side scene: looking for potential hazards vs. looking for significant orientation information. This insight gained in the qualitative analysis may contribute to a better understanding of the "looked but failed to see" phenomenon. The *driver motive* to look may play an important role in explaining this phenomenon. Drivers can have different motives to look in a certain direction: to check the road scene for potential hazards, to look at an advertisement, to look for a known person, to look for significant orientation information etc. In the case of this study, the driver had to fulfil two tasks: the driving (tactical & operational) and the navigation (strategic) task. The navigation task was more complex in the printed instruction scenario. Based on the situation, and depending on the type of route guidance available, the driver decides whether it is appropriate to pay more attention to the driving or to the navigation task. This behaviour in time-sharing between two parallel tasks is in accordance with Wickens' multiple resources theory (1984). In both situations, drivers look at the side scene, but the difference is whether drivers direct their attention focus to potential hazards (vulnerable road users, vehicles) or to guidance/orientation information (e.g. street name sign). In the second case, drivers may estimate that they are still able to perceive any potential hazards by their peripheral perception. This may lead to missing information and/or to inappropriate reactions such as not giving way to a pedestrian and/or cyclist who intends to cross the road even if the driver looks in the appropriate direction. Taking the results of Werneke and Vollrath (2012) and Brown (2005) which explain the *looked but failed to see phenomenon* into consideration may justify these findings. As the accidents occurred in circumstances that were clearly visible and less complex than other situations, drivers may have valued these situations as appropriate to spend resources not only on the driving task but also on other tasks. Thus, the role of the drivers' motivation to look may play an important role to explain cases of the "looked but failed to see phenomenon".

5.4.4. *Overall safety effect of type of route guidance*

In general, the results indicate that participants were pretty aware of their resources and they adapt their behaviour according to the particular situation. However, considering the results of Werneke and Vollrath (2012) and the statistics Brown (2005) referred to, drivers occasionally make inadequate decisions that lead to accidents. Using the navigation system to assist in route guidance allows drivers to focus on the driving task and to avoid potential risky situations where drivers may make inappropriate attention allocation decisions that may lead to accidents.

In contrast to this potential contribution of the navigation system to increase traffic safety, some less positive influences of navigation system use were found. When drivers used the navigation system they tended to drive faster, look (in direction) for shorter periods of time to the road ahead and longer away from the road scene than when using the printed instruction. When using a navigation system, the strategic task is simplified as drivers are relieved by the navigation system in the strategic task of having to navigate. When using the printed instruction, the strategic task is more complex. The additional resources may lead drivers to feel safer when using the navigation system as route guidance than when using the printed instruction. This supports the risk allocation (Fuller, 2011) and risk compensation (Wilde, 1982, 1994) theories; riskier behaviour is initiated when drivers feel safer in order to strive for a certain level of risk perceived as appropriate. Thus, when using the navigation system, drivers feel safer and compensate this feeling by driving faster and spending more time looking away from the road scene.

In summary, the use of the navigation system has the potential to improve traffic safety: it simplifies the strategic task by reducing the navigation task. The driver can pay more focused attention on the tactical and operational driving task. Alternatively, drivers may adapt their behaviour in a risky way when they use the navigation system. Such adverse behavioural adaptation could reduce the safety effect.

5.5. *Discussion*

5.5.1. *Field drives: internal and external validity.*

A field driving study must consider certain conditions that are not controllable. In this study, weather and traffic conditions were not constant between all participants and between the two rides and may have influenced the results. In general, most of the drives were done in dry conditions, however, sometimes it was more cloudy or sunny than other times. The qualitative analysis revealed that cases when the sun was low seemed to impair the drivers' glance behaviour. All rides were done between 10 am and 4 pm to avoid rush hours and to enhance similar traffic conditions. The number and location of other vehicles (passenger cars) present during the test drives was counted and compared and they appeared to be balanced between the two conditions. The colour and size of passenger cars present and weather conditions were not compared.

The factors discussed above as well as weather and traffic conditions may have also influenced driver glance behaviours by impairing or catching the attention because of the characteristics of these conditions. Referring to the SEEV model of Wickens et al. (2001, 2009), this would reflect the bottom-up processes of driver attention allocation that are determined by characteristics of the environment.

Different weather conditions may require different efforts for recognition of se the relevant scene and may also lead to different glance behaviours. Additionally, different characteristics of present vulnerable road users and vehicles may differ in salience and could attract the drivers' glances differently. As there were no indications for any unbalance, for the interpretation of the results it was assumed that these weather and traffic characteristics were balanced between the conditions and had no influence on the data and results.

An advantage of a field study is that participants drive in real traffic conditions. Since it was a given route that was driven by all drivers twice, information concerning exactly the same intersections in the two different navigation conditions was obtained. The two test rides were embedded in a naturalistic driving observation study with a duration of five weeks per participant. The first test drive was made after the one-week adjustment period, thus participants were already familiar with the observation equipment in the vehicle (cameras) and with the navigation system. Two observers accompanied the participants during the test rides. The observers were trained to observe the participants unobtrusively and to create a familiar atmosphere to the participants. It can therefore be assumed that the behaviour displayed was their real driving behaviour. This combination and the embedding of two test rides in a naturalistic driving study ensured a good internal and external validity.

All participants drove the first time the same unknown route using the navigation system as route guidance and for the second drive they used the printed instruction. A point of potential concern is a possible learning effect in that drivers would memorise the route which would simplify the navigation task. If there was a learning effect, however, it is likely to be very small because it was an unknown route lasting 1 hour and there were at least three weeks between the rides. It is unlikely that they memorised the route.

5.5.2. *Experienced navigation system users.*

Another potential limitation of this study is the fact that only experienced navigation system users participated. It can be assumed that the participants were adapted to use this type of guidance. For future research it would be interesting to add a group of non-experienced navigation system users to be able to exclude a potential “unlearn (using a printed instruction) effect” as reason for any differences found in glance behaviour between the two route guidance conditions.

5.5.3. *Combination of qualitative and quantitative research.*

The combination of the qualitative and quantitative analysis supported the interpretation of the results and allowed us to gain rich information. To sum up the significant results from the quantitative analysis: participants drove faster through intersections when they were supported by the navigation system; they looked for shorter periods of time at the side road scene when they used the navigation system in comparison to when they used the printed instruction and they looked longer away from the road scene when they were supported by the navigation system. Regarding these results from a traffic safety point of view, a possible conclusion is: use of the navigation system leads more to an endangering behaviour such as driving faster and paying less visual attention to the road scene than when using a printed route instruction as navigation support. Integrating the results from the qualitative analysis, it was found that from a traffic safety point of view using a printed instruction does not lead to less endangering driver behaviours than when using the navigation system. In fact, two reasons why drivers drive slower when they use a printed instruction and why they look longer to the side road scene could be identified: (1.) when participants used the printed instruction to establish an unknown route, they had to perform a task in addition to the driving task: they had to orientate themselves and subsequently find their way. Thus, they had limited resources compared to when the navigation system was used and when the participant only had to fulfil the driving task. In order to perform both tasks successfully participants had to share resources and consequently g drove slower. (2.) They looked longer to the side scene not because they paid more attention to potential appearing hazards such as road users but because had to find relevant information required for them to be able to f orientate themselves. So, the motivation to look at the side scene was not only to check for potential hazards but also to find orientation information. When they used the navigation system, participants showed a compensation behaviour in the other direction. Since the strategic task was simplified by gathering route guidance information from the navigation system, they 'only' had to fulfil the driving task. As a result, participants had the resources to drive faster and to look longer away from the road scene.

Taking only the quantitative results into consideration could have lead to a misinterpretation of the results. Glance behaviour, focus of glances and the duration of glances are often taken as indicators for visual attention and could have lead to the interpretation that using a printed instruction may lead to a safer driver behaviour than when a navigation system is used. However, integrating the qualitative results, it can be seen that both use of a printed instruction and a navigation system- may induce behaviours that could be endangering. In general, however, drivers seem to be aware of the risks and consequently try to compensate for them. Further on, the motivation of drivers to look for orientation information could be identified. These were not derivable when only the quantitative results were considered. The discussion highlighted that consideration of the combination of results gained in qualitative and quantitative analyses served to gain a comprehensive understanding of the complex process: the role of cognitive and motivational processes and their interplay. All in all, both sets of results (from the quantitative and the qualitative analyses) were enriching and were complementary to each other.

5.5.4. *Areas of interest.*

In this study the focus was on glance behaviour to various areas of interest. The scheme shown in Table 12 (p.131) served as base for data coding. Within this study the scanning *within* the particular areas of interest was not further specified. This would be an interesting topic for further research: to investigate same research question and to analyse drivers' scanning behaviour within the various areas of interest. To answer this research question may give an impression of drivers' differences in the visual field of view due to the use of different navigation guides and how intensive the certain areas of interest are scanned. Having this information may serve to make a more detailed statement about drivers' level of situation awareness.

5.5.5. *Look but failed to see.*

Even if drivers seem to be generally aware of their skills, it seems plausible that there are some inadequate decisions drivers make as a result of their motivation to establish the correct route. In the qualitative analysis, it was observed from the glance and body movement behaviours displayed, that looking at the side scene when using a printed instruction served not only for detecting potential hazards but also for the recognition of information for route guidance. Suggestions to avoid potential *"looked but failed to see"* accidents would be to place orientation signs (e.g. street-names) more intersection centred and to design them in a more salient manner. In case a pedestrian crossing is present, the information the drivers need to orientate themselves may be placed before the pedestrian crossing. Further research is recommended to gain more enhanced understanding of the *"looked but failed to see"* phenomenon and to further develop the suggested theoretical approach. An approach could be to investigate this phenomenon in a driving simulator study that compares the two different conditions: driving an unfamiliar route with a printed instruction versus being supported by a navigation system. Quantitative and qualitative methods can be combined: (1.) recording glance data by use of an eye tracker; (2.) stopping after certain sequences and asking for the perceived present potential hazards of the experienced traffic scenes and (3.) adding a final interview while watching a (4.) video of the drivers' glance behaviours and asking the participants for their intentions to look where they looked, may give a more detailed explanation of this phenomenon.

*5.5.6. **Presence of pedestrians and/ or cyclists.***

Another issue is the drivers' behaviours in cases of pedestrians and/or cyclists who are intending to cross the road being present. Even if no near-crash situations with pedestrians and/or cyclists during the field drives were happened, in half or more cases when pedestrians and/or cyclists actually were present and moved in a crossing direction the participants did not stop. In order to enhance the drivers' awareness of potential occurring pedestrians and/or cyclists an idea would be to implement a pedestrian crossing warning in navigation systems. Inspired by the results of this study and based on the fact that at intersection situations in particular pedestrians and/or cyclists are more likely to be involved in a car accident, the researchers conducted a follow up study in which investigating the drivers' glance behaviours at intersection situations and comparing intersections that include pedestrian crossings to intersections without.

*5.5.7. **Transition towards higher levels of automation.***

Several car companies have announced their intentions to produce highly or fully automated vehicles and that these will be available on the market around the year 2020. In addition, developments of driverless cars are already highly advanced (Carfrae, 2010; Holling, 2011; Niel, 2012). Different advanced driver assistance systems have been introduced on the market, such as the navigation system, adaptive cruise control system, intelligent speed adaptation, forward collision warning and lane keeping assistance systems. New driver assistance systems are gradually being introduced and various tasks of the driver are being eliminated. As a result, the driving task is continuously changing from an operating task towards a supervising task and eventually the role of the driver may fully disappear with the introduction of driverless vehicles.

In this study, one task of the driver was simplified: the navigation task. The effects of eliminating this task was investigated using a driving behaviour model (Figure 14, p.123) and based on the models of Rasmussen (1987) and Michon (1985). The driver had to fulfil two tasks: the driving (tactical & operational) and the navigation (strategic) tasks. The navigation task was simplified when the navigation system was used instead of the printed instruction. The study shows that eliminating a subtask from the driver could affect the driver behaviour on other subtasks. The simplification of the strategic task by elimination of the navigation task resulted in more focused attention on the tactical and operational driving tasks. When supported by the navigation system, the driver acts in a highly automated manner and according to Rasmussens' (1987) rule displays skill-based behaviour. When the printed instruction was used, the participant had to think about how to reach the destination and had to share cognitive resources between the orientation and the vehicle operational tasks. This influenced the lower levels of driving: the participants drove slower and used their visual attention not only to perceive potential hazards but also to find relevant orientation information (such as street signs or public buildings).

Alternatively, it may be argued that route guidance support may result in adverse traffic safety effects by increasing the tendency of drivers to display more risky behaviour (driving faster, paying less visual attention to the road scene) when being assisted. Given the rapid transition in the automotive industry, it is highly relevant to further investigate effects of eliminating subtasks of the driver on the overall driving performance. Relevant research topics to investigate are: adverse behavioural adaptation, risk homeostasis, workload homeostasis and management of driver workload, driver in the loop and out the loop, partial adaptation of cooperative systems and partial adaptation of advanced driver assistance systems or highly automated driving.

6. Final discussion and overall conclusion

"The process of scientific discovery is, in effect, a continual flight from wonder."

(Albert Einstein, 1879-1955)

6.1. *Looking back, looking ahead*

This thesis had four main, general objectives. Firstly, it was aimed to identify relevant motivational factors that are affected by DAS use experience. Secondly, in contrast to past and the majority of recent studies (e.g., Popken, 2009; Wege, 2014; Dotzauer, 2015), this work aimed at identifying the role of actual DAS use experience when the effects of DAS on driver behaviour are investigated. Thirdly and fourthly, this work intended to gain a better understanding of influencing variables on driver attitudes towards DAS use and of the effects of motivational processes on cognitive processes in response to DAS use experience.

In order to achieve these objectives, three empirical studies addressing four different research questions were carried out; a focus group study, a questionnaire study and a field operational test study. Within these studies, qualitative and quantitative methods were applied to collect subjective (e.g., perception of risk, beliefs concerning DAS, beliefs concerning carrying out secondary activities while driving) and objective data (e.g., glance data, speed). The qualitative approaches included focus group studies and analyses based on the grounded theory, as well as behaviour observations. The quantitative analysis were based on conducted questionnaire-, video-, and GPS data.

This work provided an in-depth-view in drivers' motivational aspects when the effects of DAS use are investigated. Thereby, the role of drivers' actual experience in DAS use was highlighted, too. A central outcome of this thesis is the 'STADIUM' model. The STADIUM model is a theory that was developed based on the outcomes of focus group discussions (Chapter 2). STADIUM explains the interplay of motivational factors that determine the engagement in secondary activities while taking DAS use experience into account. The STADIUM model takes following four motivational factors that are linked to drivers' motivation to carry out secondary activities while driving into account: safety-related beliefs concerning DAS, perception of risk, perceived behavioural control and safety-related beliefs concerning carrying out secondary activities while driving. The STADIUM model could not be confirmed quantitatively completely (see Chapter 3). However, seven of the tested nine direct relations stated within the model were found to be significant. Thereby, the significant role of all considered motivational variables and DAS use experience and their effect on being engaged in secondary activities could be highlighted. As using DAS and potential resulting negative behavioural adaptation is an important safety issue, in order to gain a better understanding of potential influencing variables and underlying processes, the role of system functionality, drivers' usage experience, gender, age, and sensation seeking in drivers' attitudes towards assistance systems was considered in detail (see Chapter 4). Twenty-nine different DAS were taken into account. Main interesting outcome was: in terms of safety, drivers' evaluated systems differently and the more experienced drivers are in using DAS the higher they judged DAS in terms of safety. The role of motives in showing attentive behaviour depending on DAS (the navigation system) use could be underlined in the field study introduced in Chapter 5. The relevance, enrichment and need of combining qualitative and quantitative approaches when the effects of DAS on driver behaviour are investigated could be shown, too.

Following, the outcomes are discussed in terms of hierarchical driver behaviour models, implications, limitations and future research needs.

6.2. *Hierarchical driver behaviour models: Be motivated to pay attention*

Most important idea behind hierarchical models is the assumption that changes on higher levels potentially lead to changes on lower levels. Drivers' motivational processes are mainly represented on higher levels whereas cognitive processes are mainly represented on lower levels of driver behaviour models. The majority of recent and past studies investigating the effects of DAS on human behaviour focused on changes in cognitive processes such as drivers' level of attention, awareness, workload etc. (e.g., Popken, 2009; Wege, 2014; Dotzauer, 2015). The relevance of this kind of research is clear: paying attention to the environment while driving in order to be able to react appropriately to the given situation obviously represents both, drivers' cognitive processes and the tactical level of the driving task that is often treated as 'the' driving task (e.g., Nilsson, 2005). However, as introduced with the different hierarchical driver behaviour models: driving includes more than the situation of steering a car and reacting to the situation appropriately represented in Hatakka's (1998, 2000) two lowest levels: vehicle manoeuvring and mastering traffic situations. It includes drivers' attitudes towards traffic safety, towards behaving safely in traffic, drivers' perceived risk and other motivational factors, too.

This work could show and highlight that drivers' motivation is reflected in driver behaviour that is often linked to cognitive processes: glance behaviour and task sharing. Results of the studies introduced in Chapter 2, 3 and 5 could show that DAS use (experience) influences driver motivation to pay attention to the driving task. Simply said it was underlined that, if the driver is not willing to behave safely, the driver will not show a safe behaviour and if the driver is not willing to pay visual attention to other road users the driver will not pay attention. Results of the studies introduced in Chapter 2 and 3 showed that the beliefs concerning distracting behaviour significantly determine if the distraction behaviour is (intended to be) carried out or not. The results of the qualitative analysis presented in Chapter 5 led to the conclusion that driver motives are different due to DAS use in comparison when no DAS is used. In the quantitative analysis within this study (introduced in Chapter 5) it could be shown that the use/no use of DAS (and thus having different motives) result in different glance behaviour. Thus, the outcomes of this work underline and support the hierarchical approaches of driver behaviour of Michon (1985) and Hatakka (2000). Referring to the six categories of potential domains that may be affected by DAS use and its affected dimensions (Jenssen, 2010) there is a missing link between the effects of changes in drivers' motives and motivational processes on drivers' driving performance and cognitive processes. Jenssen distincts following categories that are affected by the use of DAS: perception, cognition, performance, driver state, attitudes and the adaptation to environmental conditions. Thereby, five of these six categories represent the first and the second level of Hatakka's (1998, 2000) hierarchical driver behaviour model: vehicle manoeurvering and mastering traffic situations. Only one category 'attitudes' represents the third level of Hattaka's model: goals and context of driving. According to the results of this work, the motivational categories: risk perception, perceived behavioural control and beliefs concerning safety-endangering behaviour should be added to Jenssen's distinction.

Jenssen (2010) proposed five stages of behavioural adaptation due to DAS use: the first encounter phase, the learning phase, the trust phase, the adjustment phase and finally the readjustment phase. The phases reflect a process of behavioural adaptation in response to DAS use within a time period of one to two years. Jenssen states that after this time, drivers' behaviour can be assumed as stable. Although, it is not underlined motivational processes play an important role in each phase. Jenssen refers in almost every phase to drivers' level of trust in the system. Other motivational processes are neglected in his phases. However, as could be shown in this work, motivational factors such as perceived risk, perceived behavioural control, safety-related beliefs play an important role in influencing drivers (intended) behaviour and are affected by DAS use experience. Thereby, based on the outcomes of this work, it can be hypothesized, that the more experienced drivers are in using DAS, the stronger is the expected effect on their motivational factors. It is highly recommended to take this research issue in future research on behavioural adaptation due to DAS use into account.

Still, although hierarchical driver behaviour models are well established, research on driver motives and motivational processes that are represented on higher levels of those models and its consequential effects on traffic safety lacks in comparison to research on the effects on cognitive processes. According to the results of this work, it could be demonstrated that in order to gain a holistic understanding of driver behaviour in response to DAS use, it is important to consider also higher levels of driving beside those levels that represent cognitive processes and vehicle-steering-performance.

6.3. *The STADIUM model*

The STADIUM model, which was introduced in the study outlined in Chapter 2, was developed based on a qualitative and empirical approach. The model describes the interplay of several motivational factors that influence drivers' willingness to carry out secondary activities while driving and how this depends on drivers' DAS experience. In contrast to other motivational driver behaviour models (e.g. Näätänen, Summala, 1974, Wilde, 1982, 1994) and approaches that describe behavioural adaptation due to DAS use by motivational processes (Jenssen, 2010), the STADIUM model takes into account more relevant motivational aspects and proposes a more complex interplay of those variable. The majority of past and recent studies that consider motivational factors when DAS are used, focus on perceived risk (e.g. Rajaonah, Tricot, Anceaux, & Millot, 2007), acceptance (e.g. Molin & Marchau, 2004) and trust (e.g. Rajaonah, Tricot, Anceaux, & Millot, 2007). The STADIUM model considers the following motivational factors into account:

- safety-related beliefs concerning DAS
- perceived risk
- perceived behavioural control
- safety-related beliefs concerning carrying out secondary activities while driving

In addition, the model considers drivers' experience in using DAS. The interplay of those variables and their characteristics justifies the driver's willingness to carry out secondary activities while driving. Further, external variables that influence perceived behavioural control were identified. The STADIUM model suggests that DAS use experience determines driver safety-related beliefs concerning DAS and driver perceived behavioural control directly. Perceived behavioural control is additionally expected to be influenced by beliefs concerning DAS, by beliefs concerning secondary activities and by actually carrying out secondary activities while driving. Thereby, perceived behavioural control is hypothesized to affect driver perceived risk (that is directed linked to safety-related beliefs concerning secondary activities) and driver beliefs concerning carrying out secondary activities which determines the actual engagement in secondary activities. The included interplay of motivational factors is assumed to be affected by a number of other external variables (beside DAS use experience) such as the type/state of the vehicle, the traffic situation, other road users etc.

6.3.1. ***Comparison with the Theory of Planned Behaviour.***

The STADIUM model differs from the classical TPB (Ajzen, 1991) and its extended versions (e.g. Zhou, Horrey & Ruifeng, 2009; Holland & Hill, 2008; Forward, 2009). It integrates elements of the TPB in order to predict drivers' engagement in secondary activities, focusing on the impact of DAS use experience. Thereby it relates the target behaviour to the specific context of DAS use and its long-term effects (DAS use experience). The model seeks to explain behavioural adaptation to DAS use. Therefore, in contrast to the TPB, the STADIUM model includes motivational factors related to this context: safety-related beliefs concerning DAS use additionally to safety-related beliefs concerning the behaviour of interest.

In line with the TPB, the findings of the study presented in Chapter 2 suggest that carrying out of secondary activities while driving is directly determined by the driver's attitude towards the behaviour. Moreover, the remaining two essential factors included in the TPB, norms and perceived behavioural control, emerged as relevant influence factors in the STADIUM model. Norms included in the STADIUM model reflect a person's belief about what should be done or not. Thus, a slightly broader construct is applied compared to the TPB. It considers norms as approval or disapproval of significant others and related social pressure. Based on the fact that participants' reported norms strongly represented attitudes, the two constructs were aggregated to one category 'safety-related beliefs' in the STADIUM model whereas they are separate categories in the TPB.

Furthermore, the observed interactions among the variables differ from the TPB. Driver beliefs concerning carrying out secondary activities showed to be directly related to perceived behavioural control and to the targeted behaviour. The other way round, the execution of the behaviour (engaging in secondary activities) also showed to influence perceived control. In addition, the perceived level of risk had an influence on beliefs concerning the target behaviour, rather than on the execution of secondary activities while driving itself, as established in some extended TPB models.

Finally, the STADIUM model considers actual behaviour whereas the TPB relies on the intentions to perform a particular behaviour as the most proximal determinant of actual behaviour (Ajzen, 1991; Ajzen & Fishbein, 2005). During the focus group discussions, the participants reported their past and habitual behaviour while driving rather than their behavioural intentions.

*6.3.2. **The STADIUM model and its relevance for understanding driver behaviour.***

The STADIUM model contributes to a better holistic understanding of driver behaviour. It may serve as basis to explain outcomes of past and recent studies. Thus, the STADIUM model for instance can be used to explain the outcomes of the study introduced in Chapter 5 where glance behaviour at intersections in response to using the navigation system or a printed route instruction was compared. Results of this study showed that drivers have different glance behaviour when they use navigation system in comparison when they use the printed route instruction for navigation. The qualitative analysis suggested that the use of different route guidance types results in different motivations where to look at and how long.

According to the STADIUM model, when drivers used the navigation system for guidance they may have experienced increased control while driving compared to when they used the printed route instruction (in line with Wicken's multiple resources theory, 2002). This increased behavioural control may have induced a perception of reduced risk while driving with lowered degree of visual attention to the road environment when they used the navigation system which resulted in looking more often and longer away from the road scene.

The outcomes of the study presented in Chapter 5 also revealed more stable glance behaviour during the trip when drivers were supported by the navigation system unlike when they used the printed route instruction. In line with the STADIUM model this underlines the influence of situational variables on driver behaviour. Depending on the situation, drivers perceived an appropriate control to perform the driving task safely and accordingly they were able to assess if it is safe/unsafe to look at the printed instruction. Finally they decide to act based on this assessment.

In conclusion, the STADIUM model proposes that motivational factors have a substantial influence on road traffic behaviour and related safety issues. It highlights that motivational factors are central in determining a driver's decision-making regarding engagement in secondary activities while driving, and consequently, underlines the relevance of these factors for the development and implementation of traffic safety measures.

6.4. *Applying qualitative or quantitative methods when effects of DAS use on driver behaviour are investigated?*

The study introduced in Chapter 5 investigated the effects of using a navigation system vs. using a printed route instruction on driver glance and speed behaviour. When the results from the qualitative analysis were incorporated, it was found that from a traffic safety point of view using a printed route instruction does not lead to a less endangering driver behaviour than when using the navigation system. Actually by means of the qualitative glance analysis, it could be identified that there are two reasons why drivers drive slower when they use a printed route instruction and why they look longer at the side road scene. When drivers use the printed route instruction to find an unfamiliar route, they have to complete an additional task to the driving task: they have to orientate themselves and find the way. So, the motivation to look to the side scene was not only to check for potentials hazards but also to find orientation information. When they used the navigation system, drivers showed compensation behaviour in the other direction. Since they only had to fulfil the driving task, they had the resources to drive faster and to look longer away from the road scene.

So, respecting only the quantitative results could have lead to a misinterpretation of the results. Glance behaviour analysed quantitatively is often taken as indicator for visual attention and could have lead to the interpretation that using a printed route instruction may lead to safer driver behaviour than when a navigation system is used. However, integrating the qualitative results, it can be seen that both, using a printed route instruction and using a navigation system may induce behaviour that could be endangering. But in general, drivers seem to be aware of risks and try to compensate it. Further on, it could be identified the motivation of drivers to look for orientation information that were not derivable when only the quantitative results were considered. Concluding, the results of the study underline the view on applying mixed methods of Johnson, Onwuegbuzie and Turner (2007). Combining the results of the quantitative and the qualitative analyses provided “the most informative, complete, balanced, and useful research results” (p.129).

In Chapter 2 the STADIUM model explaining the interplay between motivational factors that determine the drivers’ decisions to carry out secondary activities while driving was developed based on the results of focus group studies. In a follow up study, the questionnaire study (see Chapter 3), the STADIUM model was tested quantitatively and could not be confirmed completely. However, the focus group discussions fulfilled their function as qualitative method to serve to generate theoretical knowledge whereas the questionnaire study served to test the theoretical model. So, for each research question of the particular studies, the chosen methods were appropriate and considering the results of both studies in any case enriching. This goes in line with the functions of qualitative and quantitative methods stated by Johnson and Onwuegbuzie (2004). Additionally, considering the results of both studies as a whole provides a better understanding of the relations between the variables of interest.

All in all both information were enriching: results from the quantitative and the qualitative analyses. However, as shown in Chapter 5 analysing the data only quantitatively or only qualitatively could have lead to a misunderstanding of the results. Given the results of this work, it is highly recommended to combine research on motivational factors and cognitive processes when driver behaviour in terms of safety is investigated.

*6.5. **Limitations of this research***

In the focus group study (see Chapter 2) and the questionnaire study (see Chapter 3 and 4), DAS use experience was defined as an interplay of the use and duration of the particular systems, the current frequency of driving with the particular systems activated, and the subjective familiarity with them. Technical systems that support the driver can be quite different in their functioning. The systems can provide information to the driver, warn the driver, intervene with driving or combine these functions. Additionally, systems may support different tasks that might be assessed differently in terms of importance for safe driving: one system may support the driver in steering the vehicle by keeping a stable speed and distance to the leading vehicle, another system might only regulate the front light. In this study, it was assumed that the higher the drivers score in the built DAS index, the more they are familiar with automated driving. As systems are heterogeneous, the proposed way of determining DAS use experience can lead to biases. This fact was taken into account by recognising that participants with high DAS use experience are familiar with mostly the same systems and that the same is true for participants with low DAS use experience.

As underlined in Chapter 2 and 3, considering this *actual* DAS use experience can be seen as potential limitation but also as advantage of this research. In the study introduced in Chapter 3 it was found that actual DAS use experience is significantly directed related to participants' beliefs concerning DAS, and perceived behavioural control. Additionally it was found to be indirectly related to safety-related beliefs concerning secondary activities. Findings from the study of focus group study (see Chapter 2) and the fact that for the variable 'safety-related beliefs concerning DAS' correlations to other variables of interest were found to underline that actual DAS use experience seem to be a supporting and important factor. On the one hand, with these studies (Chapter 2, 3 and 4) a view on 'real drivers' with actual DAS use experience in total was gained. Thus, external validity of this study can be evaluated as high. However, still it is unknown whether *actual* DAS use experience may be determined by variables that were not collected within the questionnaire study and that were not controlled. Thus, the interpretation of the results is ambiguous, too.

In the study introduced in Chapter 5 only experienced navigation system users were considered. This could be a potential limitation of the study. It can be assumed that the participants were adapted to use this type of guidance.

The questionnaire study introduced in Chapter 3 was performed in order to test the core of the STADIUM model, focusing on the influence of actual DAS use experience on the hypothesized relations between motivational factors that finally determine drivers' willingness to carry out secondary activities while driving, quantitatively. The model was developed based on data conducted within focus group discussion (see Chapter 2). The tested model could not be confirmed as a whole by this study. However, seven (respecting an Alpha level of .10) of nine stated directed relations were found to have significant path coefficients. Within the questionnaire, a general view/state on drivers': safety-related beliefs concerning DAS, perceived behavioural control, perceived risk, safety-related beliefs concerning carrying out secondary activities and the intention to carry out secondary activities was collected. In contrast, within the focus group discussions, a more situational view on those variables of interest was gained. When participants discussed about the potential risk of carrying out secondary activities, they put themselves in certain situations and put things in perspective depending on the situation. Based on this discussion and this situational view drivers have, the STADIUM model was developed which includes also the category 'external variables'. However, the traffic situation was not taken into consideration within the questionnaire study as this study focused on the role of the motivational factors and as the inclusion of external variables was limited due to the character of the questionnaire. Thus, a reason why the tested model was not confirmed as a whole with the data of this questionnaire study might be that different views of drivers on the variables were inherent in the two studies.

The STADIUM model and the identified motivations are all safety-related. However, the motivation to use DAS and consequently gain experience in using DAS might also be comfort-related or because of the affinity to use new, advanced technologies, etc. The participants in the focus group discussions (see Chapter 2) focused on safety-related motivations which could have been triggered by the dynamic of the focus group discussions and by social desired statements given by the focus group participants. It should be kept in mind that not only safety-related motives but also other motives may play a role in effects of DAS use on driver behaviour, a fact which should be taken into account in future research.

The found effects within the field study introduced in Chapter 5 were rather small. This could be due to the nature of the field study; a field driving study explores certain conditions that lie beyond control. Two conditions, weather and traffic, were taken into account throughout the study and these varied for each participant and also differed between the two runs. This may have affected the outcome. Most of the driving was carried out under nice weather conditions. The qualitative analysis asserted that when the sun was low, the drivers' glance behaviour seemed to be impaired. Regarding traffic, the drives were performed at specific times (between 10 am and 4 pm) so as to avoid rush hours and maintain similar traffic conditions. For each test run, the number and position of other vehicles (passenger cars) present was counted and compared and they appeared to be balanced within the two conditions. The colour and size of passenger cars and weather conditions were not considered as potential influence factors in the statistical analysis. Both factors - weather and traffic conditions - may have affected driver glance behaviour by impairing or catching their attention as a result of the specific elements or characteristics of the conditions involved. Referring to the SEEV model of Wickens et al. (2001, 2009), this should reflect in the bottom-up processes of driver attention focus that the characteristics of the environment determine. Diverse weather conditions may require varying efforts when recognising a relevant scene and this may which alter the glance behaviour. Also, different characteristics of vulnerable road users and vehicles present may differ in salience and as a result would have various effects on driver glance behaviour. The results from this study were interpreted under the assumption that both weather and traffic conditions were balanced and had, therefore, no influence on the data obtained.

Driver glance behaviour that is examined in a field study is to some extent limited; the data obtained cannot be as accurate as the data collected by an eye tracker as part of a simulator study. This study examined changes in glance behaviour when it focuses on various areas of attention. Data were coded according to the scheme shown in Table 12 (p.131). Scanning of the scene within the particular areas of interest was not further specified. This is a potential topic of interest for additional future research: (the same research question and) the analysis of driver scanning behaviour within the various areas of interest. The research may provide an insight into how driver glance patterns change according to different designs of intersections and how closely concrete areas of interest are scanned. With this information in hand, a more detailed statement could be made concerning drivers' level of situation awareness.

In contrast to this field study, Werneke and Vollrath (2012) conducted a driving simulator study. As mentioned above, a simulator study involves the use of special equipment (e.g. eye tracker system) which collects data automatically, and in this way is more accurate compared to a field study. Furthermore, a simulator study allows for conditions to be more tightly controlled. Internal validity of a simulator study can be evaluated as higher than in a field study, however, external validity has to be considered more critically due to the laboratory conditions that may produce artificially, distorted behaviour.

In general, it is important to note again, that qualitative research produced results that are not representative whereas quantitative research may lack in answering the 'why'. These are limitations of the methodological approaches that were applied within this work in general and that should be considered, when the results of the studies introduced in this thesis are applied.

6.6. Implications

The extended diamond, introduced in Chapter 1 (see Figure 4, p.18) illustrates relevant domains that should be taken into account when traffic safety issues are discussed. It includes the interplay between following domains: the individual (road user, related to the topic of this thesis: the driver), the vehicle and its features, the infrastructure and its features, the society, the interaction with other road users and intelligent transport systems (related to the topic of this thesis: DAS). The diamond states the interplay between these relevant domains, to say: any changes in one of the domains potentially lead to changes in one or more of the other domains.

Central domains in this work were: the individual (and its characteristics) and DAS. Nevertheless, the outcomes are relevant to derive implications on the society domain, too. Note, implications that are stated will focus on the potential increase of traffic safety and will not take driver comfort issues into account.

6.6.1. Individual & DAS.

In Chapter 2, a qualitative study was illustrated in which drivers participated in focus groups and discussed how safe they feel while driving, which safety-related beliefs they have concerning DAS and concerning carrying out secondary activities, how much control they perceive on the road and if they are willing to carry out secondary activities while driving. A theoretical model of the interplay between these variables of interest was developed based on the results and analysed quantitatively in a follow up questionnaire study. Results show that motivational factors play a decisive role in influencing the drivers' general willingness to carry out secondary activities.

The outcomes of the studies highlighted issues that should be taken into account when traffic safety shall be improved and which part the individual plays in road safety. According to the TPB (Ajzen, 1991), behaviour is determined by attitudes and norms towards the behaviour, and perceived behavioural control. Gather from the STADIUM model, driver engagement in secondary activities while driving is mainly determined from safety-related beliefs concerning carrying out secondary activities. Thus, it could be underlined, that safety-related beliefs are a main factor influencing driver decisions to pay attention while driving. Additionally, it can be concluded that perceived behavioural control is indirectly linked to the intention to carry out secondary activities while driving. In order to avoid the gradual introduction of higher numbers of DAS that aim at increasing traffic safety by their functionality, leading to unintentional behaviours that decrease traffic safety like secondary activities while driving, it is necessary to raise public awareness and ensure proper DAS introductions when DAS are installed. Consequently, safety-related beliefs are a central category that should be influenced in a traffic safety increasing manner by applying well-developed awareness raising campaigns for instance. On the one hand public campaigns can target awareness of system functionality and its potential positive effects on traffic safety when drivers are attentive. And, on the other hand, they can provide information regarding the risk of carrying out secondary activities while driving due to a wrong understanding of DAS, leading to a contrary effect on traffic safety.

Results of the study presented in Chapter 4 revealed reasons why DAS are assessed as positive or negative in terms of safety. The effects were significant for system functionality, DAS use experience and age. It is suggested that these aspects (system functionality, its usage and its potential positive and negative effects on traffic safety) are included in driver education programs and that they are properly introduced to new system or new vehicle purchasers. However, awareness campaigns are widespread already whose level of success may be questionable. Barr and Prillwitz highlighted in their Theory of Interpersonal Behaviour (TIB, 2012): „[O]ne needs to understand the fundamental motivations (and barriers) underlying consumption which relate to issues such as perceived wants and needs, the symbolic and sign value of goods and services and what it means to have a good quality of life" (p. 808). Thus, behaviour is a stable component that is fundamentally influenced by relevant motivations such as attitudes, norms and perceived behavioural control for example and habits. Concluding, in order to implement *successful* awareness raising campaigns, the measures should be applied continuously and comprehensively since it can be assumed that it takes time until motivations such as attitudes and norms and following behavioural habits change. The measures should be developed in a participatory process including the target group (especially taking different age groups into account) in order to be not instructive but finally effective.

Another result that was found in the focus groups study and the follow up questionnaire study was that drivers judge DAS rather sceptical especially when they are not familiar with using the particular DAS. In order to improve the safety effect of DAS instead of leading to the converse effect and in order to increase drivers' skills to handle DAS also in critical situations, drivers should be trained *before* they start driving DAS equipped cars. Some car manufactures already offer such trainings when drivers buy a fully equipped new car. However, considering that DAS become more and more spread not only in higher class cars but also in middle class and even small class cars, this is too little. Trainings should be offered whenever a DAS equipped car is sold and should be even mandatory for drivers, what leads us to the society and its potential functions in improving traffic safety related to DAS.

6.6.2. ***Society & DAS.***

According to Bamberg (2011) transport political countermeasures that aim at changing road user behaviour should focus on factors and processes that successfully influence attitudes. In both, the focus group (see Chapter 2) and the questionnaire studies (see Chapter 3) it could be shown that attitudes play an important role in affecting driver behaviour. Positive relations were found between safety-related beliefs concerning carrying out secondary activities and the intention to carry out secondary activities. These results support the outcomes of past studies that already highlighted the role of secondary activities or distractions leading to traffic accidents (e.g. Stutts, Reinfurt, Staplin & Rodgman, 2001, Klauer, Dingus, Neale, Sudweeks & Ramsey, 2006; and McEvoy, Stevenson & Woodward, M., 2007).

In order to improve traffic safety and to avoid positive beliefs concerning carrying out secondary activities while driving transport political countermeasures may be applied. Thereby, Bamberg (2011) does not support measures that are based on rewards. He states that basic attitudes are not changed by rewards since it is assumed that persons fall back in their used behaviour when rewards are dropped. Additionally, (new) incentives have to be very obvious to the individuals so that they become relevant. Thus, incentives that aim at leading to changes in driver behaviour can be really expensive and such kind of measures do not lead to changes in intrinsic motivation. However, punishment measures are not well accepted in society. Bamberg pleads instead of applying approaches that are based on rewards or punishments to implement intervention-concepts that are based on the knowledge of behavioural science. Although rewarding and/or punishing elements can be used in this frame, according to Bamberg in focus should be to create a voluntary, intrinsic motivated wish to change. He suggests intervention-countermeasures that are based on a social-ecological approach. This approach assumes that individual knowledge, attitudes and behaviour are fundamentally affected by institutional structures, cultural dynamics and social relations within a group. Examples for such countermeasures that are implemented on different levels are legally and police countermeasures, mass-medial campaigns or school-based interventions. Concluding, for traffic safety and aiming to change driver attitudes towards carrying out secondary activities in a way that this is seen rather negatively than positively by the society, countermeasures such as mass-medial-campaigns could be effective. School-based measures, that inform about (and explain) the consequences of carrying out secondary activities while driving could be applied for youngsters that are about to make their driver license. Participants of the focus groups criticised that DAS are used without knowing them and their functionality. In order to improve the correct usage of DAS and consequently traffic safety, mass-media campaigns could be also used to inform and explain the functionality and potential limitations of particular DAS. This could lead to both, improving the attitudes towards DAS and the correct application of DAS and consequently may improve traffic safety. However, applying legal regulations that prohibit carrying out secondary activities while driving in combination with explaining and informing society in detail about consequences of carrying out secondary activities is assumed to successfully lead to changes in driver attitudes and consequently in -behaviour. Recommendations for future research that may contribute to safety implications too is suggested below.

6.7. *Outline: Recommendations for future research*

The results of this work contributed to an in-depth-view of driver motivational aspects when DAS and infrastructural countermeasures are investigated. A central outcome of this thesis is the STADIUM model describing the interplay of motivational factors that determine the engagement in secondary activities while taking driver assistance systems taking DAS use experience into account. The core of the STADIUM model was tested quantitatively and could not be confirmed completely by the questionnaire study introduced in Chapter 3. However, given the limitations of this study, for future research it is recommended to conduct *all* variables of interest for different situations, and thus including the influence of *external variables* as stated in the model, and to test the complete model based on these data. This could be realised by conducting a questionnaire survey asking either for detailed situations or to combine the survey with a field study in which the participants are observed and asked in real time while experiencing the (several) driving situation(s). Including the further exogenous (independent) variable as proposed by the STADIUM model is assumed to strengthen the results of the model. Concluding in order to implement the recommendations it is suggested to ask for example for:

- The activation of the respective system so that it can inform, warn or intervene if necessary is dangerous when it is raining
- When it is raining the respective system should be activated in order to be able to inform, warn or intervene if necessary
- Driving more than 110 km/h on a wet rural road while raining is…
- How would you estimate the general risk while driving when it is raining?

- In general it is dangerous to carry out 'secondary activities' while driving when it is raining.
- It should be generally forbidden to carry out other activities while driving when it is raining.
- I carry out other thing while driving when it is raining

When asking for the factors within the STADIUM model, it is expected that if the external variables are collected as suggested, then they rather reflect the outcomes of the focus group study introduced in Chapter 2. It is assumed that in this way the explanation value of the involved variables which explain the underlying motivations to carry out secondary activities while driving depending on the level of DAS use experience increases.

The studies introduced in Chapter 2, 3 and 4 took actual DAS use experience of the participants into account. As the role of DAS use experience on driver safety-related attitudes and other motivational variables could be underlined in the studies, this can be seen as clear strength. It is highly recommended to take the actual DAS use experience in future studies that investigate the effects of DAS on driver behaviour into account in order to control its influence on effects. However, it is still possible that actual DAS use experience is determined by variables that were not considered in this study and that could not be controlled. Thus, the interpretation of the results is also two-folded. For future research, it would be interesting to perform a study that controls variables that might determine actual DAS use experience. The participants within this study were heterogeneous. In order to exclude potential determining unknown variables, a suggestion would be to investigate a more homogeneous group such as employees of a company (with different affiliation time) that drive DAS-equipped cars. Additionally, DAS and its characteristics are quite different. Additionally, for future studies it would be of interest to divide the variable DAS use experience in sub-groups such as 'experienced with using information systems', 'experienced with using systems that intervene' etc.

In Chapter 5 the effect of using a navigation system as route guidance in comparison to using a printed route instruction was investigated. The participants were experienced navigation system users. It can be assumed that the participants were adapted to use this type of guidance. For future research it would be interesting to add a group of non-experienced navigation system users to be able to exclude a potential "unlearn (using a printed instruction) effect" as reason for any differences found in glance behaviour between the two navigation conditions.

The qualitative analysis introduced in Chapter 5 led to the conclusion that drivers have different motives in response to navigation system use in comparison to when they use a printed route instruction. This interpretation was based on the qualitative analysis of driver glance behaviour. However, it has to be underlined that this was concluded based on the glanced analysis but not on discussions or interviews with the participants. For future research it is recommended to involve the participants actively in the analysis and to ask them why they behaved the way they did. Additionally, a 'side-effect' was found when drivers were using the navigation system for route guidance they tended to stop more often when pedestrians intended to cross zebra crossing than when they were using the printed route instruction. The number of situations of pedestrians who intended to cross the zebra crossing was very limited. It is recommended to test the derived hypothesis that navigation system users are more aware of potential hazards than those drivers who use a printed route instruction in more detail.

Creswell and Plano Clark (2011) highlighted that the applied methodological approach has to be appropriate for the respective research issue. Creswell and Plano Clark became pioneers of applying and underlining the advantages of the mixed method approach in human sciences. Accordingly, it is highly recommended to select the methodological approach carefully and conscientiously based on the research issue. It has to be noted that it is important to consider the potential limitations when either quantitative or qualitative methods are applied.

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8. Annex: Overview of studies that investigated driver behaviour

Table 14. *Overview of studies that investigated driver behaviour.*

Reference	Topic	Approach: Qualitative	Approach: Quantitative
Scott-Parker, B., Watson, B., King, M.J. & Hyde, M.K. (2015). "I would have lost the respect of my friends and family if they knew I had bent the road rules": Parents, peers, and the perilous behaviour of young drivers. *Transportation Research Part F*, *28*, 1-13.	Social influence on young driver risky driving behaviour	small group interviews	surveys
Helman, S. & Reed, N. (2015) Validation of the driver behaviour questionnaire using behavioural data from an instrumented vehicle and high-fidelity driving simulaotor. *Accident Analysis and Prevention, 75*, 245-251.	Investigation to whether the DBQ is a valid measure of observed behaviour in real driving and simulated driving		questionnaire
Rowe, R., Roman, G.D., McKenna, F.P., Barker, E. & Poulter, D. (2015). Measuring errors and violoations on the road: A bifactor modeling approach to the Driver Behavior Questionnaire. *Accident Analysis and Prevention, 74*,.118-125.	A bi-factor model approach was used to investigate issues that are not covered by the DBQ		questionnaire
Kaber, D., Pankok, C.J., Corbett, B., Ma, W., Hummer, J. & Rasdorf, W. (2015). Driver behavior in use of guide and logo signs under distraction and complex roadway conditions. *Applied Ergonomics*,*47*, 99-106.	Investigation of the impact of signage types on driver behaviour		visual behavior and performance recorded, simulator driving study
Haque, M. & Washington, S. (2015). The impact of mobile phone distraction on the braking behaviour of young drivers: A hazard-based duration model. *Transportation Research Part C*, 50, 13-27.	Comparison of the braking profiles of drivers distracted by the mobile phone to non-distracted drivers		recording of specific factors, driving simulator study
Wang, J., Li, K. & Lu, X.-Y. (2014). Effect of human factors on driver behavior. In Y. Chen & L. Lingxi (Eds.), *Advances in intelligent vehicles* (pp. 111-157). Elsevier. ISBN: 978-0-12-397199-9.	The analysis of the differences between subjective evaluation and objective experiments in terms of the effects of human factors on driver behaviour		analaysis of various parameters

Reference	Topic	Approach: Qualitative	Approach: Quantitative
Wang, J., Li, K. & Lu, X.-Y. (2014). Comparative analysis and modeling of driver behavior characteristics. In Y. Chen & L. Lingxi (Eds.), *Advances in intelligent vehilces* (pp. 159-198). Elsevier. ISBN: 978-0-12-397199-9.	The comparison of driver behaviour characteristics influenced by various factors		analysis of test-drives
Rolim, C., Baptista, P., Duarte, G., Farias, T. & Shiftan, Y. (2014). Quantification of the impacts of eco-driving training and real-time feedback on urban buses driver's behaviour. *Transportation Research Procedia*, *3*, 70-79.	Assessment of the impacts of on-board devices that provide real-time feedback and eco driving training on bus drivers' behaviour		assessment of data collected, quantification of the impact of feedback
Bella, F. (2014). Effects of combined curves on driver's speed behavior: driving simulator study. *Transportation Research Procedia*, *3*, 100-108.	Assessment of a simulator study aimed at evaluating the effects on the driver's speed behaviour		driver simulator study
Bastos Silva, A., Santos, S., Vasconcelos, L., Seco, A. & Pedro Silva, J. (2014). Driving behavior characterization in roundabout crossings. *Transportation Research Procedia, 3*, 80-89.	Characterization of driver behaviour while crossing various roundabouts		perfomance of test drives
Wallen Warner, H. & Aberg, L. (2014). Drivers' tendency to commit different aberrant driving behaviours in comparison with their perception of how often other drivers commit the same behaviours. *Transportation Research Part F, 27*, 37-43.	The analysis of the difference between drivers' self-reported tendency to commit different aberrant driving behaviours in comparison with their perception of how often other drivers commit the same behaviours measured by the DBQ		questionnaire including questions on the DBQ
Gras, M.-E., Font-Mayolas, S., Planes, M. & Sullman, M.J.M. (2014). The impact of the penalty point system on the behaviour of young drivers and passengers in Spain. *Safety Science, 70*, 270-275.	Investigation of self-reported changes in the behaviour of young drivers and passengers following the implementation of the PPS in Spain		surveys
Ellison, A.B., Bliemer, M.C.J. & Greaves, S.P. (2015). Evaluating changes in driver behaviour: A risk profiling approach. *Accident Analysis and Prevention, 75*, 298-309.	Application of Temporal and Spatial Identifiers used to control for the road environment and Driver Behaviour Profiles		collection of data

Reference		Approach	
	Topic	Qualitative	Quantitative
Brewster, S.E., Elliott, M.A. & Kelly, S.W. (2015). Evidence that implementation intentions reduce drivers' speeding behavior: Testing a new intervention to change driver behavior. *Accident Analysis and Prevention, 74*, 229-242.	Test of the effects of implementation intentions in the context of drivers' speeding behaviour		questionnaire
Tey, L.-S., Zhu, S., Ferreira, L. & Wallis, G. (2014). Microsimulation modelling of driver behaviour towards alternative warning devices at railway level crossings. *Accident Analysis and Prevention, 71*, 177-182.	Comparison of driver behaviour towards two novel and two conventional warning devices at railway crossings		driver simulator study
Lavrenz, S.M., Pyrialakou, V.D. & Gkritza, K. (2014). Modeling driver behavior in dilemma zones: A discrete/continuous formulation with selectivity bias corrections. *Analytic Methods in Accident Research*, *3-4*, 44-55.	Investigation of the effect of cell phone technology and calling behaviour on decisions whether to go through an intersection at a yellow light		driver simulator study
Newnam, S., Mamo, W.G. & Tulu, G.S. (2014). Exploring differences in driving behaviour across age and years of education of taxi drivers in Addis Ababa, Ethiopia. *Safety Science*, *68*, 1-5.	Exploration of the differences in self-reported driving behaviour across age groups and years of education		occupational driver behaviour questionnaire
Oz, B., Ozkan, T. & Lajunen, T. (2014). Trip-focused organizational safety climate: Investigating the relationship with errors, violations and positive driver behaviours in professional driving. *Transportation Reseach Part F, 26*, 361-369.	Investigation of the relationship between trip-focused organizational safety climate and driver behaviours in professional driving.		Driver behaviour questionnaire, postive driver behaviours scale,
Vaa, T. (2014). From Gibson and Crooks to Damasio: The role of psychology in the development of driver behaviour models. *Transportation Research Part F,* 25, 112-119.	Presentation of a brief history and perspective of behavioural model development in traffic psychology		
McNally, B. & Bradley, L.B. (2014). Re-conceptualising the reckless driving behaviour of young drivers. *Accident Analysis and Prevention, 70*, 245-257.	Aim to re-conceptualise reckless driving behaviour and to contribute to existing road safety literature		on-line self-report questionnaire
Cordazzo, S.T.D., Scialfa, C.T., Bubric, K. & Ross, R.J. (2014). The Driver Behaviour Questionnaire: A North American analysis. *Journal of Safety Research, 50*, 99-107.	Adaption of the DBQ for the North American driving population		questionnaire

Reference		Approach	
	Topic	Qualitative	Quantitative
Johnson, M., Oxley, J., Newstead, S. & Charlton, J. (2014). Safety in numbers? Investigating Australian driver behaviour, knowledge and attitudes towards cyclists. *Accident Analysis and Prevention, 70*, 148-154.	An online survey was conducted to investigate a range of driver and cyclist behaviours on the road		online survey
Farah, H., Musicant, O., Shimshoni, Y.,Toledo, T., Grimberg, E., Omer, H., & Lotan, T. (2014) Can providing feedback on driving behavior and training on parental vigilant care affect male teen drivers and their parents?. *Accident Analysis and Prevention, 69*, 62-70.	Investigation of the driving behaviour of young novice male drivers during the first years of driving		IVDR system used to track driving trips
Kay, J.J., Savolainen, P.T., Gates, T.J. & Datta, T.K. (2014). Driver behavior during bicycle passing maneuvers in response to a Share the Road sign treatment. *Accident Analysis and Prevention, 70*, 92-99.	The results of a controlled-field evaluation of sign treatment		Four field studies
Merat, N., Jamson, A.H., Lai, F.C.H., Daly, M. & Carsten, O.M.J. (2014). Transition to manual: Driver behaviour when resuming control from a highly automated vehicle. *Transportation Research Part F, 27*, 274-282.	Investigation of driver's ability to resume control from a highly automated vehicle in two conditions		driver simulator study
Thijssen, R., Hofman, T. & Ham, J. (2014). Ecodriving acceptance: An experimental study on anticipation behavior of truck drivers. *Transportation Research Part F, 22*, 249-260.	Research to what extent drivers are willing to improve their anticipation behaviour		test drives
Gueho, L., Granie, M.-A. & Abric, J.-C. (2014). French validation of a new version of the Driver Behavior Questionnaire (DBQ) for drivers of all ages and levels of experiences. *Accident Analysis and Prevention, 63*, pp. 41-48.	Aim to validate a new version of DBQ on a sample of French drivers in order to gain better understanding of different driver behaviour		questionnaire
Farah, H. & Koutsopoulos, H.N. (2014). Do cooperative systems make drivers' car-following behaviors safer?. *Transportation Research Part C, 41*, 61-72.	Investigation of the impact of an infrastructure-to-vehicle (I2V) co-operative system on drivers' car-following behaviour		test drives
Martinussen, L.M., Moller, M. & Prato, C.G. (2014). Assessing the relationship between the Driver Behavior Questionnaire and the Driver Skill Inventory: Revealing sub-groups of drivers. *Transportation Research Part F, 26*, 82-91.	Exploration of DBQ and DSI data with cluster analysis to identify sub-groups of drivers that potentially present different levels of danger in traffic		questionnaire

Reference	Topic	Approach: Qualitative	Approach: Quantitative
de Ona, J., de Ona, R., Eboli, L., Forciniti, C. & Mazzulla, G. (2014). How to identify the key factors that affect driver perception of accident risk. A comparison between Italian and Spanish driver behavior. *Accident Analysis and Prevention, 73*, 225-235.	Investigation of driver behaviour and attitudes while driving and specific focus on different methods for identifying factors that affect the driver's perception		surveys
Kuo, J., Koppel, S., Charlton, J.L. & Rudin-Brown, C.M. (2014). Computer vision and driver distraction: Developing a behaviour-flagging protocol for naturalistic driving data. *Accident Analysis and Prevention, 72*, 177-183.	Computer vision solution was developed and tested to improve the accuracy and speed of processing NDS video data for the purpose of quantifying the occuring of driver distraction.		test sets
Zhong, S., Zhou, L., Ma, S., Jia, N. & Wang, X. (2014). Guidance compliance behaviors of drivers under different information release modes on VMS. *Information Sciences, 289*, 117-132.	Based on SOAR, the cognitive process of drivers' guidance compliance behaviour is described. Simulation experiments explore the properties of two guidance information release modes		questionnaire, simulator study
Zhou, L., Zhong, S., Ma, S. & Jia, N. (2014). Prospect theory based estimation of drivers' risk attitudes in route choice behaviors. *Accident Analysis and Prevention, 73*, 1-11.	Prospect theory application to describe drivers' route choice behaviour under Variable Message Signs (VMS)		questionnaire, simulator study
Oz, B., Ozkan, T. & Lajunen, T. (2013). An investigation of professional drivers: Organizational safety climate, driver behaviours and performance. *Transportation Research Part F, 16*, 81-91.	Investigation of the relationship among organizational safety climate, driver behaviours and performance of Turkish professional drivers		Driver behaviour questionnaire, driver skills inventory,
Capaldo, F.S. & Biggiero, L. (2013). Experimental survey and modeling for the driver behavior in vehicle platoons. *Procedia - Social and Behavioural Sciences, 138*, 279-288.	The study of driver behaviour in vehicle platoons starting from traffic lights		surveys
Stillwater, T. & Kurani, K.S. (2013). Drivers discuss ecodriving feedback: Goal setting, framing, and anchoring motivate new behaviors. *Transportation Research Part F*, 85-96.	A driver feedback experiment was conducted	interviews	questionnaire

Reference	Topic	Approach: Qualitative	Approach: Quantitative
Rosey, F. & Auberlet, J.M. (2014). Driving simulator configuration impacts drivers' behavior and control performance: An example with studies of a rural intersection. *Transportation Research Part F, 19,* 99-111.	Two driver simulator studies conducted to evaluate the impact of a message posted on a variable sign		simulator study, questionnaire
de Ona, J., de Ona, R., Eboli, L., Forcinit, C., Machado, J.L. & Mazzulla, G. (2014). Analysing the relationship among accident severity, drivers' behaviour and their socio-economic characteristics in different territorial contexts. *Procedia - Social and Behavioural Sciences, 160*, 74-83.	The investigation of the relationship among road accident severity, users' driving behaviour and socio-economic characteristics by comparing data from two urban areas with different characteristics	face-to-face interviews	questionnaire
da Silva, F.P., Santos, J.A. & Meireles, A. (2014). Road accident: driver behaviour, learning and driving task. *Procedia - Social and Behavioural Sciences, 162*, 300-309.	Assessment of learner and experienced driver performances		video-recording
Martinussen, L.M., Hakamies-Blomqvist, L., Moller, M., Ozkan, T. & Lajunen, T. (2013). Age, gender, mileage and the DBQ: The validity of the Driver Behavior Questionnaire in different target groups. *Accident Analysis and Prevention, 52*, 228-236.	Illustration that the original DBQ and the Danish four-factor DBQ are relatively stable across subgroups indicating factorial validity and reliability of the DBQ		questionnaire
Scott-Parker, B., Watson, B., King, M.J. & Hyde, M.K. (2014). "I drove after drinking alcohol" and other risky driving behaviours reported by young novice drivers. *Accident Analysis and Prevention, 70*, 65-73.	Exploration of the self-reporting compliance of drivers with road rules regarding substance impaired driving and the interrelationships between substance-impaired driving and other risky behaviours		surveys
Chen, C.-F. &, Kao, Y.-L. (2013). The connection between the hassles-burnout relationship, as moderated by coping, and aberrant behaviors and health problems among bus drivers. *Accident Analysis and Prevention, 53*, 105-111.	Investigation of the effects of bus driver burnout on aberrant behaviour and health problems		questionnaire

Reference	Topic	Approach	
		Qualitative	Quantitative
Bachoo, S., Bhagwanjee, A., & Govender, K. (2013). The influence of anger, impulsivity, sensation seeking and driver attitudes on risky driving behavior among post-graduate university students in Durban, South Africa. *Accident Analysis and Prevention, 55*, 67-76.	Exploration of the role of anger, impulsivity, sensation seeking and driver attitudes		questionnaire
Hassan, H.M. &, Abdel-Aty, M.A. (2013). Exploring the safety implications of young drivers' behavior, attitudes and perceptions. *Accident Analysis and Prevention, 50*, 361-370.	Identification and quantification of significant factors associated with young drivers' involvement in at-fault crashes. Investigation of reasons to why young drivers engage in risky driver behaviour		questionnaire
Nakagawa, Y., Park, K. & Kumagai, Y. (2013). Elderly drivers' everyday behavior as a predictor of crash involvement- Questionnaire responses by drivers' family members. *Accident Analysis and Prevention, 50*, 397-404.	Focus on elderly drivers and why drivers are involved in crashes		questionnaire
Simsekoglu, O., Nordfjaern, T., Zavareh, M.F., Hezaveh, A.M., Mamdoohi, A.R. & Rundmo, T. (2013). Risk perceptions, fatalism and driver behaviors in Turekey and Iran. *Safety Science, 59*, 187-192.	Examination of traffic and non-traffic risk-perception, fatalism and driver behaviour in Turkey and Iran		questionnaire
Tey, L.-S., Wallis, G., Cloete, S. & Ferreira, L. (2013). Modelling driver behaviour towards innovative warning devices at railway level crossings. *Accident Analysis and Prevention, 51*, 104-111.	Comparison of driver behaviour towards two novel level warning devices at railway crossings with two conventional warning devices		simulator study
Vardaki, S. & Yannis, G. (2013). Investigating the self-reported behavior of drivers and their attitudes to traffic violations. *Journal of Safety Research, 46*, 1-11.	Investigation of driver self-reported behaviour and attitudes to risky behaviour related to the traffic violations of speeding, drink-driving and cell-phone use using cluster analysis	personal interview for questionnaire completion	questionnaire
Yang, Q., Overton, R., Han, L.D., Yan, Y. & Richards, S.H. (2013). The influence of curbs on driver behaviors in four-lane rural highways-A driving simulator based study. *Accident Analysis and Prevention, 50*, 1289-1297.	Understanding of driver behaviour on rural highways before and after curb installation and different speed limits		questionnaire, simulator study

Reference		Approach	
	Topic	Qualitative	Quantitative
Rhodes, N., Pivik, K. & Sutton, M. (2015). Risky driving among young male drivers: The effects of moods and passengers. *Transportation Research Part F*, 28, 65-76.	Examination of the effects of induced mood and the presence or absence of passengers on risky driving in young male drivers.		questionnaire, simulator study
Scott-Parker, B., Watson, B., King, M.J. & Hyde, M.K. (2014). Young novice drivers and the risky behaviours of parents and friends during the Provisional (intermediate) licence phase: A brief report. *Accident Analysis and Prevention, 69*, 51-55.	The examination of young drivers with Provisional licences and whether their driving behaviour is influenced by their parents' and friends' driving		online survey
Habibovic, A., Tivesten, E., Uchida, N., Bargman, J. & Aust, M.L.(2013). Driver behavior in car-to-pedestrian incidents: An application of the Driving Reliability and Error Analysis Method (DREAM). *Accident Analysis and Prevention, 50*, 554-565.	Analysis of causation of car-to-pedestrian incidents by observation of video recordings		video recordings
Chakrabartya, N. & Guptab, K. (2013). Analysis of driver behaviour and crash characteristics during adverse weather conditions. *Procedia - Social and Behavioural Sciences, 104*, 1048-1057.	Study of visual traits and psychometric behaviour of drivers along with choice of speed, reaction time and driving behaviour during adverse weather under simulated and realistic environment conditions.		simulator study
Jimenez-Parra, B., Rubio, S. & Vicente-Molina, M.-A. (2014). Key drivers in the behavior of potential consumers of remanufactured products: a study on laptops in Spain. *Journal of Cleaner Production, 85*, 488-496.	First approach to determining basic characteristics of the profile of potential consumers in order to most suitably manage their remanufactured products		questionnaire
Hamdar, S.H. & Schorr, J. (2013). Interrupted versus uninterrupted flow: A safety propensity index for driver behavior. *Accident Analysis and Prevention* 55, 22-33.	Development of a quantitative safety propensity index (SPI) that captures the overall propensity of a given surrounding environment to cause unsafe driving.		Data was collected from different sources
Delhomme, P.,Cristea, M. & Paran, F. (2014). Implementation of automatic speed enforcement: Covariation with young drivers' reported speeding behaviour and motivations. *Revue europeenne de psychologie appliquee, 64*, 131-139.	Comparison of young drivers' intentions and beliefs about speeding between the introduction of ASE and its completion via a large survey based on the Theory of Planned Behaviour.		questionnaire

Reference	Approach		
	Topic	**Qualitative**	**Quantitative**
Moller, M. & Haustein, S. (2014). Peer influence on speeding behaviour among male drivers aged 18 and 28. *Accident Analysis and Prevention, 64*, 92-99.	Analysis of the attitudes and behaviours related to traffic violations of male drivers		questionnaire
Foss, R.D. & Goodwin, A.H. (2014). Distracted driver behaviors and distracting conditions among adolescent drivers: findings from a naturalistic driving study. *Journal of Adolescent Health, 54*, S50-S60.	The study of driver distraction in young drivers		Data colection (video, audio, vehicle kinetic information)
Biondi, F., Rossi, R., Gastaldi, M. & Mulatti, C. (2014). Beeping ADAS: Reflexive effect on drivers' behavior. *Transportation Research Part F, 25*, 27-33.	Examination of the early and late effects on lane keeping and speed maintenance produced by both the onset of and prolonged exposure to a continuous beep like those emitted by ADAS		questionnaire
Berthaume, A.L., Romoser, M.R.E. & Collura, J., Ni, D. (2014). Towards a social psychology-based microscopic model of driver behavior and decision-making: modifying Lewin's Field Theory. *Procedia Computer Science, 32*, 816-821.	Employment of filed theory to construct a conceptual framework for a new microscopic model		
Shackel, S.C. & Parkin, J. (2014). Influence of road markings, lane widths and driver behaviour on proximity and speed of vehicles overtaking cyclists. *Accident Analysis and Prevention, 73*, 100-108.	Study builds on previous research and fills in gaps by considering the presence of cycle lanes, different lane widths, different lane markings, vehicle type, vehicle platooning and oncoming traffic		Recordings from ultrasonic detector and cameras
Ross, V., Jongen, E.M.M., Wang, W., Brijs, T., Brijs, K., Ruiter, R.A.C. & Wets, G. (2014). Investigating the influence of working memory capacity when driving behavior is combined with cognitive load: An LCT study of young novice drivers. *Accident Analysis and Prevention, 62*, 377-387.	Investigation of the interaction between verbal VM load and WM capacity on driver performance		simulator study
Shimshoni, Y., Farah, H., Lotan, T., Grimberg, E., Dritter, O., Musicant, O., Toledo, T. & Omer, H. (2015). Effects of parental vigilant care and feedback on novice drier risk. *Journal of Adolescence, 38*, 69-80.	Examination of the effects of parent training in vigilant care and technological feedback on driving risk of novice male drivers		questionnaire

Reference		**Approach**	
	Topic	**Qualitative**	**Quantitative**
Scott-Parker, B., Goode, N. & Salmon, P. (2015). The driver, the road, the rules...and the rest? A systems-based approach to young driver road safety. *Accident Analysis and Prevention, 74*, 297-305.	Argument that for substantial improvements to be made in young driver road safety what has been learned from driver-centric research needs to be integrated into a systems approach		
Pradhan, A.K., Li, K., Bingham, R., Simons-Morton, B.G., Ouimet, M.C. & Shope, J.T. (2014). Peer passenger influences on male adolescent drivers' visual scanning behavior during simulated driving. *Joural of Adolescent Health, 54*, S42-SS49.	Study of simulated driving by young male drivers with male peer passengers		simulator study
Houwing, S. & Twisk, D. (2015). Nothing good ever happens after midnight: Observed exposure and alcohol use during weekend nights among young male drivers carrying passengers in a late licensing country. *Accident Analysis and Prevention, 75*, 61-68.	Examination of the incidence of dangerous trip conditions and risk taking among young male drivers and comparison to a reference group with a low passenger fatality rate		survey
Eilers, M., Mobus, C., Tango, F. & Pietquin, O. (2013). The learning of longitudinal human driving behavior and driver assistance strategies. *Transportation Research Part F*, 21, 295-314.	Presentation of machine-learning alternatives to train assistance systems and estimate probabilistic driver models from human behaviour traces		simulator study
Warner, H. W., Ozkan, T., Lajunen, T. & Tzamalouka, G. (2011). Cross-cultural comparison of drivers' tendency to commit different aberrant driving behaviours. *Transportation Research Part F*, 14, 390-399.	Identification of key items which are rated differently by drivers from Sweden, Finland, Greece and Turkey and to examine how these items relate to drivers' self-reported accident involvement.		questionnaire
Iversen, H. H. & Rundmo, T. (2012). Changes in Norwegian drivers' attitudes towards traffic safety and driver behaviour from 2000 to 2008. *Transportation Research Part F, 15*, 95–100.	exploration of changes in driver behaviour in traffic and attitudes in Norway over the nine-year period from 2000 to 2008		questionnaire
Demir, M. & Çavusoglu, A.(2012). A new driver behavior model to create realistic urban traffic environment. Transportation Research Part F, 15, 289–296.	development and evaluation of a driver behaviour model		simulator study

Eidesstattliche Erklärung

Die vorliegende Arbeit wurde von mir selbstständig verfasst.

Ich habe keine anderen als die angegeben Hilfsmittel verwendet.

Juliane Haupt

Wien, den 02.01.2016

Curriculum Vitae

Personal Details

Name:	Juliane Haupt
Position:	Project Manager Innovation Aerospace
Affiliation:	Berlin Partner für Wirtschaft & Technologie
Date of birth:	March 21st, 1980
Nationality:	German
Office Address:	Fasanenstr. 85, 10623 Berlin
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Scientific Education

September 2010 – June 2016	Doctoral programme in Psychology at Chemnitz University of Technology; Thesis: "Be motivated to pay attention! How driver assistance system use experience influences driver motivation to be attentive"
February 2010 – January 2013	Marie Curie Initial Training Network 'ADAPTATION'
October 2004 – July 2009	Studies in Psychology at Chemnitz University of Technology 15th July, 2009 Graduation as 'Diplom Psychologin' with "very good" Diploma Thesis: "How different levels of automation in lateral control and demands on hazard perception influence drivers' eye movements: The standard deviation of gaze a measure for hazard perception"

Professional Experience in Science

June 2016 –	**Project Manager Innovation Aerospace at Berlin Partner für Wirtschaft & Technologie**
February 2010 – May 2016	**Scientific Researcher/Project Manager Mobility** at FACTUM – work in several national (e.g. OPERMO, GoGreen, MultiMotiv) and international (e.g. AVENUE; ADAPTATION; INTERACTION, Guide2Wear) research projects
March 2012- May 2012	**Scientific Researcher** at SWOV, Leiden (the Netherlands) – Collaboration in a study investigating drivers' cognitive processes
September 2009 – January 2010	**Research Assistant** at Chemnitz University of Technology - Chair cognitive and engineering psychology Prof. Dr. Josef Krems, Chemnitz (Germany)- Assistance within the project „Methodological Aspects of Naturalistic Driving Studies and Field Operational Tests“
October 2006 – August 2009	**Student assistant** at Chemnitz University of Technology - Chair cognitive and engineering psychology Prof. Dr. Josef Krems, Chemnitz (Germany) - Assistance within the project "Drivers' reliance on lane keeping assistance systems as a function of the level of assistance" – dissertation-project of Dr. Anke Popken
April 2007- July 2008	**Tutor research methods and evaluation** at Chemnitz University of Technology - Chair research methods and evaluation Prof. Dr. Peter Sedlmeier, Chemnitz (Germany)

Awards & Fellowship

2010-2013	**Marie Curie Research Fellowship of Excellence Scholarship , European Union 7th Framework Programme**
2011	**Poster Award,** **Best poster** for “Wie ein Fahrerassistenzsystem über die Zeit die subjektiv wahrgenommene Sicherheit beeinflusst “, 7. Gemeinsames Symposium der DGVP und DGVM, Potsdam, 9. und 10. September 2011
2009	**Human-Machine-Award (1st place)** For “Der energiesparende Innenraum”, Tag der einfachen Produkte, Chemnitz, 12. November 2009

Publications

Journal Paper

- Haupt, J., Kahvedžić-Seljubac, A., Risser, R.(2015). The role of driver assistance experience, system functionality, gender, age and sensation seeking in attitudes towards the safety of driver assistance systems. *IET Journal of Engineering, 9*(7), 716-726. doi: 10.1049/iet-its.2014.0199

- Haupt, J., van Nes, N., Risser, R. (2015). Look where you have to go! A field study comparing looking behaviour at urban intersections using a navigation system or a printed route instruction. *Transportation Research Part F, 34*, 122-140. doi:10.1016/j.trf.2015.07.018.

Book Chapter

- Haupt, J.(2015). ADAPTATION: Ein interdisziplinärer und systematischer Ansatz FahrerInnenverhalten in Abhängigkeit der Nutzung von Fahrerassistenzsystemen zu untersuche. In. C. Chaloupka-Risser (Eds.). *in motion – Humanwissenschaftliche Beitrage zur Sicherheit und Ökologie des Verkehrs 5* (pp. 48-58). Salzburg: INFAR – Institut für Nachschulung und Fahrer-Rehabilitation. ISBN: 978-3-200-04406-7

- Dotzauer, M., Berthon-Donk, V., Beggiato, M., Haupt, J. & Piccinini, G. (2014). Methods to assess behavioural adaptation over time as a result of ADAS use. In A. Stevens, C. Brusque, & J. Krems (Eds). *Driver adaptation to information and assistance systems* (pp. 35-56). IET published book. ISBN: 978-1-84919-639-0; E-ISBN: 978-1-84919-640-6

- Haupt, J. & Risser, R. (2014). Motivational factors when investigating ADAS impacts on driver behaviour. In A. Stevens, C. Brusque, & J. Krems (Eds). *Driver adaptation to information and assistance systems* (pp. 145-172). IET published book. ISBN: 978-1-84919-639-0; E-ISBN: 978-1-84919-640-6

- Haupt, J. & Risser, R. (2011). Different types of drivers' social problems. In Y. Barnard, Ralf Risser & Josef Krems (Eds.), *The safety of intelligent driver support systems* (pp.137-148). London: Ashgate publishers, 2011

- Lietz, H., Petzoldt, T., Henning, M., Haupt, J., Wanielik, G., Krems, J.F., Mosebach, H., Schomerus, J., Baumann, M., Noyer, U.(2011). Methodische und technische Aspekte einer Naturalistic Driving Study. *FAT-Schriftenreihe 229*. Berlin: Verband der Automobilindustrie (VDA).

- Ausserer, K., Haupt, J. & Risser, R. (2009). Evaluation of a child restraint campaign in Austria, in: Forward, S. & Kazemi, A. (Eds.). *A theoretical approach to assess road safety campaigns* (pp. 137–192). Belgian Road Safety Institute: Brussels

Conferences

- Haupt, J. & van Nes, N. (2014). Der Einfluss von Gefahrenantizipierung und Absichten auf das Fahrerverhalten: Eine Feldstudie mit verschiedenen Navigationsmodi und Kreuzungssituationen. *Conference Proceedings of the 9th Joint Symposium of the German Company of Traffic Psychology and the German Company of Traffic "Körperliche und geistige Gesundheit und Verkehrssicherheit"*. Kirschbaum Verlag: Bonn

- Haupt, J. & van Nes, N. (2014). Combining qualitative van quantitative methods when analysing driver behaviour. *Poster presentation at the 27th International Co-operation on Theories and Concepts in Traffic Safety (ICTCT).*

- Haupt, J., Pokriefke, E.(2013).The human point of view on risk factors: Irrationality in perception. *Presentation held at the 26th International Co-operation on Theories and Concepts in Traffic Safety (ICTCT)* conference. Maribor, October 24-25, 2013.

- Risser, R. & Haupt, J.(2013). ADAPTATION: An interdisciplinary and systemic approach to investigate drivers response to ADAS use. *Presentation held at the 26th International Co-operation on Theories and Concepts in Traffic Safety (ICTCT) conference*. Maribor, October 24-25, 2013.

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"You picked it up, you'll carry."

(Daniel Bell, *1983)