Towards an effective measurement of driver distraction in real life and in low cost simulation

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Contents

Acknowledgements 5

Figures 6

Tables 8

1. Background and Motivation 9

2. Assessment of Driver Distraction 11
    - 2.1. Definitions: Driver distraction vs. Driver secondary task 11
    - 2.2. Driving: Interacting with the environment by using a complex tool 12
    - 2.3. Methods for assessing frequency of driver secondary tasks and performance impairment due to them 16
    - 2.4. Research questions 30

3. Frequency and types of driver secondary tasks in Germany 32
    - 3.1. Method 32
    - 3.2. Results 33
    - 3.3. Discussion 37

4. Examinations of the Lane Change Task 42
    - 4.1. Practice effects on LCT baseline performance 42
    - 4.2. Alcohol effects on LCT performance: an attempt to find an external criterion 49
    - 4.3. Conclusions and implications for LCT use as a tool of distraction measurement 55

5. Conclusions 59
    - 5.1. Achievements 59
    - 5.2. Implications 59
    - 5.3. Limitations 61
    - 5.4. Further Research Needs 61

6. References 63

7. Publications 70

Curriculum vitae 102

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Figures

Figure 1: Driving task model after Donges (1999) 13

Figure 2: Driving tasks and associated levels of action regulation (Vollrath & Schießl, 2004, p. 344) 13

Figure 3: Distraction results from breakdowns of multilevel control that is shared between telematic interactions and driving. (Lee & Strayer, 2004, p. 585) 15

Figure 4: Lane Change Task: “Change your lane immediately as you recognize the next sign.” With the symbols shown, the driver was to change to the right lane (arrow). (ISO 26022:2010, p.5) 24

Figure 5: Driving performance measures in the LCT. (Huemer & Vollrath, 2010b, p.1985) 25

Figure 6: Crash risk under the influence of alcohol as a function of blood alcohol concentration (BAC) in the Grand Rapids Study of 1964 by Borkenstein (1975) and the German Study of 1994 by Krüger et al. (1995). The given numbers are Odds Ratios. (Vollrath & Krems, 2011, p.135) 26

Figure 7: General objective impairment (regarding all performance categories) on the right side (Schnabel et al., 2010, p.71) and impairment of tracking on the left (Schnabel, 2011, p.94). Given are percentages of significant findings per BAC group. 27

Figure 8: Performance in the sustained wakefulness condition expressed as mean relative performance and the percentage blood alcohol concentration equivalent. Error bars ± s.e.m. (Dawson & Reid, 1997, p.23) 28

Figure 9: Mean (95% CI) SDLP difference from placebo after single doses of MDMA during the road tracking test in the evening and in the morning after a night of sleep loss. (* = equivalence to BAC 0.5% shown, upper bound of the 95% CI is above the non-inferiority margin of 2.4 cm) (Ramaekers, 2011, p.5) 29

Figure 10: Frequency and Duration of secondary task occupation in driver groups. For each driver group, mean number of tasks (white bars, whiskers represent SD) and mean duration of occupation with tasks (black bars, whiskers represent SD) is given. (Huemer & Vollrath, 2011a, p.1708) 34

Figure 11: Frequency and Duration of specific secondary task types. Frequency (white bars) and driving time (black bars) of the specific secondary task types are given for all drivers. Frequency is given relative to sample, duration relative to driving time. (Huemer & Vollrath, 2011a, p.1708) 35

Figure 12: Subjective evaluations of secondary task distraction and danger. Each driver was asked to rate one of his reported task types, considering general danger, actual distraction and actual danger of task. The number of drivers rating each task is given in the second column. (Huemer & Vollrath, 2011a, p.1710) 37

Figure 13: Overall Mean deviations (on the left; Huemer & Vollrath, 2011c) and SDLP while lane keeping only (on the right) in the LCT over time 44

Figure 14: Overall Mean deviations (on the left; Huemer & Vollrath, 2011c) and SDLP while lane keeping only (on the right) in the LCT 45
Figure 15: SuRT performance for the different training regimes over time (Huemer & Vollrath, 2011c).. 46
Figure 16: Overall Mean deviations (on the left; Huemer & Vollrath, 2011c) and SDLP while lane keeping only (on the right) in the LCT 46
Figure 17: Mean deviations in the CTT performance for the different training regimes over time (Huemer & Vollrath, 2011c).. 47
Figure 18: Mean deviation (± SD) in LCT for alcohol and placebo (Huemer &Vollrath, 2010b, p.1986) 50
Figure 19: Effects on mean deviation and SDLP during lane keeping (Huemer &Vollrath, 2010b, p.1986) 51
Figure 20: Differences to baseline in SDLP in relation to individual peak BAC (Huemer &Vollrath, 2010b, p.1987).. 51

Tables

Table 1: Secondary task types in literature. Secondary tasks are grouped after a complemented nomenclature first found in Stutts et al. (2001). (Huemer & Vollrath, 2011b, p. 1704) 18
Table 2: Overview of the frequency of different types of secondary tasks as found in the different study types. Minimum and maximum frequency found for the different study types are given to show the large range of results. (Huemer & Vollrath, 2011b, p. 1705) 19
Table 3: Driver characteristics (Huemer & Vollrath, 2011a, p.1708) 33

1. Background and Motivation

Driver distraction became one of the most prominent topics in traffic research when drivers started to use their now widely accessible mobile phones while driving at the beginning of the millennium. The increasing use of non-driving related technologies in vehicles has drawn attention to safety relevant aspects of driving beside those of passive and developing active safety features of the vehicle itself.

Some consequences emerged from this development. At first, most countries, one after another banned the use of hand-held mobile phone use while driving; in Europe only Sweden and Albania do not have such legislation (Engström, 2011). Secondly, research programs were started on driver distractions and the effects of mostly new in-vehicle technology devices on crash causation were examined. Research on this topic is two-fold. On the one hand, governments and safety initiatives are interested in the magnitude of driver distractions found in traffic and in its safety effects on the traffic system. They are also interested in reducing harm on society and thus want to know what kind of distractions lead to what kind of harm and how to reduce these effects. On the other hand, vehicle manufacturers are interested in the effects of special systems they want to introduce in their products as they need to show that these system can be used while driving without negative effects on traffic safety. Both lines of research use different methods to examine the field of driver distractions as well as in these lines methods and data are diverse.

To answer the questions on magnitude and severity of driver distractions impact on traffic safety it has to be known *what kind of* possibly distracting activities are done in traffic, *how often* they are found and to *what extent* they have impact on traffic safety. Thus, at first it is needed to define activities to be examined. In a second step the frequencies of these activities in driving need to be gathered for normal, accident-free driving as well as for crashes to be finally able to estimate the impact of special activities by comparing these data. In this line of research data sets need to be large as questions are related to the driving population in general. This requires large effort and thus, only few studies have been conducted.

A literature review on driver distraction was performed as a first step of the present work, showing that driver distraction prevalence is found to be high in international studies (see chapter 2.3.2). Crash involvement as well as crash risk was here found to be high in some data, too. The analysis of the literature also revealed large differences between studies that may on the one hand be due to different definitions and data acquisition methods but on the other hand also may be due to cultural differences leading to different driving behavior. Unfortunately for Germany there is no data available on distraction involvement in crashes nor does data exist on the frequency of distractions in driving in general. Thus, for estimating the possible problem of driver distractions with regard to traffic safety for Germany, an attempt to estimate the prevalence of distracting activities had to be developed. On the basis of the reviewed literature on driver distraction, the scope of the problem was defined. As a second step, an interview method was developed to estimate drivers' activities in a resource effective way. Results of the interview study (presented in chapter 3) demonstrate that distraction is a major problem in Germany and will probably even increase in relevance as more and more drivers will have vehicles with modern devices to be used while driving. These topics are addressed in the first two papers submitted for the dissertation (Huemer, 2010a; Huemer, 2011b).

The second line of work mentioned above, deals with the evaluation of specific tasks. Here, manufacturers of devices that may be used while driving need to know if their device can be handled safely while driving. As the principles underlying driver distraction are not yet fully understood (see chapter 2 for theoretical background) methods are developed for standardized measurement of the distracting potential posed by tasks and devices. Here, different attempts are found, some of them leading to ISO-certified international norms as the Lane Change Task (LCT, Mattes, 2003; Mattes & Hallén, 2009; ISO 26022:2010) and the Occlusion method (ISO/DIS 16673.2, 2005). Those tests have to meet certain criteria to ensure that they are evaluating relevant features of tasks and users' performance and that they do this in a reliable manner. Although now certified, for the LCT some questions have not yet been answered. On the one hand, different laboratories using the LCT get large differences in baseline driving data in their test samples, thus questioning the reliability of the procedure. As practice has large influence on performance, practice effects on LCT performance have to be examined and guidelines for training need to be developed. This was done for the present work in three studies which are presented in a paper submitted for the dissertation (Huemer & Vollrath, 2011c). On the other hand, no criterion has yet been developed to be able to discriminate *safe tasks* from *unsafe tasks* by using the LCT performance measure only. Therefore a study has been conducted for finding such a criterion. Here, alcohol effects on LCT performance were examined. Aim of the study was to find an LCT performance equivalent to the legal limit of alcohol while driving for setting this performance as criterion. This experiment was also published as a part of the dissertation (Huemer & Vollrath, 2010b). The LCT studies are found in detail in chapter 4.

Overall, the present work contributes to understanding the problem of driver distraction and its' hazardousness in Germany as well as contributing to help to reduce this hazardousness by developing methods to decide for better human machine interfaces (HMI) that prevent distraction. For this it is essential to know how distracting activities have an impact on driving and what kind of distractions pose safety related problems. The challenges in the assessment of both, the problematic tasks as well as their mechanism in impact on driving, are discussed in the following chapter.

2. Assessment of Driver Distraction

For the determination of driver distractions' impact on traffic safety, two kinds of information have to be gathered. On the one hand one needs to know to what extent specific distractions impair drivers' ability of safe driving. This means that for any task under suspicion to be hazardous its hazardousness needs to be quantified. For example, if it is stated that driving while using the telephone is unsafe this statement should be based on data showing that drivers who use their telephone while driving are x-times more accident prone than those who don't. At best, it is known which specific part of telephone use (dialing, talking, listening, thinking etc.) has which impact. Therefore, the impact fist needs to be quantified. If possible, this impact would also be able to be described in a functional way, telling that, e.g. dialing needs visual and manual control which is then not directed to the street and drivers thus are not able to detect relevant stimuli and / or cannot react in a proper way and for this causing mostly rear-end crashes. On the other hand, one has to know which drivers are distracted while driving and how often this is the case for these special sources of distraction. This part of the picture is essential for a comprehensive development of countermeasures. It may be, e.g. well known that dialing while driving is extremely risky, but it would not help to decrease crash rates if this task would only be done by five drivers per year on the whole world. On the other hand, some tasks found to be less risky may become the major problem for safety if they are done by all drivers. Both types of information (special impairment by one task and its prevalence) have to be combined for developing adequate countermeasures. Thus, in the present work, both aspects are addressed.

In the following terms and definitions connected to *driver distraction* are discussed briefly as different understandings of the term's definitions are found and used in the scientific community. After dividing the 'distracting activity' from the resulting 'impairment in driving performance', opportunities to measure both of them are discussed as well as needs and attempts of combining them to get a comprehensive picture of the field.

2.1. Definitions: Driver distraction vs. Driver secondary task

To estimate the possible impact of secondary task occupation on driving behavior or even driving safety (what most authors mean when talking about driver distraction), the terms have to be defined and set into relation. Definitions of the term *driver distraction* differ between scientists and are point of discussion in recent literature (see Regan, Hallett & Gordon, 2011). Most researchers (e.g. Ranney, 2008; Trezise et al., 2006; Pettitt et al., 2005) include three aspects of a situation in their definitions of distraction. These have been integrated in a definition by the Australian Road Safety Board (Trezise et al., 2006): "Driver distraction is the voluntary or involuntary diversion of attention from the primary driving tasks not related to impairment (from alcohol, drugs, fatigue, or a medical condition) where the diversion occurs because the driver is performing an additional task (or tasks) and temporarily focusing on an object, event, or person not related to the primary driving tasks. The diversion reduces a driver's situational awareness, decision making, and/or performance resulting, in some instances, in a collision or near-miss or corrective action by the driver and/or other road user" (cited after Ranney, 2008, p. 3). All these definitions of driver distraction include performance degradation in the driving task.

As this is kind of a circular definition (*distraction is everything that impairs drivers*), in the following both parts will be split up in the following two parts of this work. Since it is not useful to estimate the prevalence of possibly impairing but unknown activities in driving, the following work will use the term *driver secondary task* for all activities meeting the first and second criterion of the definition of driver distraction but unknown, if the third criterion is met. When evaluating existing tasks' effects on driving performance, the term *performance impairment* will be used. Evaluation issues for specific tasks are presented in the second part of the present work. Before going deeper in the methods for measuring prevalence and impairment magnitude, some relevant psychological models of driving and *driver distraction* will be presented in the following chapter, as they are the framework of the examinations presented afterwards.

2.2. Driving: Interacting with the environment by using a complex tool

The act of driving a vehicle is mostly found to be described in the framework of controlling a dynamic process. Bellet, Bailly-Asuni, Mayenobe and Banet (2009, p.1207), for example, state: "Car driving can therefore be defined as activity of regulating and maintaining the status of the dynamic process (i.e. the driving situation) within the limits of acceptable and safe changes. […] Regulatory models of driving have been developed mainly by two professions: firstly as regulatory models by engineers and secondly within a psychological action regulation framework by psychologists."

The first models of the driving task came from the engineering perspective as engineers were the first professionals forced to think about human factors in improving their products as in military, nuclear, and aviation technologies human failures became the prominent "causes" for system breakdown. The main engineering models exist from Bernotat (1970) and Michon (1985) respectively. Both models describe driving as a regulatory process within three levels. Michon's (1985) description is based on the time frame of action within a level mainly. In the shortest time frame tasks like steering or braking and accelerating are done, all completed within seconds. This level is called the operational level. In the tactical level, driving maneuvers like overtaking are mostly completed within seconds as well. Higher order aims in driving as plans about where to drive or when to arrive are comprised at the strategic level. Decisions here are made within minutes Bernotat (1970) defines three levels as well which are called navigation, steering and stabilization. Within all these levels, the vehicle has to be controlled in two translator dimensions as there are the longitudinal control and the transverse control. Donges (1999) integrated information about frequency of task and cognitive demand in this model. According to this, driving tasks at the navigational level need more cognitive resources but are less frequent in driving compared to stabilization tasks, which need much less cognitive effort (see Figure 1).

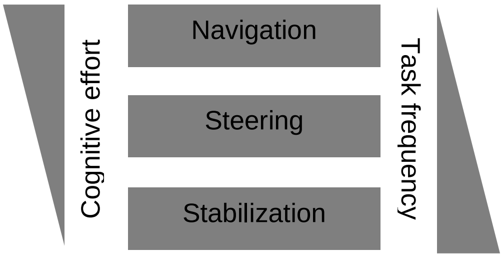


Figure 1: Driving task model after Donges (1999)

A more driver related model of the driving task is found in Rasmussen (1986). In this model of information processing, actions are described also within three levels. They are differentiated by drivers' familiarity with the task, substituting the *effort* in Dongens' model by *familiarity*. New tasks are carried out on a knowledge-based level of regulation, almost no abstraction in representation is found and mental models of these tasks are almost not elaborated. If a person fails to complete a task at this level of regulation, the cause of failure is to be found in erroneous thoughts about facts or in limited rationality. On the rule-based level of regulation, more elaborated models exist about the task and working-memory representation is more complex and more abstract. Actions are regulated by if-then-rules, representing input conditions and associated actions. Failure in this level is mostly to be explained by confused input conditions. At the most abstract level of task representation, tasks are carried out on a skill-based level. This means, execution of tasks is no longer conscious. Failures within this level are, in this model, caused by stereotyped actions carried out while not recognizing changes in the environment that contradict these actions. His model is in accordance with some psychological models of action regulation (e.g. Hacker, 1998; 2005; Frese & Zapf, 1994) and can thus be linked to psychological models of information processing. Vollrath und Schießl (2004) assigned Rasmussen's (1986) levels of action regulation to the driving task levels of Michon (see Figure 2), stating that most stabilization tasks are carried out at the skill-based level, most maneuvers are regulated rule-based and that navigation tasks are carried out based on drivers knowledge.

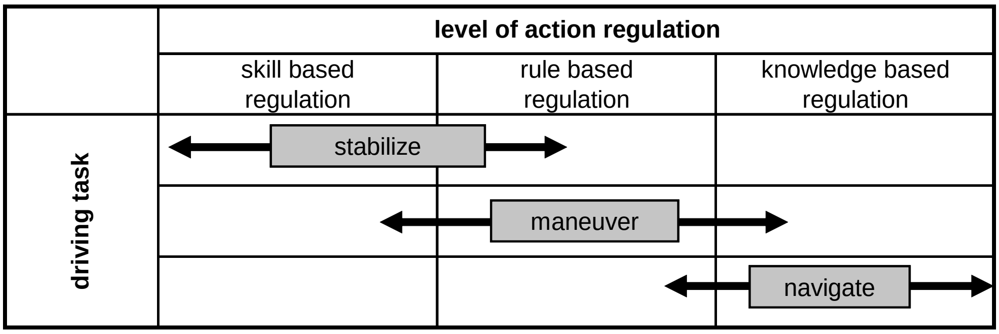


Figure 2: Driving tasks and associated levels of action regulation (Vollrath & Schießl, 2004, p. 344)

2.2.1. Driver Distraction: Attention allocation in a secondary task paradigm

In the previous section the relevant tasks in driving were described. If secondary tasks can be described in an analogue way their effects would be predicted based on these theories. Thus, as well as the driving task has to be set in a psychological framework, any secondary task or distraction needs to be, too.

This has been done by Lee and Strayer (2004, see Figure 3), who integrated both tasks into one framework, using the three-level description of the driving task. In their framework, *driver distraction* is the outcome of situations in which telematics-human shared control broke down. At the strategic level, society dependent variables like technology availability, social norms, regulations or productivity pressure influence both, route choice for the driving task and device activation for the telematic task. At the tactical level, the decision of starting a secondary task while driving is described. Roadway and telematic dynamics result in roadway and telematic demands. If activity priorities lead to scheduling conflicts, performance decreases in one or both tactical behaviors, leading to distraction related incidents like poor headway, speed or lane *choices* and, for the telematics control, in poor effort allocation policy. These poor choices have an effect on the demands at the operational level. This results in resource conflicts in controlling roadway and telematics demands at the same time. If demands cannot be met, telematics and / or driving performance suffer. This results in errors in telematic use (at best) or (worse) in safety margin violation in driving. Safety margin violations are found in poor headway, speeding and lane keeping behavior and may results in critical incidents and crashes. Thus, only examining tasks' or systems' effects on the operational behavior level is not sufficient to get the whole picture.

Influences of the society at the strategic level may regulate personal norms of device use and subjective safety ratings for tasks. At the operational level, driver state variables (e.g. fatigue, routine in driving / device use) as well as road variables (e.g. weather conditions, familiarity for driver) may greatly influence target performance choices for drivers as well as appropriate effort allocation. At the operational level only the basic control of tasks is described, neglecting almost all conscious choices of drivers. However, emerging from the hierarchy of this model, it is absolutely necessary to ensure that any secondary task does not impair driving performances at operational level since recovery from a breakdown at this certain point is unlikely.

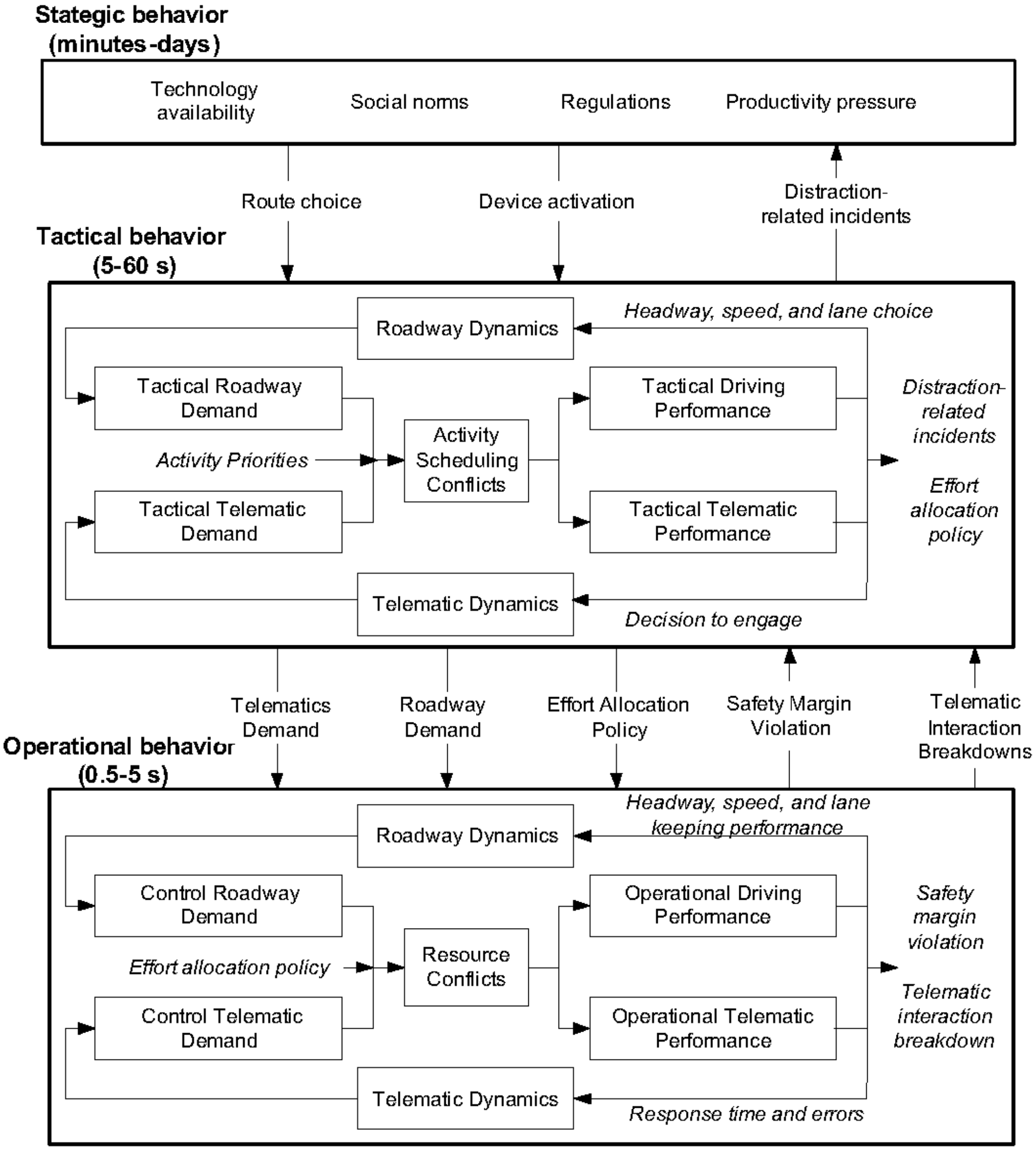


Figure 3: Distraction results from breakdowns of multilevel control that is shared between telematic interactions and driving. (Lee & Strayer, 2004, p. 585)

For strategic behavior, research is mostly concerned about prevention and mitigation (for an overview, see e.g. Regan, Lee & Young, 2009). Research on the effects of secondary tasks on driving performance just begins to examine task operation at the tactical (e.g. Metz, Schömig, Krüger, 2011) level. At the operational level, which is the level that is looked at in this work, a great body of research exists. Although the best examined level of operation, some blind spots do still exist. Existing knowledge and open questions will be discussed in chapter 2.3.4. Above, in chapter 2.3, the general methods for assessing driver secondary tasks prevalence as well as special tasks impairing effects are discussed. Existing knowledge is briefly presented and research needs are derived.

2.3. Methods for assessing frequency of driver secondary tasks and performance impairment due to them

In principle, some types of studies are feasible for investigating frequency and performance impairments by driver secondary tasks. In the following section, the two major approaches used for the two dimensions of the problem field are presented and discussed. Epidemiological data is used for estimating frequency of driving with secondary tasks. In combination with crash data it is used to estimate crash risks of tasks, too. In chapter 2.3.1 epidemiological methods and in chapter 2.3.2 international data gathered with these methods are presented. Experimental data is used for determination of effects of specific tasks or task components on specific driving related performance measures. Methods used here are discussed in chapter 2.3.3 and findings reported in the results of the literature analysis are presented in chapter 2.3.4. An extended description is found in Huemer and Vollrath (2010a) and Huemer and Vollrath (2011b).

2.3.1. Epidemiological approach: prevalence of secondary tasks

Frequency data on driver distraction can be gathered by subjective reports or by driver observation. There are different types of interview-studies. Data can be gathered in telephone surveys (as done by by McEvoy, Stevenson & Woodward, 2006) in Australia and by Royal (2002) in the US or in online surveys, as done by Lansdown (2010), Sullman & Baas (2004), and Young & Lenné (2010).There are two basic limitations of these types of data. First, it is questionable whether the sample really represents the driver population. More specifically, online data collection restricts the sample to those drivers who have access to the internet. Second, the answers may be subject to self-reporting biases, such as social desirability effects (e.g., under-reporting) and inaccurate recall. For example, af Wåhlberg, Dorn and Kline (2011) found substantial correlations between self-reported accidents and self-reported risk-behavior. They did not find correlations with objectively recorded accident frequencies. While this rises to some questions about self-reported accidents, research on secondary tasks while driving, which has directly investigated the degree of correspondence between self-report and observed driving behavior, has generally supported the accuracy of self-report (e.g., see Sullman & Taylor, 2010). This may be due to the fact that secondary task behavior is not regarded as being socially unacceptable.

The second type of studies on exposure to secondary tasks is observation studies. Here exposure data in normal driving is gathered. By observing rather than doing interviews, most reporting biases are eliminated. Here, two approaches were described in literature. Johnson et al. (2004) used photographs of randomly chosen drivers at a highly frequented road in New Jersey and rated secondary task engagement and task type later on by three trained raters. The other approach is naturalistic driving studies as done by Stutts et al. (2005) or in the *100-Car Naturalistic Driving Study* (Klauer et al., 2006). Naturalistic driving studies are in principle a possibility to get all information on distractions and its effects. Here, a sufficiently high number of vehicles are equipped with measurement devices for a longer time and drivers' activities are recorded as well as vehicle data. In principle, all kinds of activities can in this way be associated to critical driving situations or even accidents as well as degrading driving performance while engaged in any activity could be found. As these data are generated in real driving situations, transferability is highest. Drawbacks of naturalistic driving studies are any impairing distractions that cannot be observed, as e.g. daydreaming. Some other tasks are hard to be analyzed as they are mostly not recorded because of data privacy protection, e.g. drivers singing, or phone call content since audio data is usually not recorded. As accidents are rarely found in these studies, risk estimates are hardly possible. An exception is the 100-Car Naturalistic Driving Study (Klauer et al., 2006) in which a number of accidents as well as near-accidents or critical events were analyzed. It is thus the only source of data for actual risk of specific secondary tasks, here given in odds ratios as well as population attributable risks. As accidents are rare events, a high number of observations resulting in a high number of equipped cars are and / or a long observation time is needed. Together with the time-consuming data analysis naturalistic driving studies are a resource consuming approach.

The third type of study is crash data analysis. These data can be combined with frequency data of specific tasks to result in case-control studies to give relative crash risk and hazardousness estimation for distractions (e.g. Glaze & Ellis, 2003; Gordon, 2005; Hanowski, Perez & Dingus, 2005; Stevens & Minton, 2001; Stutts, Reinfurt, Staplin & Rodgman, 2001). When it is known from crash data that a specific proportion of crashes can be to be associated with a specific task and if it was known that in a certain number of driven kilometers drivers are engaged in this task, a relative crash risk could be calculated. Crash data is mostly based on police reports, thus the quality of the collected data highly depends on the quality of the reports. It is at least questionable whether those reports meet the demand of a scientific study. Data are mainly collected by police officers at crash scenes. As officers do not have any direct information on secondary task engagement and as drivers in crashes are often not able or willing to report them it can be assumed that the accident risk due to secondary tasks is certainly underestimated in these studies. However, as long as exposure is not taken into account (e.g., by examining secondary task involvement in crash-free driving) these odds ratios are a mixture of exposure and risk. As culture as well as traffic differs largely between countries, results from one country cannot easily be transferred to another. Unfortunately, unlike many other countries, e.g. USA (Stutts et al., 2001) or New Zealand (Gordon, 2005; 2007), the German crash reporting system has no categorization for distraction related crashes.

2.3.2. Previous findings on frequency and crash risk of driver secondary tasks

As a first step to investigate frequency of driver secondary tasks, a literature analysis was performed. Method and results are reported in detail in Huemer and Vollrath (2010a). Within this analysis, three types of studies were found investigating frequency and crash risk of driver secondary tasks, subjective data, observational data and crash statistics. Secondary tasks types are categorized in a schema first used by Stutts et al. (2001). The resulting nine different task types are shown in Table 1. The first group of tasks concerns *eating and drinking*. The second type comprises all *smoking related tasks*. The third group comprises all tasks concerning *clothing and body care* like taking off the jacket or snubbing the nose. The next group includes all tasks related to any *integrated device* in the vehicle, from positioning of mirrors to manipulation of in-car-telephones. All manipulation of *non-integrated devices* like mp3-players is found in the fifth group. *Passenger-related tasks* are summarized in the sixth group. Any other task carried out in the vehicle concerning any other item is found in the group *other tasks*. Tasks like singing or daydreaming which do not involve any items are found in the group *self-initiated tasks*". In the last group all distractions outside the vehicle are summarized.

Table 1: Secondary task types in literature. Secondary tasks are grouped after a complemented nomenclature first found in Stutts et al. (2001). (Huemer & Vollrath, 2011b, p. 1704)

	Secondary task type	**Description**
1	Eating / Drinking	-
2	Smoking related	-
3	Clothing & body care	▪ Snub nose ▪ Change clothes
4	Integrated devices	▪ All adjustments necessary for driving (mirrors, seat etc.) ▪ Manipulation of integrated devices
5	Other devices	▪ Manipulation of non-integrated devices (mobile phone, mp3 player)
6	Passenger related tasks	▪ Talking ▪ Gestures and touching ▪ Receiving and giving any device
7	Other tasks	▪ Animal related ▪ Searching things ▪ Reading and writing ▪ Cleaning up
8	Self-initiated tasks	▪ Talking to oneself, daydreaming ▪ Singing ▪ Thinking about something
9	Outside distraction	▪ Track related (e.g., construction sites) ▪ Looking at something. (pedestrians, advertisements) ▪ Listening to something (e.g., music from outside, sirens)

In Table 2, a summary of results is displayed. As one can see here, task types differ widely with regard to their frequency, their duration and their relevance for accident causation. Operating devices is often reported but mostly short and probably not so relevant with regard to accidents. Passenger related tasks are also often reported, last longer and are often found in accidents. However, both task types are rated to be safe by drivers. Clothing and body care tasks, in contrast, are rarely reported but account for a similar number of accidents as passenger tasks. While the frequency of outside distractions differs widely between studies, it is quite frequently reported in accidents.

To sum up, international data show that some secondary tasks are prominently found in driving and some tasks are often found in crashes. Both types have the potential to be a challenge for traffic safety. As data differs widely between studies that were done in different countries, the differences may be due to cultural difference in traffic. For Germany unfortunately none of these data exist.

Table 2: Overview of the frequency of different types of secondary tasks as found in the different study types. Minimum and maximum frequency found for the different study types are given to show the large range of results. (Huemer & Vollrath, 2011b, p. 1705)

Data Source	**Subjective Data ^{X}**		**Observational Data ^{Y}**		**Crash Data ^{Z}**	
	Drivers reporting engagement [%]		Observed engagement in driving time [%]		Engagement in analyzed crashes [%]	
Secondary Task Type	**min**	**max**	**min**	**max**	**min**	**max**
Integrated devices	94	100	1.28	5.13	0.10	2.18
Passenger-related	40	81	0.56	16.20	0.45	6.50
Internal (self- initiated) tasks	69	72		11.54	0.55	7.50
Outside distraction	3	58	0.00	1.62	3.79	27.50
Other devices	1	66	1.30	4.97	0.00	5.30
Eating / Drinking	18	51	0.26	4.61	0.22	1.90
Smoking related	2	10	0.00	1.55	0.12	0.22
Clothing & body care	3	8	0.00	6.50	0.50	6.50
Other tasks	1	25	0.30	5.11	0.35	3.85
All Task Types			**3.14**	**41.30**	**1.76**	**38.00**

^{X} subjective data sources:
Royal (2002); McEvoy et al. (2006); Lansdown (2010); Young & Lenné (2010)
^{Y} observational data sources:
Klauer et al. (2006); Stutts et al. (2003); Sayer, Devonshire & Flannagan (2005); Johnson et al. (2004)
^{Z} crash data sources:
Stevens & Minton (2001); Stutts et al. (2001); Glaze & Ellis (2003); Gordon (2007); Hanowski et al. (2005)

2.3.3. Experimental approach: quantifying the impairment caused by secondary tasks

Experimental studies are the only way to causally infer consequences in driving performance to specific tasks. Here, in controlled settings ranging from arbitrary laboratory settings to high-fidelity driving simulators, features of potential distractions are varied and effects on driving relevant performance measures analyzed. This means that only in experiments features of the situation can be varied independently and thus their influence on the situations outcome can be determined. For example, if it was found in crash analyses that dialing on the telephone is often a task done by drivers involved in crashes but it is also often found that these crashes with dialing drivers were under bad weather conditions, these data cannot distinguish between the influence of dialing and the influence of bad weather on drivers ability to drive safely. In experiments both features of the situation can be manipulated independently and determination of each feature's influence is possible. Experiments are, if conducted in an appropriate manner, reliable sources of information. This means, in experiments circumstances that need to be understood can be replicated and higher grained analyses of existing data can be developed. So if we know from an experiment that using the telephone decreases the ability of lane keeping, in a higher-resolution replication we are able to analyze the dialing task independent from the listening task and should though be able to show the decreasing lane keeping ability (even if using other measure for lane keeping ability) when putting data together again. In this way, results of experiments can be validated with the help of following experiments. Validity of experimental data is given if the experimental design is carefully constructed and operationalization is according to the theories tested. This means, that the chosen measures for lane keeping ability in the examples above should in both cases have something in common. In other ways, the results would not be the same. To be external valid, these measures should be related to lane keeping while driving in reality. As settings are controlled and driving situations and tasks are very specific transferability of results to real driving situations is sometimes questionable. In experiments drivers are urged to do secondary tasks that they perhaps would not do in these situations while driving in reality. Thus, experiments cannot give direct data on relative crash risk of distractions. But as experiments are the only way of causal attribution of effects to certain variations in situations, they are the source of empirically developed theories. In addition to that, they are constructed in accordance to these theories to test their implications. By this, experiments are essential to develop functional understanding for the processes that lead to the unwanted outcomes in driving, namely crashes. And by understanding the functional processes, experiments may also give hints how to prevent these outcomes and in this way help to make traffic safer.

To sum up, experimental methods are used to understand the functional and causal relationship between features of driving situations and drivers' performance on certain measures that are supposed to be related to traffic safety. Experiments cannot give information on prevalence of secondary tasks and are thus, as well as epidemiological studies, needed to be supplemented by the other to give a comprehensive understanding of the problem field of driver distraction and traffic safety.

Experimental methods are thus used to show if a given task can be done while driving in a safe manner or, if not, to which extent drivers are impaired. The better the driving task is understood the better experiments can be constructed in testing relevant requirements on drivers. The same applies to the secondary tasks tested. Thus, if effects of additional tasks on driving relevant performance are wanted to be determined, driving relevant tasks and performance measures should be used as primary task. Experimental settings for secondary tasks effects on driving performance range from arbitrary laboratory setups to high fidelity motion based driving simulators (for an overview, see Regan, Lee & Young, 2009). Driving performance can be assessed by the drivers' performance in controlling the vehicle in traffic, as there are the longitudinal control of the vehicle (speed and distance), the lateral control of the vehicle (lane keeping) and the drivers' ability to react to traffic events (e.g., other road users, but also traffic lights and signs). An extensive review of existing measures and effects is given by Johansson et al. (2004). Some driving performance measures have been found to be sensitive to driver distraction of different types. To summarize their findings, for the longitudinal control of the vehicle, speed and headway to the preceding vehicle are used as driving performance measures. For these, controversial effects are found with regard to secondary tasks. In the lateral control of the vehicle, direct steering metrics (e.g. steering wheel angle) or lane keeping performance (e.g. standard deviation of lane position) are used. For steering metrics, fewer but greater corrective movements are found to be made with secondary tasks. Lane keeping was found to be poorer while accomplishing visually demanding secondary tasks but was found somewhat improved with cognitive tasks.

2.3.4. Previous findings on driver secondary tasks effects on performance

In the previous sections the experimental approach has been described. Now, in the following chapter, the major results of experimental studies on driver secondary tasks effects on driving related measures are summarized. They are found in more detail in Huemer and Vollrath (2010a).

For integrated devices, different studies examined different tasks and devices. For driving related adjustments (e.g. adjusting mirrors) it was found by Stutts et al. (2005) that drivers were looking less frequently at the ongoing road and hands were found less often at the steering wheel. For use of entertainment systems like radio and other audio devices rather few experimental results exist and mostly those tasks are used as reference tasks as they are widely accepted and thus rated safe (Ranney, 2008). Though, Jäncke, Musial, Vogt & Kalveram (1994) found that listening to the radio alone can be detrimental while driving. Young, Regan and Hammer also reported in their 2003 review negative effects of these tasks on driving measures especially for young drivers. For navigation systems the most distracting task is manual address entry (Young et al., 2003). They are found to be less detrimental for driving if they are speech based and even less, if routing is done turn-by-turn rather than giving an overview over the whole route (Young et al., 2003). Ranney (2008) stated that these systems are rather prone for over-use by drivers and thus may become an unnecessary source of distraction. Use of the mobile phone while driving is the most investigated secondary task while driving. As early as 1998 Green and in 1999 Reed & Green showed that not only the physical components of telephone talk leads to impaired driving but also do the cognitive parts. In a review on more than twenty studies, McCartt, Hellinga and Bratiman (2006) found consistently longer drivers' reaction times when doing telephone tasks while driving. Collet, Guillot, and Petit (2010) again reviewed the existing literature on phone use while driving and conclude:

> "Previous studies have shown that most variables related to driving were affected by cell phone use: reaction time; visual perception and discrimination; gaze orientation; glances away from the road scene. All indicators attest a general decrease in the first stages of processing information, i.e. encoding and integrating data from the environment. While reaction time gave information about sensory-motor coupling, the motor stages were also affected through variables related to vehicle control, i.e. lane-keeping variation, car following distance and speed reduction. These results may be completed by physiological indicators to bring complementary and objective data related to drivers' functional state and their ability to process information." (p. 597)

Text messaging while driving has recently caught focus of attention as well. Owens, McLaughlin, & Sudweeks (2011) compared texting-while-driving tasks on a closed track. They found higher workload, longer glace duration in the vehicle and impaired vehicle control while texting, especially while writing messages compared to baseline driving. Comparing hand-held texting to an in-vehicle system that "reads" messages aloud, the in-vehicle-system was less detrimental but in a risky range, too. Passenger related tasks are rarely investigated experimentally. In studies dealing with crash risk, passengers are mostly found to have a protective effect (Engström, Gregersen, Granström & Nyberg, 2008; Lee & Abdel-Aty, 2008; Rueda-Domingo et al., 2004; Vollrath, Meilinger & Krüger, 2002). Maciej, Nitsch and Vollrath (2011) compared different modes of driver - passenger conversations and telephone tasks. They found drivers to make shorter utterances and more pauses while driving. Passengers also reduced speaking time by making more but shorter utterances. This special mode of conversation was found only in the passenger conditions. The protective effects of passengers seemed thus be due to adaption to the driving situation by both, drivers and passengers. The only experimental study on eating and drinking while driving (Young, Mahfoud, Walker, Jenkins & Stanton, 2008) revealed no significant effects in driving parameters, although these were found negative effects in some naturalistic driving studies (Sayer, et al., 2005) and in crash data (Stutts et al., 2001). For the groups of internal or self-initiated tasks no experimental studies exist as well as for outside distractions or other tasks in the car. Smoking tasks and clothing/body care tasks also have not been examined experimentally. As some of these tasks are quite commonly found in observational and crash data (e.g. use of other devices and outside distractions, see Table 2), effort should be invested in finding out, what exactly happens while these task are done that leads to crashes. As presented above, a large body of research demonstrates the negative effects of distracting activities on driving related performance. For this reason, it is problematic for vehicle manufacturers to introduce new systems into their products as they might be too distracting. To ensure that new systems are not distracting, a method for testing these new systems is needed.

2.3.5. Tests for assessing performance decrements while driving

Although the experimental studies presented above have shown that distraction may be detrimental to different aspects of driving, there are also huge differences in the results. These may be due to the different traffic scenarios used as well as the different metrics. It is therefore very problematic to compare different studies and, accordingly, different in-vehicle information systems (IVIS) which were used in those studies. However, this comparison is crucial for developing and testing new IVIS, because a HMI concept which does not distract too much and thus is suitable to be used while driving should be implemented as early as possible in the development process. Thus easy-to-use and standardized assessments of distraction are needed. These methods that measure certain attributes are called test. Standardized tests do this measurement in a defined manner. Standardized test procedures allow comparing subjects on the measured attributes. Tests have to meet certain primary test criteria (Bortz & Döring, 2006). They have to be (1) objective, meaning that the experimenter does not influence the results. Test results have to be (2) reliable, meaning that results should be precise. And tests need to be (3) valid, meaning that they should measure what they claim to do. Secondary criteria for test quality are (4) existing norms, (5) comparability, (6) economy, and (7) utility (Lienert & Raatz, 1994). Those secondary criteria are more concerned with practical use of the test than with its scientific values. For tests on performance decrements while driving with secondary tasks, it is thus required that a method meets these test criteria. This means, that tests have to have a defined testing procedure, a defined analysis and defined interpretation methods. Test results for a defined secondary task need to be invariant to the “tester”, in this case to the driver operating the task while driving. Measures taken in the test need to be linked to performance decrements found in real driving with secondary tasks. Task measures need to be capable to identify changes in secondary tasks demand quantity or quality. For meeting the secondary criteria, the used method should include data to compare test results (norms and comparability), and should be appropriate in consuming resources compared to gained insight (economy and utility). Among the methods available for measuring driver distraction (see Young et al., 2003) only those with standardized procedures are feasible to be called *test*.

Two methods have been supposed to become an ISO standard for secondary task demand measurement; the Occlusion Method (ISO/DIS 16673.2, 2005) and the Lane Change Task (LCT; ISO 26022:2010). Therefore, these methods are the most important tests up to now, as they are standardized and have been proven most extensively for their test qualities. The LCT finally has become an ISO-certified standard in 2010 (ISO 26022:2010). Therefore, in order to improve measurement of impairment magnitude while driving with secondary tasks, the LCT will be examined for its diagnostic qualities. The LCT procedure was also chosen for examination because it is joining two basic driving tasks and is thus the more ecologically valid test among the two. These two driving sub-tasks are lane keeping and, as a choice reaction task, lane changes.

2.3.6. The Lane Change Task

The Lane Change Task (Mattes, 2003) is used as a test procedure to measure distraction from driving due to secondary tasks. It is implemented as an ISO standard (ISO 26022:2010) with the aim to provide an objective criterion to be used to design human-machine interactions (HMI) in a way not detrimental to driving. Thus, on the one hand HMIs which distract the driver too much should be detected. On the other hand, the LCT should show which HMIs are compatible with driving. The LCT consists of a simple driving simulation that can easily be installed on any PC with a joystick steering wheel. In this task lasting for about three minutes the driver has to conduct eighteen lane changes on a straight three lane road. These are announced by traffic signs indicating the direction (left or right) and width (one or two lanes) of the lane change. The performance of the driver is compared to a standard optimum behavior resulting in an index which reflects the deviation from this standard. By comparing drivers’ performance while operating the LCT with secondary task to a baseline condition without any distraction, in-vehicle secondary task demand is assessed.

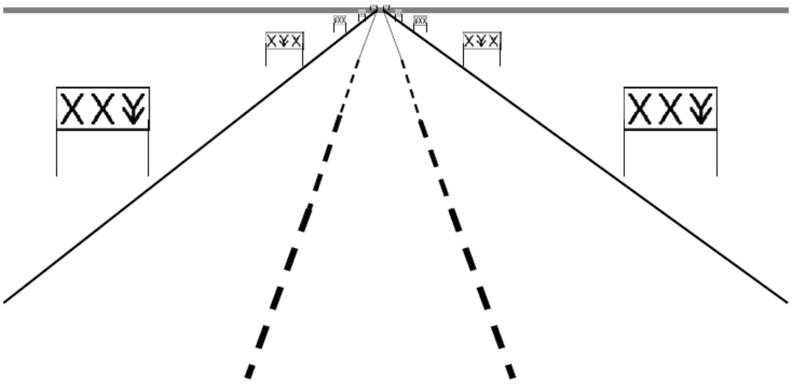


Figure 4: Lane Change Task: "Change your lane immediately as you recognize the next sign." With the symbols shown, the driver was to change to the right lane (arrow). (ISO 26022:2010, p.5)

In the ISO standard, the LCT is described as:

> "This Standard describes a dynamic dual-task method that quantitatively measures human performance degradation on a primary driving-like task while a secondary task is being performed. The result is an estimate of secondary task demand. […] The method is applicable to all types of interactions with in-vehicle information, communication, entertainment and control systems; manual, visual, haptic and auditory, and combinations thereof. Secondary tasks requiring speed variations to be performed cannot be tested with this method. It applies to both Original Equipment Manufacturer (OEM) and aftermarket in-vehicle systems. It also applies to both integrated and portable systems. […] The objective of the present document is to provide a valid, reliable and sensitive laboratory method that estimates the effect on driving performance caused by the demand from in-vehicle information and communication systems." (ISO 26022:2010, p.1)

LCT: Test procedure and performance measures

In the LCT driving simulation, the driver can see a straight section of a three-lane road and is instructed to stay on the current lane while driving at a constant speed of 60 km/h (the driver cannot drive faster than this). At some points signs are introduced which become legible at a certain distance. These signs indicate that the driver should change the lane (the target lane is shown) as soon as possible (see Figure 4). The traffic signs indicate the direction (left or right) and width (one or two lanes) of the lane change. The distance between the signs is 150 m on average. The symbols appear on the signs at a distance of 40 m (for details see ISO 26022:2010, p.7). As soon as the symbols appear, lane changes are to be performed as fast and accurately as possible. One trial consists of eighteen lane changes in a random order (left vs. right, movement across one lane vs. movement across two lanes) and takes about three minutes. The LCT includes both phases of lane keeping (between the signs) similar to other tracking tasks, and of lane changes which can be described as choice reactions (probe reaction task, ISO 26022:2010, Annex C.3, p. 21). At our laboratory a standard PC equipped with a joystick steering-wheel, gas and brake pedal was used to conduct the experiment. Driver behavior and car reactions were recorded with 62 Hz corresponding to a precision of 16 ms.

The performance of the driver is compared to a standard optimum behavior resulting in an index which reflects the deviation from this standard. Here, overall driving performance is measured by the arithmetic mean of the deviation from an ideal trajectory (see Figure 5). For this simplified ideal behavior it was assumed that during lane-keeping the car should stay in the middle of the lane. A simple linear trajectory was used to change the lane. While this is not a typical lane change behavior of a human driver, it gives an easy-to-compute standard to which the actual behavior can be compared.

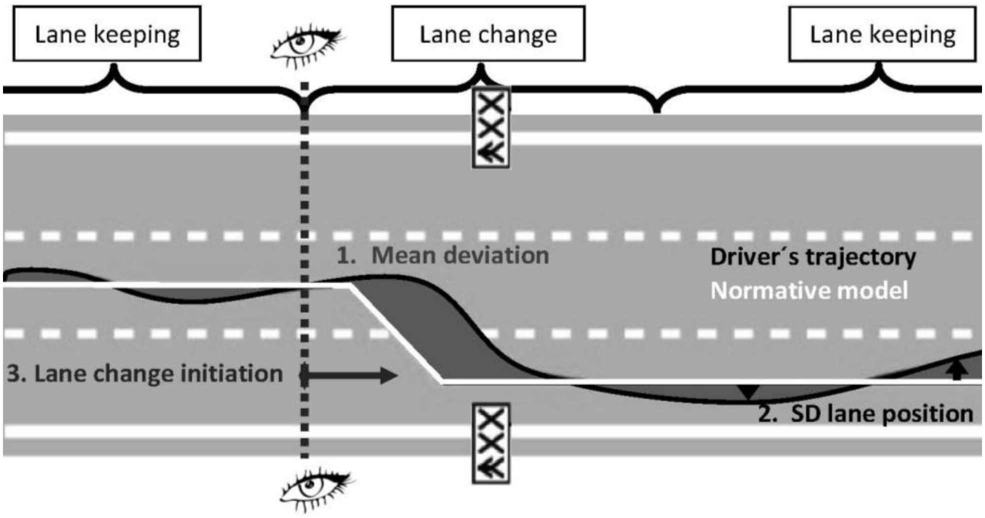


Figure 5: Driving performance measures in the LCT. (Huemer & Vollrath, 2010b, p.1985)

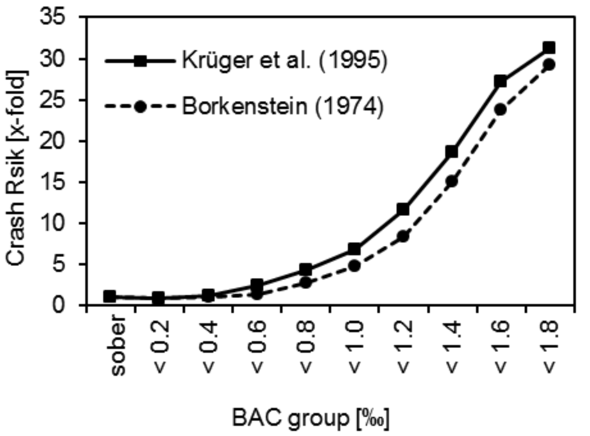
As we were, additionally to the summary measure, interested in the two sub-tasks of lane keeping and lane changing, an additional analysis was developed (for illustration, also see Figure 5). First, phases of lane keeping were separated from those of lane changing. The lane change was assumed to begin 30 m before each sign and to take 10 m. For both phases, the mean deviation from the ideal trajectory was computed separately. Additionally, for lane keeping phases the standard deviation of lane position (SDLP) was computed as measure of lateral control of the vehicle. For the lane changes, a reaction time was measured from the point where the sign became legible to the point where the driver started to steer. As the subjects could see the signs beforehand they knew in advance when a lane change was required. However, they had to wait until the sign became legible and then had to act accordingly. Thus, they could prepare for having to react but still had to select the appropriate action.

2.3.7. Bringing Crash Risk and Impairment together: The DRUID attempt

In the previous chapters, two research attempts have been presented, both dealing with the influence of secondary task occupation on traffic safety. The first, the epidemiologic attempt, gives information on the topics relevance in form of task types done, their prevalence and at best their crash involvement. The second attempt, the experimental one, gives quantitative information on the effects of special tasks on pre-defined performance criteria and is used in the test-approach.

As new systems, of course, should not be tested for their potential hazardousness in the field (here on the road), it would be best to be able to predict these effects from experimentally gathered data. Here, a transfer function is needed. At best, experimentally measured effects on single driving performance parameters (e.g. a change in lane keeping performance measured as ∆SDLP) would be transferable into a change in crash risk (e.g. given as an x-fold OR).

Some attempts have already been made into this direction, leading to the aim in the long run. These attempts are based on the large body of research that does exist on the effects of alcohol intoxication on driving. For alcohol, both, a relatively large body of research exists for crash risk while driving under its influence (e.g. Borkenstein, 1974; Krüger Kazenwadel & Vollrath, 1995; DRUID (Work Package 2), 2011) as well as for impairing effects on driving related sub-tasks (Meta-analyses by Moskowitz & Fiorentino, 2000; Krüger, Kohnen, Diehl & Hüppe, 1990; Schnabel Hargutt & Krüger, 2010; Schnabel, 2011). For crash risk, two major case control studies (Borkenstein, 1974; Krüger et al., 1995) were able to describe the increase in crash risk as a function of blood alcohol concentration (BAC). They showed that from BACs above 0.04% the crash risk increases; between 0.04% and 0.06% BAC crash risk is up to 2.5 times higher compared to driving sober, between 0.08% and 0.10% it is 4.3 times higher (see Figure 6).



BAC	**Borkenstein** (1975)	**Krüger et al.** (1995)
0	1.0	1.0
< 0.2	1.0	0.9
< 0.4	1.0	1.2
< 0.6	1.4	2.5
< 0.8	2.8	4.3
< 1.0	4.8	6.8
< 1.2	8.4	11.6
< 1.4	15.1	18.6
< 1.6	23.8	27.2
< 1.8	29.3	31.2

Figure 6: Crash risk under the influence of alcohol as a function of blood alcohol concentration (BAC) in the Grand Rapids Study of 1964 by Borkenstein (1975) and the German Study of 1994 by Krüger et al. (1995). The given numbers are Odds Ratios. (Vollrath & Krems, 2011, p.135)

Recently, in the DRUID (Driving under the Influence of Drugs, Alcohol and Medicines) project, a new meta-analysis of experimental studies on performance effects of alcohol was conducted by Schnabel, Hargutt & Krüger (2010). Herein, 450 experimental studies with 5,300 findings, conducted between 1950 and 2007, were reviewed and re-analyzed, resulting in a dose-dependent impairment function. Additionally, Schnabel (2011) was able to show that “Impairment of tracking performance begins at very low BACs of 0.02%. […] At a BAC of 0.05%, more than every second finding is significantly impaired. Thus, tracking tests are most sensitive to the effects of alcohol.” The dose-dependent impairment functions as well as the relationship of BAC and significant effects on tracking tasks are shown in Figure 7.

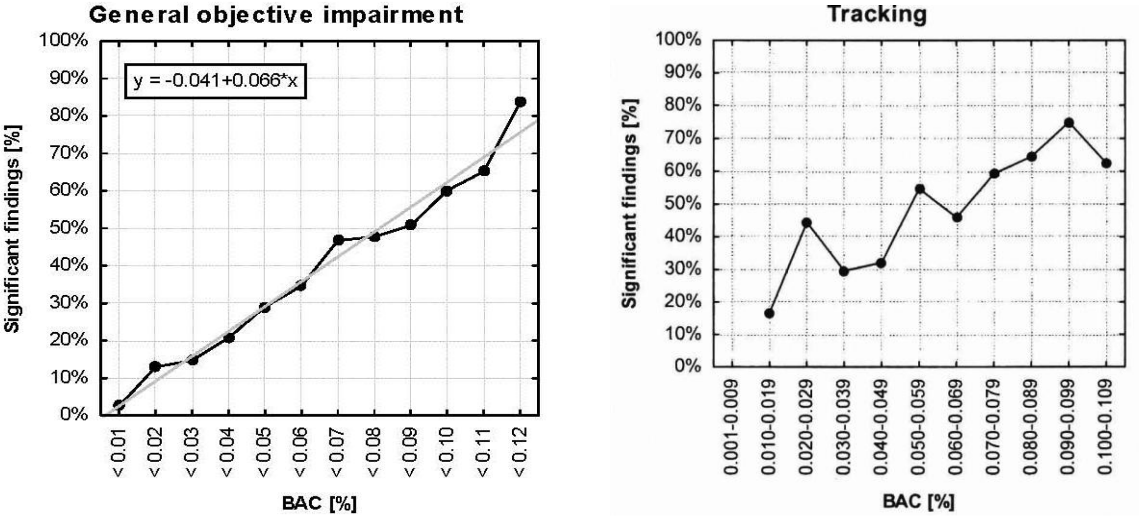


Figure 7: General objective impairment (regarding all performance categories) on the right side (Schnabel et al., 2010, p.71) and impairment of tracking on the left (Schnabel, 2011, p.94). Given are percentages of significant findings per BAC group.

As a dose dependent relationship between BAC and performance decrements for driving related tasks as well as for crash risk is found, it could be inferred that performance decrements in these tasks are valid indicators for increased crash risk. This relationship then can be used to assess the impact of other factors which also influence driving performance negatively. For example, one could examine the effect of sleep deprivation on driving related performance and describe which level of fatigue is comparable in effect size to certain BAC levels. This approach was used by Dawson and Reid (1997) who were able to find a high correlation between hours of wakefulness and certain BAC levels in a performance test (see Figure 8). Arnedt, Wilde, Munt, & MacLean (2001) were able to show this effect in driving simulation: “For mean tracking, tracking variability, and speed variability 18.5 and 21 h of wakefulness produced changes of the same magnitude as 0.05 and 0.08% blood alcohol concentration, respectively (p.337).”

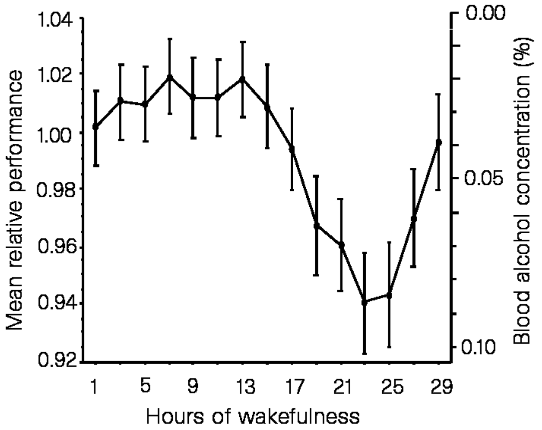


Figure 8: Performance in the sustained wakefulness condition expressed as mean relative performance and the percentage blood alcohol concentration equivalent. Error bars ± s.e.m. (Dawson & Reid, 1997, p.23)

In the DRUID project (2011), it was the aim "to gain new insights to the real degree of impairment caused by psychoactive drugs and their actual impact on road safety" (DRUID, 2011). Besides the meta-analysis reported above, experimental studies were conducted "on certain drug categories, for example stimulant and hypnotic drugs that are often indicated in epidemiological surveys to increase crash risk" (DRUID, 2011). "Their main objective is to determine tolerance levels by assessing drug effects on driving performance as a function of dose […] Results from the experimental studies thus will identify cognitive and psychomotor skills subject to drug induced impairment […]"(DRUID, 2011).

In the experimental studies of the DRUID project, drug effects on driving were examined. Following the rational of needed test for safety in the description of the Lee and Strayer model (2004; see chapter 2.2.1), effects were examined on the operational level of vehicle control (longitudinal as well as lateral control) and on the operational level of control (risk taking). In three driving scenarios the single effects of drugs as well as in combination with alcohol and with sleep deprivation were compared to baseline as well as to single fatigue and alcohol effects. In the *road tracking scenario* (automated behaviours) "participants are required to drive a 100 km course maintaining a constant speed of 95 km/h and a steady lateral position in traffic lanes. The primary driving measure is the standard deviation of lateral position or SDLP. SDLP is an index of road tracking error or weaving, swerving and overcorrecting" (Ramaekers, 2011, p.2). "The *Car Following* (controlled behaviours) task was developed to measure attention and perception performance, as errors in these areas often lead to accident causation. In this task participants are required to match the speed of a lead vehicle and to maintain a constant distance from the vehicle as it executes a series of deceleration and acceleration maneuvers. The primary dependent variable is reaction time to lead vehicle's speed decelerations. This test assesses a driver's ability to adapt to maneuvers of other motorists" (Ramaekers, 2011, p.2). Finally, "risk taking scenarios (strategic behaviors) were only embedded in studies using a driving simulator. Standard parameters that were used by respective partners were gap acceptance, number of crashes, number of red light crossings and number of crashes during sudden event scenarios" (Ramaekers, 2011, p.2). In DRUID, the effects of stimulant drugs and some medical drugs (hypnotics, opioids, non-opioids and antipsychotics) were tested in experimental settings. Results here are shown as an example for MDMA effects in Figure 9. Here, single effects of MDMA did not reach impairment in lane keeping comparable to the effect of alcohol, whereas combined effects with sleep deprivation as well as sleep deprivation alone lead to impairment comparable to the effect of 0.08% BAC.

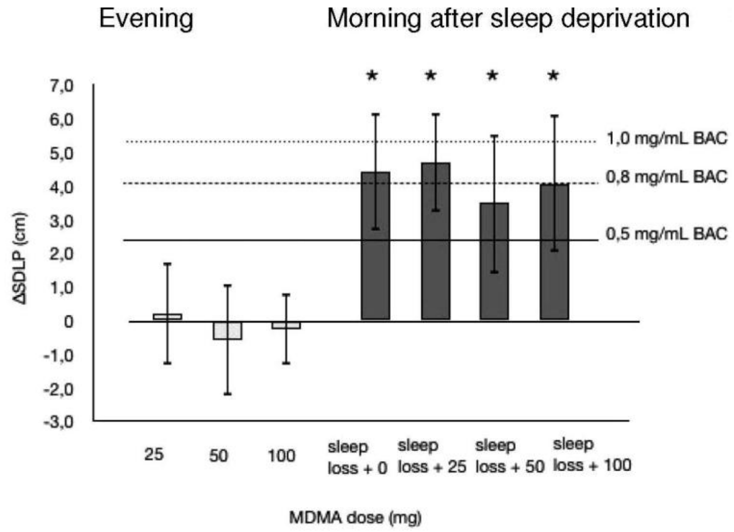


Figure 9: Mean (95% CI) SDLP difference from placebo after single doses of MDMA during the road tracking test in the evening and in the morning after a night of sleep loss. (= equivalence to BAC 0.5% shown, upper bound of the 95% CI is above the non-inferiority margin of 2.4 cm) (Ramaekers, 2011, p.5)*

One of the results of the experimental studies in the DRUID project was, that for all tested drugs (medical as well as illicit) and drug combinations it was shown that if any impairing effects in any of the test scenarios was found, there was also an effect in the ∆SDLP comparable to the effect of 0.05% BAC (Ramaekers, 2011). Thus, this lane keeping measure turned out to be the most sensitive measure for impairing effects concerning driving tasks for all drugs examined. The patterns of effects of the examined drugs vary from stimulating to relaxing. For some drugs, from their known patterns of effects some other result were hypothesized, e.g. for MDMA a higher level of risk taking behaviors was assumed. In the light of this, the sensitivity of the ∆SDLP can be seen as a useful hint on the way to find a safety relevant experimental measure.

An indeed very straightforward attempt would be to transfer ∆SDLP into OR. In this line, an increase in SDLP of 2.4 cm (under the influence of 0.05% BAC) would be transferrable into an two-fold increased crash risk (applying the Borkenstein, 1974 and the Krüger et al., 1995 data); a ∆SDLP of 4.2 cm (under the influence of 0.08% BAC) would be then transferrable into a fourfold increased crash risk and so on. This attempt surely will not be this easily developed as driving performance measures highly depend on the test scenarios they are used in (real, on-road driving compared to different fidelities of driving simulation are, e.g., compared in Bruyas et al., 2008) and as measured data is always subject to variation. But it may be possible to find reliable and valid performance equivalents for special test if there is enough data gathered. Thus it seems to be worthwhile to examine the SDLP's sensitivity of the LCT to alcohol.

Research findings like the one presented above are, or are recommended to be the basis for legislative regulations. In cases of alcohol and fatigue, research findings can be found in the German legislation. For alcohol, a legal per se limit is given (0.05% BAC, § 24a StVG). Additionally drivers' are being blamed at fault for crashes if they are found intoxicated even under this limit as impairment then is assumed. For fatigue, no per se limit exists, but for a special driver group that is prone for this impairment, legislation has been established. Commercial truck drivers are legally forced to take rest of 45 minutes after every 4.5 hours of driving and are not allowed to drive longer than nine hours a day to prevent them to fall asleep while driving (VO (EG) Nr. 561/2006). One of the major aims of the DRUID project was to give research-based recommendations for legislation concerning drugs and medicines in traffic. Here, as presented in Knoche, Legrand and Verstraete (2011), some countries are now setting per se limits for drugs based on the project's results. Looking at this development in legislation, the search for safety margins based on experimental data gets most practical relevance. Thus, valid and reliable performance measures for all kinds of impairment (by drivers' states, by drivers' traits as well as by drivers' actions) are needed.

2.4. Research questions

The present work thus presents twofold value in research on driver distraction. On the one hand, the value is a very practical one by describing the dimension of the problem of secondary task occupation in Germany, as well as by helping to improve test methods like the LCT. On the other hand, the studies on the LCT reveal some insight into learning processes in dual task situations as well as in compensation while being intoxicated by moderate doses of alcohol.

According to these two key aspects, in the following chapter at fist the prevalence of secondary task engagement in Germany is presented. Afterwards, the LCT procedure and the studies concerning practice and alcohol effects on its performance measures are presented.

2.4.1. Prevalence and tasks types

The overview on the field studies on driver secondary tasks presented in chapter 2.3.2 reveals several research needs on driver secondary tasks prevalence and hazardousness. For Germany, no data on frequency of secondary task engagement does exist. Unfortunately, even crash data does not include any information on secondary tasks or other driver distracting conditions. As traffic and culture in Germany differ from the United States or Australia, clearly German data is needed. Here, the present work adds valuable information as in an interview study first data on driver secondary tasks frequency is presented in chapter 3.

The interview protocol that was developed for this study was capable not only to gather information on frequency of tasks but also revealed valuable information about driver groups doing certain patterns of tasks. Most of the drivers were asked detailed questions about task execution. Their answers gave a glance at psychological requirements of some tasks and their relation to risk estimated by the drivers. The results of the interview study thus show that a quite comprehensive picture of secondary task engagement, including some of drivers' motives and believes can be gathered in a quite easy way.

2.4.2. Measuring effects on driving performance

For evaluation of secondary tasks hazardousness and for helping to develop better HMIs, experimental approaches are necessary. The LCT (as presented in chapter 2.3.6) has been developed to be a standardized tool for evaluation of these systems. Although the ISO norm as well as the developers of the LCT (Mattes & Hallén, 2009) and Ranney (2008) state that "The summary measure derived from the LCT has been shown to be sensitive to different types of secondary tasks and is being promoted as a standardized measure of distraction potential" (Ranney, 2008, p.8), the test qualities of the LCT are not undisputed. Burns, Harbluk, Trbovich and Lochner (2006) criticized the unspecified information about method, metrics and criteria, the unspecified sensitivity of the performance measure and an uncertain predictive validity. Some advantages have been made since their critics in the development of the ISO norm, but still major unsolved problem do exist.

Differing results between laboratories show reliability problem within the LCT test procedure. These problems may be due to practice effects that *are not considered yet* in the norm. Here the present work gives information on learning requirements in the LCT tasks as well as on training effects of LCT performance. Different training regimes and their effects on performance in LCT and in the secondary tasks have been examined. Results are summarized in chapter 4.1 and presented in detail in Huemer and Vollrath (2011c). As the LCT is becoming increasingly popular in deciding about possible detrimental effects of secondary tasks while driving, the validity of this test with regard to traffic safety and especially the ability of the LCT to detect negative effects are of crucial importance. This means, that a cut-off value is needed to tell users that an examined task now is too risky for being operated while driving. For setting such a cut-off value, an external criterion resembling safety relevant performance, is needed (see chapters 2.3.5 and 2.3.7).

As a first step into the direction to find a feasible battery of driving performance tests, for which results are linked to crash risk, the LCT was also examined on its sensitivity to the best-examined drivers' state: alcohol. Accordingly, the results from the alcohol studies mentioned above were used to implement blood alcohol concentration (BAC) limits at levels where the alcohol-related accident risk is increased or where substantial significant effects can be found in laboratory tasks which measure aspects of performance which are relevant for driving. This study on alcohol effects on LCT performance is summarized in chapter 4.2, more details can be found in Huemer and Vollrath (2010b).

3. Frequency and types of driver secondary tasks in Germany

In order to obtain the urgently needed exposure data for Germany, an interview study was conducted. At first an interview protocol was developed. An advantage of this method is that it also includes information on secondary tasks that cannot be recorded by outside observers, e.g., daydreaming as well as subjective evaluation on riskiness of tasks. To avoid drawbacks of the interview studies (like problems with remembering or underestimation biases) the interviews were conducted with drivers directly after driving in face-to-face interviews in summer 2009. Detailed information on the study can be found in Huemer & Vollrath (2010a), Huemer & Vollrath (2011a) and Huemer & Vollrath (2011b).

3.1. Method

Driver interviews were used as they provide an effective and fast means to get an overview about the frequency and types of secondary tasks. Additionally, some secondary tasks like daydreaming cannot be observed from outside but are easy to report by the drivers themselves. The interview protocol as well as the sample collection that were both intended to gather a picture of most tasks done and their special circumstances thus are described in the following.

3.1.1. Interview protocol

For the interviews a semi-structured standardized protocol was developed (for the protocol, see Huemer & Vollrath 2010a, p. 100 ff.) to gather information on the frequency and duration of every secondary task type in a first part and to get more detailed information on the tasks carried out in a second part including subjective risk estimations. In order to reduce forgetting, interviews were conducted instantly after the trip at parking sites in the same environment and context where the trip had taken place. To enhance the response rate, face-to-face interviews were chosen. Additionally, the first part of the interview was kept very short including only the most basic questions about different secondary tasks. This part of the interview is described in more detail in Huemer & Vollrath (2011a). A more detailed questioning on the conducted tasks’ circumstances followed for those drivers who accepted to spend some more time. The second part was conducted for only one secondary task with in-depth questions about one of the tasks done. Drivers were asked to report about the course of action in detail and to estimate this tasks riskiness as well as the distraction posed by the task. The results of this part of the study are found in more detail in Huemer & Vollrath (2011b). The overall time needed for the interview was thus abbreviated while at the same time basic information about secondary task involvement was obtained from all drivers.

3.1.2. Sample

Interviews were carried out at four parking areas at the motorway and three parking areas in the city of Braunschweig, Germany. These Locations were chosen because drivers usually intend to stop there and they were expected to have some spare time. Data collection was from July to August 2009, from Monday to Friday between 8.00 a.m. and 5.00 p.m. Six trained psychologist interviewers carried out the interviews in teams of two. Every vehicle driver arriving at one of the parking areas was asked to take part in the study. Out of 343 drivers, 289 agreed to give the interviews. This corresponds to a responder-rate of 84.3%. There was no strong evidence that the non-responders differ systematically from the responders. In particular, it does not seem likely that they avoided the interview because of a special engagement in secondary tasks.

3.2. Results

In a first step it was examined which characteristics of the trip or the drivers could lead to a different number of secondary tasks. Drivers differed with regard to the purpose of the trip (occupational or private). They were driving cars and trucks and the trips took place either in the city or on the motorway.

3.2.1. Driver groups

287 of the 289 drivers of the sample were assigned to one of five groups of drivers, differentiating them on vehicle type, location of the interview and driving purpose. In Table 3 the demographical data of the drivers groups is displayed, showing that driver characteristics differ between groups.

Table 3: Driver characteristics (Huemer & Vollrath, 2011a, p.1708)

Vehicle type	Location	Driving purose	N	Gender		Age		Driving expiereince		Mileage [1000 km /year]		Actual trip length [km]		Passengers	
				m	f	M	SD	M	SD	M	SD	M	SD	without	with
Car	City	Private	85	40	45	46.56	15.38	26.78	14.22	19.15	18.94	16.99	40.59	48	37
		Occupational	12	7	5	39.08	19.29	40.77	12.00	32.91	27.75	14.46	13.38	10	2
	Motorway	Private	71	53	18	51.11	13.83	30.41	31.74	20.61	18.27	235.18	113.35	15	56
		Occupational	29	23	6	41,0	19.32	23.14	13.73	51.35	34.51	161.59	136.79	24	5
Truck	Motorway	Occupational	90	89	1	42.19	17.44	40.77	23.28	128.86	54.93	222.38	147.5	85	5
Total analysed			287	212	75	45.44	13.65	25.87	13.00	58.02	60.75	149.88	146.09	182	105

3.2.2. Task engagement

This interview study on secondary tasks while driving showed that German drivers were engaged in secondary tasks quite frequently. Two to three secondary tasks per 30 min have been carried out by the drivers, lasting for about 30–50% of the driving time. In Figure 10 secondary task engagement is displayed separately for the five driver groups. Additionally, besides the average number of secondary tasks (left) the overall duration of secondary task engagement is given. Car drivers on occupational trips in the city reported the largest number of tasks (M= 3.2 tasks), lasting for about 40% of their driving time. Private car drivers in cities did fewer tasks (M=1.9 tasks) and these were shortest with about one third of the driving time. Car drivers on motorway, on private as well as on occupational trips, were doing about 2.2 and 2.3 tasks, respectively, lasting for about 41% to 42% of driving time. Truck drivers carried out about 2.7 tasks, lasting the longest with about 54% of driving time.

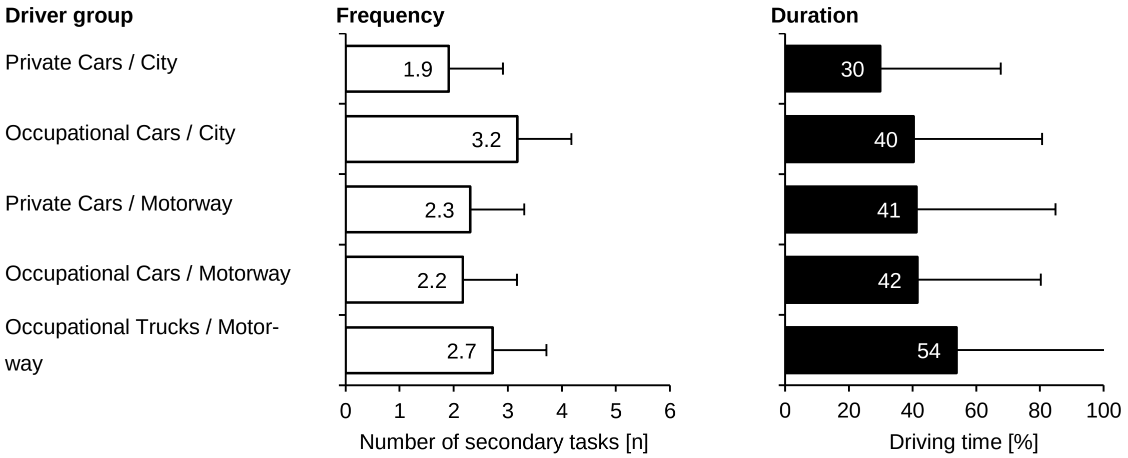


Figure 10: Frequency and Duration of secondary task occupation in driver groups. For each driver group, mean number of tasks (white bars, whiskers represent SD) and mean duration of occupation with tasks (black bars, whiskers represent SD) is given. (Huemer & Vollrath, 2011a, p.1708)

Overall, only 3.8% of drivers reported no secondary task engagement at all, 20.6% reported one task, 37.3% two tasks, 22.0% three tasks and 16% four our more tasks. Figure 11 gives the frequency and amount of time spent with different tasks sorted by frequency. The mean duration was only computed for those drivers who had conducted this task. Figure 11 shows, that using integrated devices is the task which has been reported most by the drivers (about 58% of all drivers). These tasks were relatively short as they counted for only about 5% of the driving time. Tasks related to passengers were reported also quite numerous with about 38% of drivers, but lasted substantially longer (about 39% of driving time). Self-initiated tasks were carried out by about 30% of drivers, also lasting long with about 37% of driving time. Outside distractions were found in 23% of drivers and about 10% of driving time. Dealing with other, non-integrated devices in the car were less common tasks found in 18% of drivers. These tasks lasted quite long with about 35% of driving time. Eating and drinking was less common with only 9% of all drivers. When drivers were eating or drinking anyhow, these tasks took about 30% of their driving time. Twenty-four percent of drivers were smoking; this took about one fifth of their driving time (23%). Clothing and body care was found in 10% of drivers lasting only about 3% of driving time. Any other tasks were found in 4% of drivers for about 5% of driving time. To sum up, most common task types that were reported are operating devices, passenger related tasks, and distractions from outside the vehicle as well as self-initiated, internal distractions.

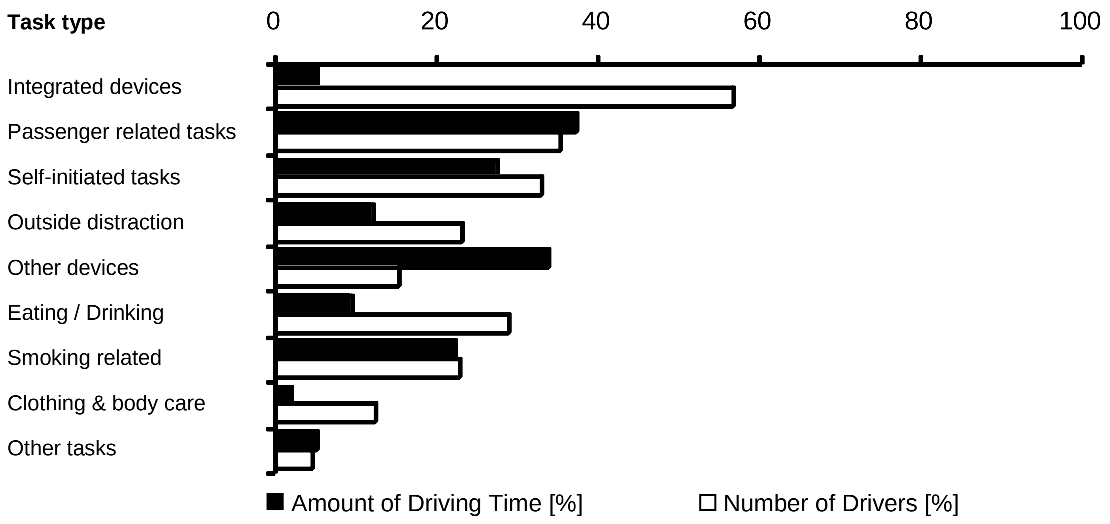


Figure 11: Frequency and Duration of specific secondary task types. Frequency (white bars) and driving time (black bars) of the specific secondary task types are given for all drivers. Frequency is given relative to sample, duration relative to driving time. (Huemer & Vollrath, 2011a, p.1708)

Reported secondary task engagement differed between five driver groups that were found in the sample. Details on this analysis are reported in Huemer and Vollrath (2011a). Different patterns of engagement were found in overall frequency and duration as well as among specific secondary task types. Private car drivers showed less engagement in secondary tasks compared to those drivers on occupational trips. Occupational drivers were more often occupied with integrated as well as non-integrated devices in the car and report more self-initiated tasks. On the motorway as compared to the city area drivers are engaged in secondary tasks for a longer time. However, self-initiated tasks and outside distractions were reported less frequently for motorway trips. To summarize, engagement in secondary tasks seems to depend on characteristics of the driving situation which is reflected in the driver groups which were examined in this study.

3.2.3. Detailed analysis of secondary task types

Different patterns of engagement were also found between specific secondary task types. Here, the results for this detailed analysis are briefly summarized. More details are found in Huemer and Vollrath (2011b).

For operating integrated devices, the most frequent tasks were audio-related tasks. This was followed by telecommunication tasks using mobile phones. Much less frequent was handling the climate control of the vehicle or using the navigation system during the trip. Most drivers controlled their device in the center console of their vehicle, about one third used controls at the steering wheel, and only 10% controlled their devices by speech based interfaces. Non-integrated device were mostly put on the co-driver’s seat and controlled at this place. Passenger related tasks were found in almost every case when drivers were carrying passengers. They lasted long and drivers talking with passengers did fewer other tasks than those drivers who had no passengers. Self-initiated or internal tasks were reported by about one third of drivers. Most drivers doing internal tasks reported planning activities. Distractions from outside the vehicle were almost exclusively described as distractions or stressors. Other traffic or constructions sites constrained or stressed drivers by making them to pay more attention to driving than normal. Results for eating and drinking showed that these tasks are widespread and mostly of short duration. Drivers eating or drinking were found to be on longer trips and thus seem to need to fulfill some basic needs while driving. Most drivers had to unpack their food before eating, which may be a safety problem if things fall down in the car and then become one of the moving objects accounting for crashes in literature. In order to eat or drink, drivers had to take their hands of the wheel. Drivers carrying passengers with them were given their food and beverages by them in the majority of cases. Smoking was reported by few drivers except for truckers. If drivers were smoking they did so for about half of the driving time having mostly one but some even two hands off the wheel. Extinguishing cigarettes in the ashtray was reported by most of our drivers may result in dangerous situations, as found in accident studies. Clothing and body care was reported in about one sixth of drivers. As detailed descriptions were only available for drivers picking sunglasses, a short task with mostly only one grasp for the glasses. Unfortunately, no further conclusions on longer or more complex tasks can be drawn from these. Other in-vehicle tasks were found infrequent and drivers doing task within this group reported reading, writing or searching for things.

Overall, the results show that those tasks which have been found more often in accident studies seem to be those tasks that drivers are occupied with for a longer time. These tasks do not need to be observable “activities” but can also be internal planning.

3.2.4. Drivers’ perspective

Subjective estimates of a tasks dangerousness, distraction, and general dangerousness were given by those 275 drivers who reported on one of their tasks in detail (see figure 12). From the drivers’ perspective, their secondary tasks are dangerous in general, but the task which they themselves had done during the trip was thought to be not so distracting and not so dangerous. In their own ratings of how dangerous a task may be drivers seem to use the length of time with eyes off the road, but also hands off the wheel as an indicator for danger.

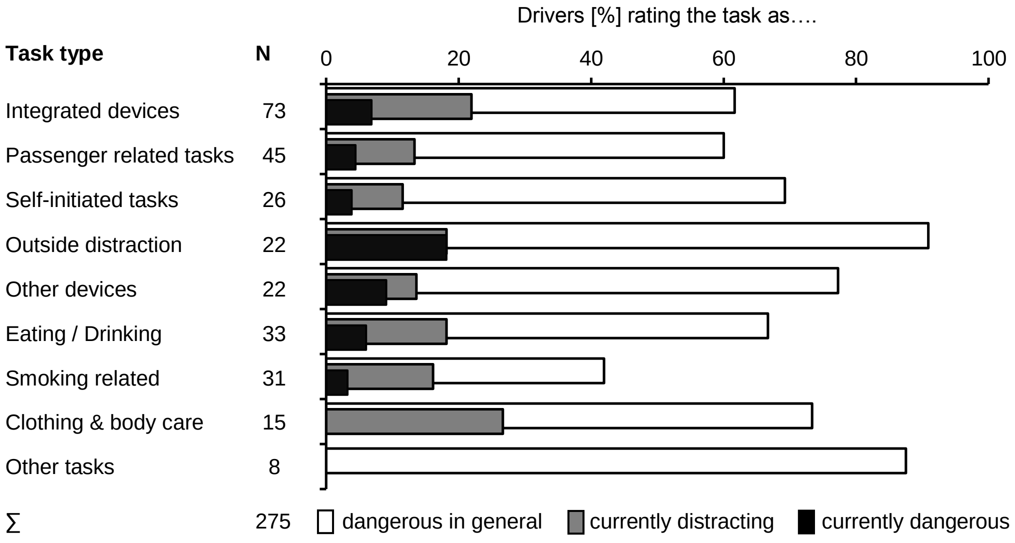


Figure 12: Subjective evaluations of secondary task distraction and danger. Each driver was asked to rate one of his reported task types, considering general danger, actual distraction and actual danger of task. The number of drivers rating each task is given in the second column. (Huemer & Vollrath, 2011a, p.1710)

3.3. Discussion

The interview study overall showed that secondary tasks are widespread in Germany. However, it also showed that the types of tasks done and their duration have typical patterns in different driving contexts. The analyses show that secondary task engagement depends on driving purpose, vehicle type and road type. On motorways, passenger related tasks are the most frequent secondary tasks, if passengers are present in the vehicle. If not, operating devices not integrated in the vehicle is a frequent activity of the drivers. In the urban area, outside distractions and self-initiated tasks are the most frequent tasks, followed by passenger related tasks. Occupational drivers, in city as well as on motorway seem to be more prone to task engagement. Therefore, a short discussion on the task engagement is included here, followed by the discussion on tasks types.

3.3.1. Driver groups: occupational drivers

More secondary tasks were found amongst drivers on occupational trips and longer tasks for drivers on the motorway. For occupational drivers the avoidance of stops and the long duration of trips may have led to their engagement in certain secondary tasks. Due to the length of the trip, private car drivers on motorways also fulfill several basic needs while driving (eating and drinking, smoking). Additionally, boredom and lack of stimulation may lead drivers to try to compensate by engagement in secondary tasks. In contrast, on short city trips, outside distraction is more prominently found and self-initiated tasks, like planning or daydreaming are more often found though shorter than on motorway trips. Especially for occupational drivers, their task engagement may on the one hand be due to the fact that they spent their working day in the car or truck, which is often boring. Thus, secondary tasks may be a way to try to stay alert and awake. On the other hand, especially occupational car drivers may have some additional accountancy work to do that they could do while driving instead of doing it at home after their working day.

3.3.2. Task types: Which tasks need a closer look?

Dealing with devices was the most common secondary task group reported. Here, vehicle controls and audio tasks were the most common tasks. In the literature (see figure 1) these tasks were mostly reported to be done by all drivers. In our study they had been done by 23% of drivers. Tasks were reported to have very short durations (less than 1% of driving time in our study and, e.g., 3.8% of driving time in the Stutts et al. study, 2003). They were rated as potentially dangerous by only 60% of drivers in our study. Young & Lenné (2010) found 53% of drivers to rate these tasks as at least moderately dangerous. Up to here, audio and vehicle control tasks do not seem to be the most urgent safety problem, but if crash data is integrated, the picture changes. The tasks were found equally often or more often in distraction-caused crashes (11.4% audio tasks and 1.5% telecommunication tasks in Stutts et al, 2001; 12% of distraction crashes in both task groups in Gordon, 2007). Analyzing risk related data, audio tasks are not found to be less risky than telecommunication as well. Klauer et al. (2006) reported Odds Ratio of 2.3 (although non-significant) for audio tasks compared to 2.8 for telecommunication tasks. Those telecommunication tasks were reported in our interviews rather often, being in line with the literature (about 1/3 of drivers, see table 1). Duration of tasks was longer in our study (20% of driving time) compared to 3.8% in Stutts et al. (2003). Tasks were executed with one hand off the wheel for half of the drivers with integrated devices. Non-integrated devices sometimes had to be taken from the front passenger seat, resulting in rather long task times with hand off the wheel. This finding is in line with Stutts et al. (2003) finding that drivers were using their phone while having one hand off the wheel in 8% of driving while usage and eyes on the device for 67% of usage time. Klauer et al. (2006) found telecommunication to have a significantly increased Odds Ratio and a high Population Attributable Risk of 3.6. Although these tasks are risky, they are not that prominent in crashes with only 1.5% of crash causation (Stutts et al., 2001). They are rated very risky by the Young & Lenné (2010) sample with 97% rating some of the sub-tasks to be moderately dangerous or above. However, in our sample they were rated only medium risky with 61% of drivers rating them as dangerously. To sum up, the picture of device tasks is not the straightforward “phone tasks are extremely dangerous” and “vehicle control and music are okay”. Telecommunication is risky, but audio and vehicle control tasks may not be less risky, although rated in this way by drivers as well as researchers.

Passenger related tasks were found in the present study in almost all cases in which drivers were carrying passengers. This is in line with the reported engagement in the literature (see table 1). Drivers talking with passengers did fewer other tasks than those drivers who had no passengers. They may not need to distract themselves from the boring driving task as much as drivers who travel alone. Tasks lasted longer in our findings than reported in the literature. Passenger related tasks were rated less dangerous compared to other studies (60% in our study, up to 94% for dealing with children in Young & Lenné, 2010). Although passengers are found to be protective against accidents (Klauer et al., 2006), passenger related tasks have been rather often found in crashes (6.5%, see table 1). Here, the explanations seems to be the difference in distraction amount and quality between caring for children and talking to someone who is attending to traffic related demands as well (see Maciej, Nitsch & Vollrath, 2011) and additionally helps the driver to stay awake.

Self-initiated or internal tasks were reported by about one third of drivers. Most drivers doing internal tasks reported planning activities. These tasks have been reported by 72% of drivers in the reviewed literature. Internal task lasted about 30% of driving time (in this study as well as in the literature) and were often found in crash analyses (up to 7.5% of crashes). Tasks were rated as moderately dangerous in our sample (69%) and have been found to be rated riskier in Young & Lenné (2010) with up to 94% of drivers rating them at least moderately dangerous. For self-initiated tasks, as they are hard to investigate, no information is available on objective risk measures. Looking at the crash analyses which may suffer from under-estimation, more information is needed.

Distractions from outside the vehicle were almost exclusively described as distractions or stressors. Other traffic or construction sites constrained or stressed drivers by making them pay more attention (than normal) to driving. The detailed descriptions showed how drivers define a distraction: a situation that is more complex than normal. Our finding on frequency and duration of this task type was contrary to the literature. In our sample, tasks were long lasting (33% of driving time compared to 1.6% in literature) and done by fewer drivers (15% compared to 58% in the literature). Distractions from outside have been very often found in crashes (27.5% of crashes, see table 1) and have a high Odds Ratio of 2.8 as well as high Population Attributable Risk of 3.6 in the Klauer et al. (2006) data. These distractions are generally rated to be dangerous by drivers, so they seem to be aware of the problem, although legislation seems to have neglected this risk in the past.

Results for *eating and drinking* showed these tasks to be commonly found (currently done by 23% of our sample, reported in the literature for about 51% of drivers) and commonly of short duration (4.65% of driving time in the literature, 12% in our sample). In our sample drivers who ate or drank were found to be on longer trips and therefore had to satisfy basic needs more often compared to drivers who travel on short distance only. In order to eat or drink, drivers had to take at least one hand off the wheel. Preparing and consuming food or beverages has been found to increase significantly the time with hands off the wheel as well as time looking at the food in the Stutts et al. (2003) study as well as increasing incidents per time. Klauer et al. (2006) found these tasks to have lightly increased Odds Ratio of 1.6 and a rather high Population Attributable Risk of 2.2. Eating and drinking has not been found very often in crashes (only in 1.9%) but this rather small number is higher than for telecommunication tasks. Risk estimates by drivers were rather low, in our sample with 60% as well as in the Young & Lenné (2010) data (58% rating eating and drinking as at least moderately dangerous). To put this together, eating and drinking seems to be one of the tasks under-examined and underestimated in safety concerns. Drivers should be promoted to take a rest for fulfilling their nutrition needs.

Smoking was reported by few drivers except for truckers. Drivers in this study rated smoking potentially but not currently dangerous; only 42% rated it dangerous, in the Young & Lenné (2010) study this rating was higher (64% of drivers). If drivers were smoking they did it for about half of the driving time having mostly one but some even two hands off the wheel. Extinguishing cigarettes in the ashtray as reported by most of our drivers may result in dangerous situations, e.g. reaching for a burning cigarette that has fallen down, as found in accident studies.

Clothing and body care was reported by about one sixth of drivers. As detailed descriptions were only available for drivers taking sunglasses, a short task with mostly only one grasp to the glasses. Unfortunately, no further conclusions on longer or more complex tasks can be drawn from our data.

Other in-vehicle tasks were found infrequent in our data as well as in literature (5% of driver reporting the tasks). Drivers doing task within this group reported reading, writing or searching for things. The tasks lasted one third of driving time in our study but are reported to be shorter in other data (only 5% of driving time). They were rated as risky by 87% of drivers in our sample and even higher (97%) in the Young & Lenné (2010) sample. The estimated objective risk supports this impression strongly, as Klauer et al. (2006) found an Odds Ratio of 2.2 and an extreme Population Attributable Risk of 8.8. Crash data support this picture only to some extent. *Other tasks* have not been found in this extreme fashion (within 3.8% of crashes only) in crashes. Our study showed that especially truck drivers do writing and reading tasks. Thus, something may be done in legislation or in technical support to not force them to note things manually but perhaps record them orally.

Overall, the results showed that some tasks which are not that well examined or realized as a problem by legislation, were found to be prominent in our data: outside distractions, internal tasks and eating or drinking. The overall estimation of the danger posed by the different tasks was very similar to the danger ratings found in other interview studies (Patel et al., 2008; Young & Lenné, 2010) or in the focus group of Baker (2007). Some tasks clearly seem to be underestimated in danger when comparing subjective ratings to crash involvement. Among these are passenger tasks (excluding ‘talking only’), internal tasks and the (mostly complex) other tasks, like writing or reading. Here, some more investigation in circumstances of tasks becoming dangerous is needed. Additionally, drivers are needed to be made aware of the dangers posed in everyday-tasks, too. Baker (2007) stated that tasks resulting in hands off the wheel are more likely to be rated dangerous. Here, some investigation on danger and risk rating mechanisms in drivers may help to understand the mismatch between subjective and objective danger.

3.3.3. Method’s evaluation, limitations and further research needs

From a methodological point of view, using face-to-face interviews directly after the trips can be evaluated as a success. Drivers are well able to report their tasks and thus it is possible to get an assessment of drivers’ secondary task engagement quite fast. The high response rate and the results being similar to other studies support the impression that drivers honestly reported their engagement in secondary tasks to their best knowledge. We found no indication of under-reporting bias in our data. In contrast, self-report enables the assessment of internal distraction which cannot be seen in video observations.

The frequencies of secondary tasks reported in this study are hard to compare with those of the international interview and online studies described above because the latter did not obtain information on a trip basis but in a more general manner. But if done, the estimations are very similar to those of the international observation studies, even if a little higher in frequency. This difference may be due to the different method as self-initiated tasks and outside distractions are hard to observe, but easy to report. It may also be due to difficulties to give good time estimation about the duration of the task. Finally, it could also be cultural differences. In order to examine this more closely it would be valuable to have a direct comparison between observation and report data by interviewing observed drivers directly after their trip in a way comparable to the one used in our study.

In this study only a small sample of German drivers was examined. This gives some restrictions to the sample. On the motorway, almost all types of drivers are represented, as commercial drivers on transit operate at all daytimes, as commuters are represented at least in the afternoon and as occupational drivers could be asked within their working hours. In the specific city area at least two groups of drivers are missing in the sample, as families with working parents are unlikely to do their shopping within the interview times. Additionally, drivers of trucks and delivery vans usually do not stop at parking places of the shopping centers. The time of data collection was vacation time in Germany, thus an untypical number of families on holiday trips may be found on the motorway. As some special driver groups with accident high risk (e.g. young drivers) or high workload (short-distance commercial deliverers) are missing in the data, this should clearly be obtained in following studies. Thus, more exhaustive studies need to be done in order to achieve a representative picture of distracted driving in Germany.

4. Examinations of the Lane Change Task

As discussed in chapter 2.3.5, easy to use, valid and sensitive tests for the assessment of secondary tasks' effects on driving performance are urgently needed to ensure that only safe systems are brought into traffic. As also discussed, the LCT is the most promising candidate for this challenge but it also leaves the researcher and user with some open questions. For answering some of them, four experiments have been conducted.

One problem is the large differences in baseline performances in the LCT that are found between different laboratories using the LCT. The mean deviation, which is the central measure of the LCT, differs in large numbers between studies (baseline mean deviations between 0.64 m and 1.60 m found by Weir, Kwok & Peak, 2007; Rognin, Alidra, Val, Lescoaut & Chalandon, 2007; Young, Lenné & Williamson, 2011). Therefore it is very hard to compare the results of different studies for different IVIS. One major factor influencing test performance is the level of practice. Training in general improves performance as actions are automated with practice (Lee & Anderson, 2001). This point is not clearly addressed in the ISO norm yet. Thus, in the present work, training effects on LCT performance have been examined in the first three of the presented experiments. They are briefly presented in chapter 4.1; more details are reported in Huemer and Vollrath (2011c).

The fourth experiment deals with the effects of alcohol on driving performance as measured in the LCT setup. It is described in chapter 4.2 and results are published in Huemer and Vollrath (2010b). Here an attempt was made to find the magnitude of performance decrement measured in LCT outcome variables equivalent to driving performance impairing doses of alcohol. At the same time the sensitivity of LCT performance measures as well as added measures was examined.

4.1. Practice effects on LCT baseline performance

The first aim of the following studies was to clarify the large differences between baseline performances found between LCT-using laboratories that were suspected to result from differing training states of the participants. Accordingly, the second aim was to derive the minimum training needs to ensure comparable results between test sites and test results respectively. In the first study, the effect of practice on LCT performance in single task situation is examined. In the second and third study, effects of training with secondary tasks are explored. In these, we compared different training regimes, including practice of both, single task practice in LCT and in the secondary task, as well as dual task practice.

4.1.1. Secondary tasks

The two secondary tasks used for dual task situations were on the one hand the SuRT secondary task (ISO/ DIS 26022, 2007) and on the other hand the Critical Tracking Task (CTT; Dynamic Research, 2006). These tasks were chosen for the following reasons: First, they have been proposed as reference tasks for dual-task performance in the LCT (ISO/ DIS 26022, 2007; Mattes, 2003), secondly they are both visual-manual tasks for which difficulty can be manipulated. And finally, SuRT and CTT were the tasks used in Petzoldt, Bär, Ihle, and Krems (2010) and therefore, results could easier be compared to data which already exist.

The SuRT task is a visual search task. In this task participants have to find a target and then mark and confirm its position in the display. Each display is shown as long as participants do not confirm the current search and thus, the task can be interrupted and restarted at any time. In contrast to the SuRT which is a task that does not need continuous monitoring, many secondary tasks need this continuous operation. As learning to handle two continuous tasks may be different to learning to handle the control of one continuous task and an interruptible secondary task, we also examined the effects of training arrangements combining LCT and the Critical Tracking Task (CTT). In this task, participants have to keep an unstable moving line in the center of a display. Like SuRT, the CTT is recommended as a reference task in the ISO draft of 2007 (ISO/ DIS 26022, 2007). More detailed descriptions on both tasks are found in Huemer and Vollrath (2011c). For the CTT specifically, we wanted to know if in this task participants benefit from a simultaneous training.

4.1.2. Method

Details on the tasks' setup, measures and participants are described in Huemer and Vollrath (2011c). In all three studies, participants have been instructed to complete their lane change as fast and accurately as possible, according to the ISO standard (ISO 26022:2010). They were told that an efficient lane change typically is finished prior to reaching the sign, according to ISO original terms. They were not enforced to finish prior to the sign.

Experimental procedures

Single effects of training on the LCT performance measures

All participants completed forty runs of the LCT in blocks of ten runs. There were two different regimes of runs, as we were interested in any possible effects of breaks between practice occasions.

Dual task training I: LCT and SuRT

Data collection was divided in two steps. Firstly, participants were trained in their specific training regime and secondly, afterwards, a test session was held. In the first step, there were three different types of training: block-training, alternated training, and simultaneous training. For details see Huemer and Vollrath (2011c). After these training sessions, regardless of the condition, each participant had practiced twenty runs of the LCT and at least twenty minutes of the SuRT task. In the second step, a "test session" was held. In these test sessions, participants had to operate both tasks simultaneously. Here, six runs of the LCT with simultaneous operation of the SuRT task were administered.

Dual task training II: LCT and CTT

Design and procedure were similar to the fist dual task study; using ten practice trials and three test trials. However, as the alternated training was shown to be not effective, only the blocked training and the simultaneous training were compared. Further details on the methods are found in Huemer and Vollrath (2011c).

4.1.3. Results

Single effects of training on the LCT performance measures

As there were no differences found between groups, pooled data was tested for performance changes only. In the analysis the main effect of LCT run was significant. As shown in Figure 13, participants started the first run at a mean deviation of about 1.1 m and improve rapidly in the first six runs down to about 0.8 m. Thereafter, performance improves more slowly to about 0.75 m at the end of our testing. For the SDLP while lane keeping phases an improvement of about 10 cm from 23 cm at the beginning to about 13 cm at the end of training was gained by drivers.

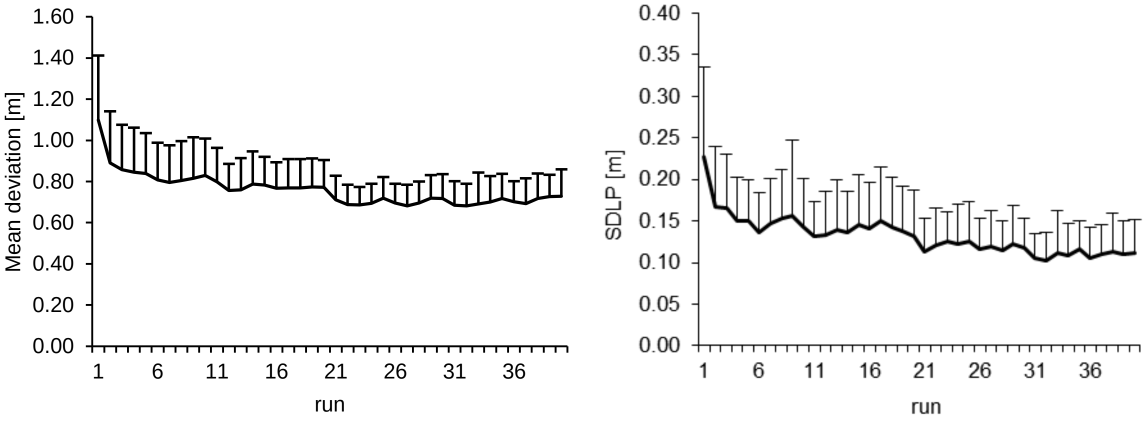


Figure 13: Overall Mean deviations (on the left; Huemer & Vollrath, 2011c) and SDLP while lane keeping only (on the right) in the LCT over time

Dual task training I: LCT and SuRT

Data were analyzed in two steps. Driving performance and performance in the secondary task were analyzed separately for the test session and the training sessions. In the training sessions a main effect of the training regime as well as of the runs. No interaction was found. For SuRT performance both main effects and the interaction effect were significant. In the test sessions, neither main effects nor an interaction was found in driving performance. However, for the SuRT a main effect of run was found indicating an improved in performance over time regardless of the group. Figure 14 shows the effects of the training regimes on performance in the LCT. When looking at the overall mean deviation, performance improved in all three groups during the first five to ten trials in a very similar manner as in the first study. Only the initial peak from the first to the second run was smaller, which may be due to the fact that the participants were able to accommodate themselves to the LCT for about a minute before the first measurement. Additionally, the mean deviation was larger in the group with simultaneous practice in both tasks and this difference remains quite similar until the end of the practice trials. Looking at the SDLP while lane keeping, the pattern was quite similar but even more pronounced. The blocked and the alternated training group had a low SDLP (< 5 cm) from the beginning of training that increased in test sessions up to 20 cm for the alternated group when doing both tasks at the same time. Almost the opposite was found in the simultaneous trained group. These participants started at about 20 cm SDLP and improved down to 7 cm in the end.

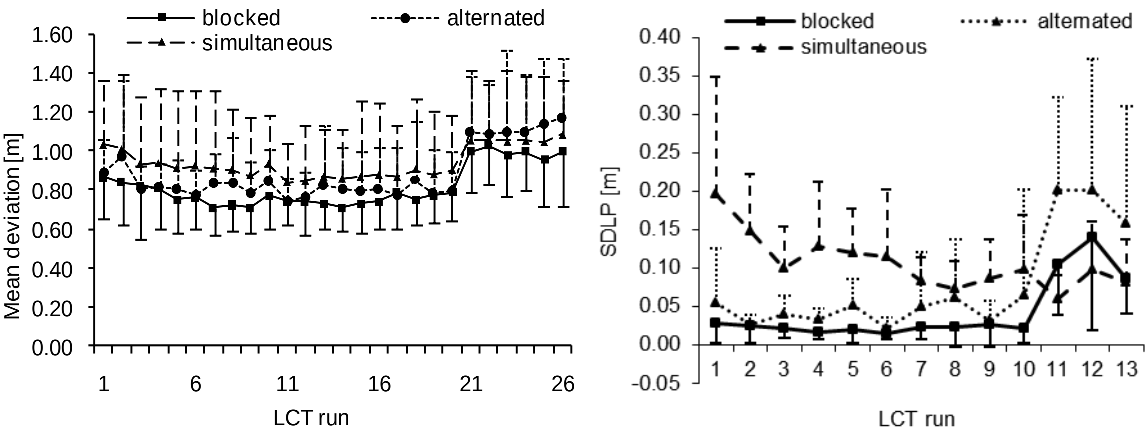


Figure 14: Overall Mean deviations (on the left; Huemer & Vollrath, 2011c) and SDLP while lane keeping only (on the right) in the LCT

As shown in Figure 15, huge differences between training regimes could be found in SuRT performance. The simultaneously trained group showed threefold longer reaction times to SuRT stimuli compared to the other two groups which operated the SuRT in training in single task condition. When looking at the test session performance when every participant operated under dual task condition, SuRT performance for the “blocked” and the “alternated” groups dropped. Here, performance of the “blocked” training group dropped to the “simultaneous” groups´ level, performance of the “alternated” group was even worse. After at least 27 min (1 min + 13 * 2 min) of SuRT practice, participants’ reaction times to stimuli decreased even in the last trials.

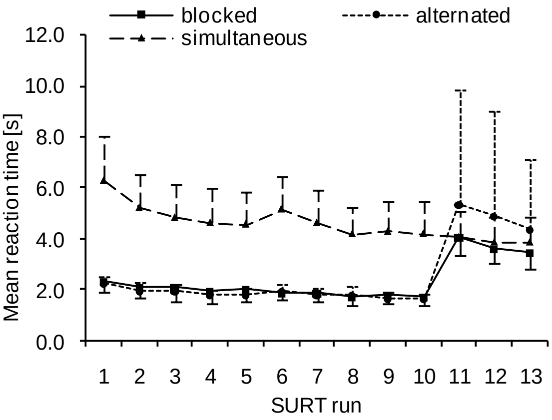


Figure 15: SuRT performance for the different training regimes over time (Huemer & Vollrath, 2011c)

Dual task training II: LCT and CTT

In the training sessions, no effects were found for LCT driving performance measures. In the test sessions as well, no effects on driving performance were found (see Figure 16).

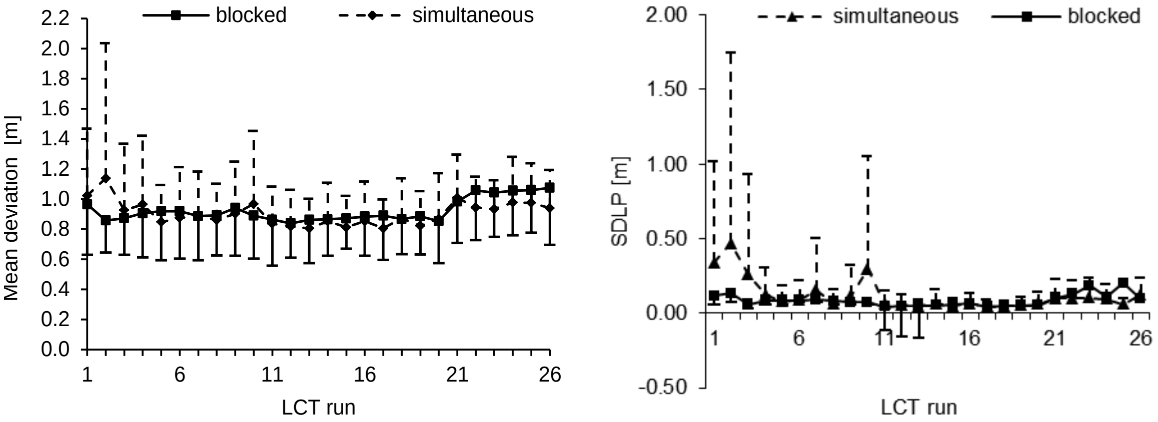


Figure 16: Overall Mean deviations (on the left; Huemer & Vollrath, 2011c) and SDLP while lane keeping only (on the right) in the LCT

Only CTT performance showed main effects of run as well as of training regime, as shown in Figure 17.

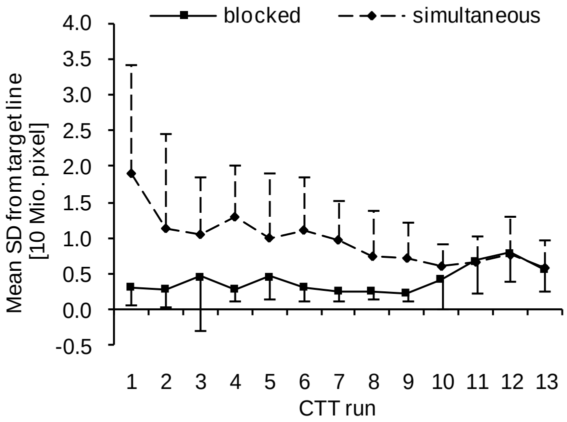


Figure 17: Mean deviations in the CTT performance for the different training regimes over time (Huemer & Vollrath, 2011c)

Quite contrary to expectations, the CTT seemed to be very well applicable to perform without disturbing the driving performance in the LCT. This may be due to the drivers focusing on the driving task which resulted in a performance decrement in the simultaneous group while performance was stable in the single task blocked group.

4.1.4. Discussion

Performance changes in LCT…

In the first of the three presented studies we found a training effect on the LCT performance. This effect was strongest within the first five LCT runs, but still an improvement was found until the tenth run. This result of performance improvements with practice were supported by the second and third study. In the second study, different from the LCT performance, performance in the SuRT was not stable even after the extensive training administered here. SuRT performance improved more slowly and continuously compared to the LCT performance. No advantages of simultaneous training could have been shown. In contrast, LCT performance seemed to improve slower when done with secondary task training. In blocked training, learning seemed to be more homogeneous compared to alternated training. Additionally, it could be shown that the negative effect of the SuRT task on the LCT performance is found even after this extensive training. Thus, training in dual task performance did not influence the sensitivity of the LCT negatively. In the third study no training effects were shown in LCT performance at all. CTT performance improved under simultaneous training. In blocked training, practicing the CTT alone, no effects were found as CTT performance was quite good in this group from the beginning. Thus, during the first ten trials participants seemed to learn how to integrate the CTT within the driving task so that the performance kept improving. However, this seems to be some kind of an implicit learning process as later on, under dual task conditions in CTT trial 11, the blocked learning group performed comparably good compared to the simultaneous learning group. Thus, if one examines the CTT without much training one will come to the conclusion that it does not impair driving. This lack of training in the CTT is at the cost of LCT performance. However, after some training, both tasks can be performed in parallel quite well. To sum this up, for SuRT as well as for CTT, learning patterns changed when performed with the LCT simultaneously compared to single task learning. For both tasks under dual task conditions, a large learning effect was found within the first three trials, which was not found in single task learning, followed by a steady improvement. Task performance in the test sessions for both secondary tasks was at the level of single task learning groups in the end. From this point of view, there seems to be no advantage for the one or the other training regime.

… Imply some training needs.

For practitioners using the LCT as a tool for HMI evaluation, the strong improvements in the first five runs of LCT practice found in the first study imply that participants have to be trained in the LCT to avoid a mixing of the effects of training and secondary tasks. When looking at the results, a minimum training of at least five runs is suggested. The results of the second study confirm the findings of the first study which has shown that a training of at least five, better ten, runs of the LCT alone is needed to get a stable performance. These effects imply that for an effective training of the participants it seems to be best to practice LCT and any secondary tasks alone until a stable performance is found. In the LCT, an absolute minimum of five runs is needed. Taking the performance improvement found thereafter, into consideration ten trials in LCT are recommended for training. For other secondary tasks like the SuRT, even ten trials may not be enough.

Learning Dual-task operation

From a theoretical point, it is interesting to note that single task practice is sufficient to achieve a good dual task performance. Dual task training did, in our studies, not provide any advantage in performance. Thus, it seems that one has to practice tasks for performing them automatically, but does not have to learn how to switch between these tasks. Additionally, it is interesting to see how the different reference tasks differ in their effect. When SuRT and LCT are combined, both tasks are performed worse in the beginning (compared to single task performance). LCT and SuRT performances improve, but small differences to single task performance are even found in the end of the extensive trainings.

When LCT and CTT are combined, performance decrements are to be found in CTT only, but these vanish over time. Drivers thus seem to be able to coordinate CTT and LCT quiet well. This is somewhat surprising because the CTT is a task which demands continuous monitoring. Therefore it was assumed to interfere more with the LCT compared to SuRT, which is a self-paced task. However, drivers seemed to use different strategies in task operation resulting in stronger distraction from the LCT when operating the SuRT. These patterns may be due to different strategies in operation of the secondary tasks. We believe drivers in the SuRT are tending to finish a search which has been started already before looking back at the LCT. This behavior results in longer periods of visual distraction from the road, leading to decrements in the LCT driving performance. It though may be assumed to be the best strategy to finish the SuRT display, as visual search may have to be started from the beginning after looking away. In contrast to this, in the CTT task, short glances seem to be sufficient to assess the bar´s deviation from the target, and corrections can be done with hardly any visual control. Thus, here only short glances would be necessary, resulting in smaller decrements in LCT performance. Comparing these presumed patterns of operating secondary tasks, the LCT seems to be sensitive to visual distraction by means of glance duration away from the driving task. This suggestion has of course to be confirmed with studies including gaze-analysis.

The LCT as a psychological test: implications from the present studies

Reliability, baselines

Unfortunately, the training effects on LCT performance shown in the present studies cannot explain the different mean deviations found in the different laboratories. Even in the first trials the performance in our laboratory was much better than compared to other laboratories. The instructions given to participants are likely to play a major role here, as Young et al. (2011) have pointed out. They state: “Unlike the instructions adopted in other LCT experiments (e.g., Harbluk, Burns, Lochner &Trbovich, 2007; Harbluk, Mitroi & Burns, 2009), the current participants were *not instructed to have completed* their lane change by the time they reach the lane change sign.” (Young et al., 2011, p.616) [Italics by the author of this paper] In the ISO standard (ISO 26022:2010), guidelines for the instruction of participants are given as follows: “Instruct participants to complete the lane change quickly and efficiently. Mention to the participant that an efficient lane change *typically is finished before* the sign is reached.” (ISO 26022:2010, Annex A, p.15) [Italics by the author] In our studies, the ISO instruction was used. This may explain why even in the first sessions 1.15 m was the worst deviation found in the initial training session and deviation went down to 0.78 m in the last training sessions. Even in training sessions starting in dual task mode (LCT and SuRT, first run in simultaneous training), the mean deviation was only 1.05 m. Thus, the instruction to finish the lane change fast may explain these differences. Moreover, providing no clear instructions may also lead to larger deviations between the subjects as some participants change their lane quite slowly while others do it fast. Thus, one would recommend using this ISO instruction in order to obtain a stable behavior between the different participants.

4.2. Alcohol effects on LCT performance: an attempt to find an external criterion

The aim of this study was to contribute to a definition of a cut-off value for the LCT, above which a secondary task should definitely not be done while driving. Following the attempt of ‘quasi-alcohol-standards’ presented in chapter 2.3.7, the first aim of this study was to examine alcohol’s effects on driving performance as measured by the LCT at a BACs of 0.05% to 0.08%. By this, a maximum impairment as measured by a ‘Δ mean deviation’ was searched for as cut-off value for safety critical impairment. As the LCT covers two basic driving tasks one would expect a significant effect of alcohol on performance in the LCT task. The LCT includes both tracking (keeping the lane) and choice reaction (changing the lane when signaled). As performance in the LCT is usually measured by computing an overall deviation from a standardized optimum performance, these two components are averaged. Thus, one would expect that the sensitivity of this task lies somewhere between the sensitivity of tracking and choice reaction time in the area of 0.05 to 0.06 g/dl (see Moskowitz & Fiorentino, 2000). In order to examine the effects of alcohol on LCT performance more closely separate performance indicators in the LCT were computed in order to distinguish between tracking performance and choice reaction.

4.2.1. Method

In this study, 23 participants were tested in a within-subjects design with placebo compared to alcohol with a maximum BAC level of 0.08 g/dl. They were tested multiple times with the LCT before alcohol consumption, during rising BAC, at peak and at descending BAC with the focus to examine alcohol effects at 0.05 and 0.08 g/dl. For details about design, participants, and procedure see Huemer and Vollrath (2010b).

4.2.2. Results

For all dependent measures, differences to baseline conditions were computed. For the overall mean deviation from the ideal trajectory results are shown in Figure 18. Beginning at the third time-point (peak BAC), performance was worse under alcohol as compared to placebo. However, there was no further dose-related change in the magnitude of the difference.

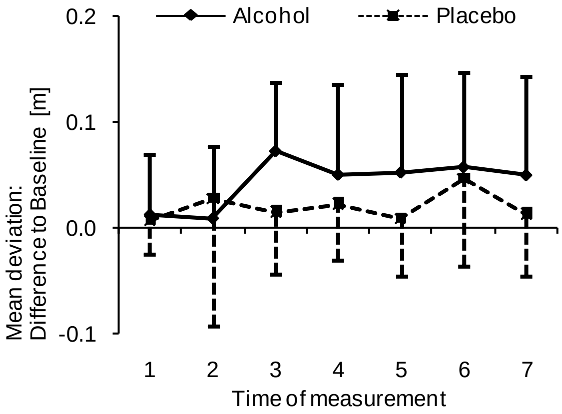


Figure 18: Mean deviation (± SD) in LCT for alcohol and placebo (Huemer &Vollrath, 2010b, p.1986)

For the lane keeping phase, the mean deviation and the standard deviation of lane position (SDLP), both showed significant main effects as well as interactions. As Figure 19 shows, mean deviation increased in both the placebo and alcohol condition with a somewhat larger increase under alcohol. This increase continues until the time-point before the last. The SDLP shows a clear alcohol effect. Performance is somewhat improved under placebo. Under alcohol, SDLP shows a very similar time-course as BAC with the strongest effect at T4 (peak BAC). However, the effect is quite small with 0.02 m (2 cm) at peak BAC. For the lane change phase, alcohol did not show significantly influence on performance.

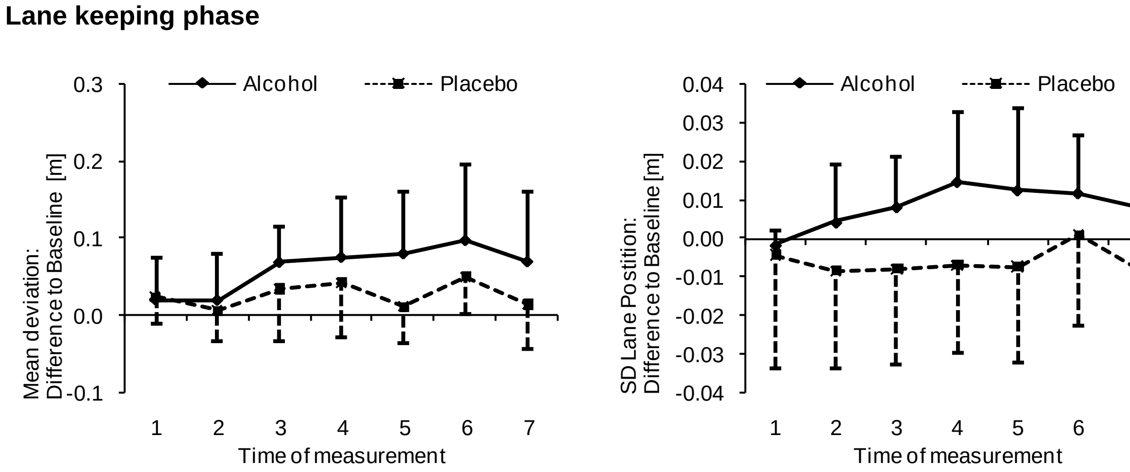
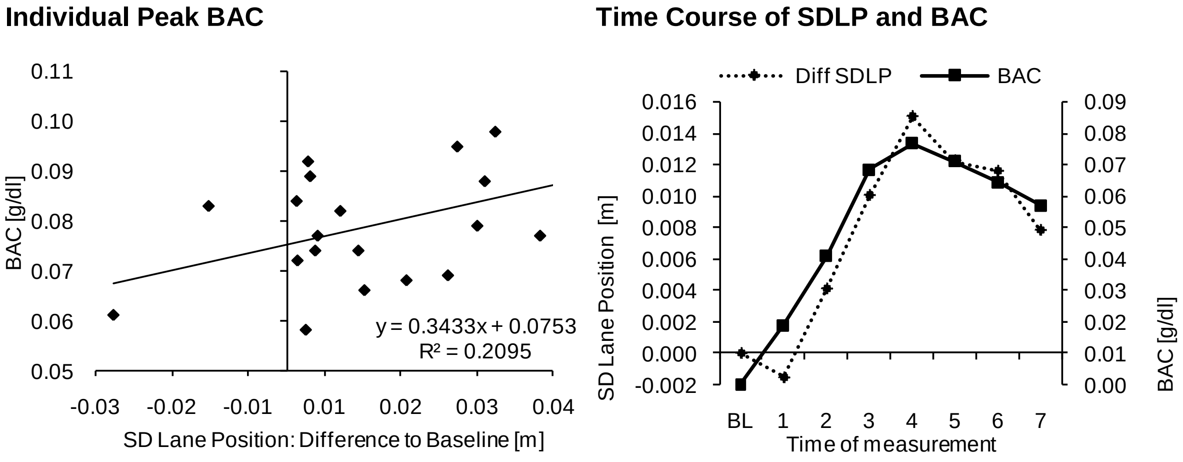

Lane keeping phase

Figure 19: Effects on mean deviation and SDLP during lane keeping (Huemer &Vollrath, 2010b, p.1986)

In a third step of the analysis, the correlation between individual BAC and performance decrement was examined. A multiple regression analysis (stepwise backwards) was computed to predict individual peak BAC including the three mean deviation measures, SDLP and reaction time. The final model includes two driving parameters, reaction time and SDLP. SDLP showed the stronger correlation with peak BAC among these two. Overall, these two parameters account for 33% of the variance of the individual peak BAC level. This shows that there is on the one hand a small correlation between SDLP and peak BAC and on the other hand decrements in SDLP over time are parallel to participants BAC. This relationship is illustrated in Figure 20. However, there is also a strong variation between the subjects.


Individual Peak BAC

Time Course of SDLP and BAC

Figure 20: Differences to baseline in SDLP in relation to individual peak BAC (Huemer &Vollrath, 2010b, p.1987)

4.2.3. Discussion

As expected from the literature about the effects of alcohol on driving performance (Moskowitz & Fiorentino, 2000) a peak BAC of 0.08 g/dl the driving performance in the LCT significantly decreased. The analysis of different phases (lane keeping and lane change) showed that this was especially due to degraded lane keeping behavior under the influence of alcohol. In the detailed analysis SDLP in lane keeping phases turned out to be the most sensitive measure to the impact of alcohol. During increasing BAC, SDLP was the first parameter to show an effect of alcohol. At the elimination phase, SDLP under alcohol was increased even at the last point of measurement. This high sensitivity was also shown at the inter-individual level where SDLP was the strongest predictor of BAC when looking at the largest BAC per subject. The effects were much less pronounced during lane changes, where an effect of alcohol was only found at the largest BAC for reaction time and mean deviation. There is a small relationship between LCT performance as measured using SDLP and individual BAC. It could be shown that parts of the LCT as measured by SDLP are sensitive to the effect of modest levels of alcohol.

Searching a cut-off value

The experiment was aimed to define a cut-off value for performance decrements in the LCT by using alcohol effects as a comparison. This showed to be not possible in a straightforward way, as a comparison of the magnitude of the effects show. When looking at the overall mean deviation which is usually used in evaluations of secondary tasks with the LCT, the alcohol effect at peak BAC sums up to a change of 0.1 m as compared to baseline. If this was used as a criterion for detecting distracting secondary tasks, this would result in excluding a multitude of tasks which are assumed to be safe (see Mattes and Hallén, 2009).

To put it differently: While it is well in accordance with the literature on alcohol, the effect of alcohol on the LCT is substantially smaller than that of different secondary tasks. In the LCT, people seem to be able to react to the lane change signs very well even under higher concentrations of alcohol. Only their lane keeping performance deteriorates to some amount. It seems that people who are under the influence of alcohol are still able to manage simple, short, foreseeable tasks like the lane change of the LCT, while tasks requiring continuous supervision and correction suffer from alcohol. With regard to using alcohol effects in order to define a cut-off value for the distraction due to secondary tasks, the straightforward way that was attempted here failed. The negative effects of alcohol on the LCT are different from those usually found with secondary tasks. Especially tasks which require eye-hand-coordination and lead to looking away from the road for a longer time lead to very strong deterioration of performance in the LCT.

Motivation as a moderating variable in the impairment of controlled actions

In general, as shown in the meta-analyses on alcohol effects, these are stronger when controlled actions are concerned. However, when a driving situation is examined including sub-tasks requiring either controlled actions or automatic behavior, alcohol effects are stronger for automatic behavior. It may be that human action control processes are responsible for this result. In research of acquired alcohol tolerance it has been shown that subjects are able to compensate for alcohol effects if they are rewarded for good performance quality (for an overview, see Sdao-Jarvie & Vogel-Sprott, 1992). However, this compensation depends on a feedback about the quality of performance. If, for example a non-contingent reward is given after the experiment, this does not result in an improved performance. These findings are interpreted to reflect action control processes where humans optimize their behavior to gain positive reinforcement. The quality of performance can easily be detected and self-assessed during lane-change phases. This enables subjects to compensate by concentration on the time-point when the sign becomes visible. As the lane change involved controlled actions this also enables to concentrate on this control and to compensate for alcohol effects. Thus, the alcohol effect for this part of the task is only found at the highest BACs. In contrary, during the lane keeping phase with automatic behavior these compensatory processes may not be involved as the behavior is not cognitively controlled.

Gawron and Ranney found a similar effect in 1988 in comparing moderate (0.07g/dl) and higher (0.12g/dl) doses of alcohol in a driving simulation with a monotonous driving situation. In the high alcohol condition, lane keeping performance decreased. Additionally, reaction time to suddenly appearing obstacles was examined which corresponds to controlled actions including an interpretation of the situation, planning a course of action and initiating and performing this action. The reaction times were not negatively affected by alcohol. In contrary, reaction time in both alcohol conditions was even faster than in the sober condition. Gawron and Ranney (1988) suggested that this could be due to a higher arousal of the subjects in the alcohol condition. However, this does not explain the decrease of lane keeping performance.

Thus, when looking at different tasks in the laboratory, controlled actions are more prone to the effects of alcohol than automatic behavior. Alcohol affects complex cognitive processes more strongly than simple, well-learned processes. However, as their name implies, complex controlled actions are also more subject to conscious efforts of the subject to control these actions. If the driver’s aim is to drive safely or show a good performance (e.g., in a psychological experiment or when a police officer is stopping the driver) he or she will try to compensate for alcohol’s negative effects. This compensation can be done more effectively in controlled actions. Thus, in the case of the lane change task, alcohol effects are less pronounced during lane change as compared to lane keeping. In the experiment of Gawron and Ranney (1988) reaction times as controlled actions were even improved under alcohol. From this point of view, this pattern of effects is due to compensatory processes and does not reflect the ‘pure’ alcohol effect. Erblich and Earleywine (1995) argue in a similar manner from the results of an experiment on dual task performance under the influence of alcohol. They found that in dual task conditions under alcohol, the most salient task seems to be “protected”. From their point of view, subjects under the influence of alcohol focus their attention on this salient task and are thus able to compensate alcohol effects. Rakauskas et al. (2008) interpret the effects of alcohol on dual task performance in their study in a similar way.

With regard to this discussion, alcohol effects on driving related tasks are not quite as straightforward as implied by the meta-analyses. Taken per se, alcohol effects on driving performance are the stronger, the more complex the involved cognitive processes are. The more difficult a task is the lower is the BAC where it is affected and the stronger are the alcohol's effects. However, there is also the driver with his or her aims including wishing to drive safely, to perform well in a laboratory task or to not be detected as intoxicated by the police. This motivation will inspire compensatory processes which are the more effective the more controlled actions are involved. This compensation may also profit from experience as more options become available and alternative options are better learned by experienced drivers. Of course, additional research is required to understand these compensatory processes better.

It is difficult to judge how these results are applicable to real-life driving behavior. If the interpretation is correct, errors in driving tasks involving automatic behavior like lane keeping would be a main reason for alcohol accidents. To our knowledge, an according analysis of alcohol accidents including a classification of the type of task involved in causing the accident is still missing. As far as complex controlled actions are involved in the accidents one would assume that this may either be due to BAC levels which cannot be compensated anymore or that these situations arose too suddenly for any compensatory action. In the laboratory experiments, subjects performed well-learned tasks again and again under the influence of alcohol. Thus, they had good opportunities to learn effective compensatory actions as well. This is probably not the case in real life driving. This is the second point for which further research in the laboratory (to understand compensatory actions better) and in the field (accidents studies to understand the causes of alcohol crashes better) is needed.

'Compensation' as mentioned here, is needed to be motivated for its occurrence. In laboratory scenarios, most subjects are motivated to perform well. It can also be assumed that drivers in real traffic are motivated to drive safely, even if alcohol-induced. However, including this new dimension into the discussion on effects on driving performance, other aspects of motivation also need to be considered, too. One crucial aspect of motivation then clearly is the decision of doing a secondary task while driving or even the decision for driving drunk. Implications of inclusion of this dimension are discussed further in chapter 4.3.

Implications for LCT incorporating the small effects found in this alcohol study

However, the pattern of alcohol effects found in this study gives rise to some caution for interpreting effects in the LCT. If a secondary task does not lead to a significant decrease in performance in the LCT, this may only be interpreted in the way that this task does not substantially withdraw (visual) attention from driving. As the standard performance measure of the LCT, the mean deviation from an ideal trajectory, is not well suited to detect performance decrement like those resulting from an alcohol intoxication, it may be that this secondary task has some other negative effect (similar to that of alcohol) which does not show in the LCT but may become obvious if another measure of driving performance would have been used. Speech tasks or verbal human-machine-interactions may be an example for these kinds of tasks. Their effect on the LCT is much less pronounced than the effect of visual-manual HMIs (e.g., Mattes, 2003). However, there are some studies (e.g. Charlton, 2009; Drews, Pasupahi & Strayer, 2008) which indicate that these tasks may also influence the driving performance negatively when appropriate driving tasks are examined.

4.3. Conclusions and implications for LCT use as a tool of distraction measurement

In the evaluation of in-vehicle systems or secondary tasks there are two possible main goals: the one is estimating the effects of some device in the most sensitive way to know most about the possible effects. The other goal is to compare a system with a safety standard and thereby assessing its safety-critical impact on driving. These different goals have different implications for the creation of an evaluation tool. For the first goal, a tool is needed that is most sensitive to the effects that need to be shown. The LCT, as it is stated in the scope of the ISO norm (ISO 26022:2010), is such a tool:

> “This Standard describes a dynamic dual-task method that *quantitatively measures human performance degradation* on a primary driving-like task while a secondary task is being performed. The result is an *estimate of secondary task demand*. The method is laboratory based, and this Standard defines the method, the minimum requirements for equipment to support the method, and procedures for collecting and analyzing data deriving from the method. The method is applicable to all types of interactions with in-vehicle information, communication, entertainment and control systems; manual, visual, haptic and auditory, and combinations thereof. Secondary tasks requiring speed variations to be performed can not be tested with this method. It applies to both Original Equipment Manufacturer (OEM) and aftermarket in-vehicle systems. It also applies to systems either portable or integrated in the vehicle. The driver behavior principles, the specific task procedures and driving task correspond only to the operation of a passenger car.” (p.1) [italics by the authors of this work]

The results of the LCT are, according to this, estimates of secondary task demands which can be compared between secondary tasks within the actual tests metrics. So, what do the results presented above imply for the evaluation of secondary task demands with the LCT?

First, using the LCT as a sensitive tool to performance degradation effects of any added task, and by this to compare effects of different systems, it clearly has to be used with the same test protocol. As the studies on training were not able to clarify the differences found between test sites using the LCT, the most promising candidate for these differences is the instructions given to the participants. Thus, clearly the same instructions concerning the lane change have to be delivered to participants to obtain comparable driving patterns.

Second, the LCT and any secondary task have to be practiced. All tasks should be learned well by participants to minimize interaction effects of practice and secondary task demand. In this line of interpretation, LCT performance should not be interpreted sole but compared to reference tasks in order to lead to results that are comparable between tests sites. Thus, participants have to show stable performance in all used tasks before starting tasks' effects examination in the LCT setup. The studies on training effects on LCT performance showed that participants strongly improve within their first LCT runs. It was also shown that different visual manual secondary tasks have different influence patterns on performance improvement in LCT as well as in their own performance. Based on the results from the first, training-LCT-only study, we suggest to supply a training of at least five, better ten, LCT runs prior to baseline performance data collection. Results from the second training study confirm the findings, in the way that a training of at least ten runs of the lane change task alone is needed to get a stable performance. The second study also showed a need for training in the suggested reference task SuRT. Additionally to single task training for all used tasks, to be on the safe side, we recommend letting participants practice the dual task situation for at least two LCT runs to minimize any potential distraction effect of the new situation on performance.

Third, in the alcohol study it was found that LCT performance is affected negatively by alcohol. However, this results only in a small degradation of the core performance indicator of the LCT, the overall mean deviation. The most sensitive measure for alcohol effects was found to be the SDLP while lane keeping. As performance under 0.08‰ BAC was only found to be 0.1 m worse compared to sober drivers in the overall mean deviation, this impairment is found not to be a straightforward cut-off criterion for secondary tasks as most tasks (and even the reference tasks used in the training studies) lead to stronger impairment. Looking at this result from a different point of view, it raises some caution for interpretation of non-significant results in LCT examinations. Furthermore the results show that a small or not significant effect of some task on the performance of the LCT as measured in the overall mean deviation does not necessarily mean that this condition does not impair driving. It is undisputed that BACs of 0.08 g/dl does impair driving performance and does increase the risk of accidents. As this impairment has only little influence on the standard measure of driving performance in the LCT, this task measure alone cannot be used as the only benchmark for secondary tasks easily. Additional measures in the LCT and additional tasks covering a wider range of driving skills and abilities are needed in order to assess driving safety effects of secondary tasks. In the present studies, the SDLP while lane keeping turned out to be the most sensitive measure and thus should be investigated further for its diagnostic qualities.

To sum up, if the LCT is supposed to be used in the line of its scope, some improvement could be achieved to enhance sensitivity. Firstly, more sensitive metrics than the standard “Mean Deviation” are available, as the result for the SDLP show. Some additional measures are suggested in the ISO norm and should, from our point of knowledge, be used for evaluations of secondary tasks. Second, if usual use of a system and its effects on driving should be evaluated, participants should be trained well in both operations, to give a realistic picture of distraction effects of the system without mixing these effects with LCT practice deficits. An additional advantage in test methodology is the higher test sensitivity in testing trained drivers, as variability between participants is substantially reduced during practice. Thus, error variability of the test is reduced as well.

A different approach is needed, if an evaluation tool is used as a safety criterion. On this, for example, Green (2009, p.456) states:

> “The lack of acceptance criteria in […] 26022 is in particular noteworthy …]. For the lane change test […] there is no agreement as to which performance measures to use - the mean delay in missed lane change initiation, number of missed lane changes, mean task completion time, total number of errors, and numerous measures of lane position and path error. In part, this reflects the fact that the test is new and research is ongoing. However, it also reflects the lack of a useful model of how people drive that can predict the effects of performing secondary tasks while driving.”

In the in 2010 established norm, the core measure of LCT is the overall mean deviation (ISO 26022:2010). In this mean deviation, the different other measures as mentioned by Green in 2009, are reflected to differing amounts. Missed lane changes as well as delays in lane change initiation lead to a far bigger mean deviation than impaired lane keeping in the lane keeping phases does (see (ISO 26022:2010, Annex B.4, p. 19). As shown in the present examinations, though, the SDLP while lane keeping was the most sensitive measure of the LCT. It was also sensitive to the small effects of moderate doses of alcohol. If in the SDLP measure of the LCT a decreased performance is found, drivers are substantially impaired in operational control of a vehicle.

As stated in chapter 2.3.7, the only criterion of accepted impairment (as used for legislation in most countries) that is related to accident risk is the impairment induced by alcohol. Thus, if the impairment by the legal amount of alcohol is set as the accepted impairment in driving, and a test like the LCT is sensitive to this impairment, the alcohol equivalent can be used as a cut-off value, even if most tasks will be rated as not suitable for driving (see chapter 4.2.3). Of course, this would be a worst case scenario in the current LCT test setup as participants here are kind of forced to continuously operate secondary tasks. On the other hand, as is shown for drugged driving or driving with medications, this “impairment criterion” of alcohol is not to be understood as a behavioral one but as a political criterion. If alcohol would really be used as impairment criterion, many normal secondary tasks should be prohibited and some drugs should be allowed in driving (see Ramaekers, 2011 Stutts, et al. 2001; Dingus et al., 2006).

As also found in the alcohol study, drivers under the influence of moderate doses of alcohol seemed to be able to compensate for the effects of alcohol in the lane change phases of the LCT, not showing strong impairment effects in reactions to the lane change signs. This can be interpreted as a motivational effect by putting effort in protection of the main task, here, the driving task. If these motivational effects want to be considered as well in the evaluation of secondary tasks, e.g. in the use of in-car devices, the test used should be appropriate to let participants “protect” the driving task.

One possibility would be to let participants decide when (and even if) to do the secondary task within the test scenario (like Metz, Schömig & Krüger, 2011). Here, the “useful model of how people drive that can predict the effects of performing secondary tasks while driving” as needed following Green (2009, p.456) takes its role. Even if the Lee & Strayer (2004) model (see Figure 3) is not a computational one, it is useful in this case. Incorporation of motivational aspects of driving and secondary task operation in evaluation of tasks imposed risks would lead to other kind of tests, as here not only the operational level of driving is concerned, but also the tactical level.

To sum up, the LCT should not be deemed to lack of a criterion metric, as no empirically formulated idea of criterion in terms of an accepted risk or accepted impairment exists. The test can be used to evaluate systems in a way of selecting the best design, excluding those systems that do show effects in missed lane changes, resulting in large mean deviations and perhaps even in resulting in impaired lateral control.

5. Conclusions

5.1. Achievements

In the present work, two areas of necessary research on driver secondary tasks have been addressed. First, data on secondary task frequency was gathered for German Drivers. Additionally to pure frequencies and durations of tasks, it was also possible to identify driver groups with different patterns. The detailed analyses of tasks and the drivers' opinions, to which extent tasks imposed dangers, give useful hints for further research. On the one hand, tasks have been found which need a closer look. On the other hand, those tasks that seem to be very risky and complex but are underestimated by the drivers could have been identified. In sum, the interviews showed that not only the technology induced tasks are potentially dangerous. At the same level, interactions with passengers other than just talking, daydreaming or planning tasks and complex other tasks like reading or writing showed to be of long durations and received high riskiness ratings by drivers. Thus, if handling the “drivers impaired by distracting activities” topic, these tasks need to be included.

In the second part of the work, a special test for assessing driver secondary tasks' effects on driving related performance, the Lane Change Task (LCT; ISO 26022:2010) was examined. Here, it could be shown that the LCT (though being an ISO certified standard now) is not standardized enough for being used reliably and validly yet. Some clear needs can be derived from the examination. At first, training status of participants needs to be equalized. If participants are wanted to be familiar with the test setup, a minimum training in the LCT as well as in the secondary tasks is needed until drivers show a stable performance. As the studies on training could not solve the puzzle of differing baselines between test sites, a clarification of the influences of the different instructions is needed and clearly only one of the options should be used. Examination of alcohol effects on LCT performance revealed the LCT to be sensitive to alcohol in lane keeping measures, most sensitive in the SDLP. But it also showed that moderate doses of alcohol as used in the experiment do not have a comparable large effect on the used measures as secondary tasks mostly have. Thus, defining a criterion by means of an alcohol standard was not possible. Further attempts are required if one wants to use the LCT to measure the absolute distraction effect. However, the LCT is well suited for comparisons between different HMIs or different tasks.

5.2. Implications

For the LCT, results like this have also been found for telephone use as early as 2002 by Burns and for different IVIS in 2009 by Wynn (2009). In both studies the effects of the secondary tasks were much stronger than those of the legal limit of alcohol. One prominent argument against the use of the alcohol criterion is the differing patterns of effects between distractions and intoxication by alcohol. Stevens, Burnett and Horberry (2010) also argue that alcohol impairs drivers constantly while secondary tasks do this only at concrete moments in time. But this is not the whole truth. A driver carrying out a secondary task may not be distracted during the whole trip, but if he or she is engaged in the task, the impairment is present. On the other side, drivers under the influence of alcohol may not be impaired during the entire trip as they may be able to compensate for alcohols effects by increased effort, especially when they are aware of their impairment.

Thus, the puzzle of evaluation of possible impairments by drivers' state or activities is not solved satisfyingly yet. There are differing possibilities of what the outcome of such an evaluation should be and, depending on the outcome, different information and methods are needed.

If the worst case, the most impairing effect of any condition on driving, is looked for, hard test conditions are needed. For example, if all drivers are wanted to be protected from the adverse effects of secondary tasks; the most vulnerable groups need to be tested for the effects. Older drivers as well as young and inexperienced drivers are reasonably suspected to be more impaired by secondary tasks. Thus, if searching for the hardest criterion, these drivers need to be the reference. Here, using the LCT as a test method for safety critical situations with new in-vehicle systems, the strong training effects found here could be used for testing. If participants in such a test scenario would be inexperienced in LCT as well as in the new system´s operation, these factors could demonstrate a worst-case scenario to test the most distracting effects of a system.

However, with respect to real driving, people will often operate different IVIS and other tasks and thus will get quite used to them. Thus, on the one hand one could argue that measuring the effect of well-learned tasks handling or even physiological conditions is more analogue to real driving. In the latter scenario, the average impairment and / or risk would be looked for.

If not only the task-to-blame but the driver-task-vehicle system is surveyed, drivers' motivations and available compensation strategies need to be taken into account as well. However, this approach will not lead to implications for legislation in the short run. Though this approach is needed from a researcher's point of view, the attentional processes underlying dual task operation in a dynamic and risky environment need to be understood first. Some questions concerning these processes arose from the present work. First, in the interview studies it turned out that drivers' ratings of riskiness of tasks differ within some task groups from the objectively found risks. Knowing how people "calculate" their feeling of risk may help to understand their willingness to engage in risky behaviors and may help to prevent it. The second question is about the awareness of impairment. If drivers are able to compensate for impairing effects and sometimes do not compensate; are they not aware of their impairment? For drugs, the non-awareness may be part of the substances effects, but what about secondary tasks? What about engaging conversations with a colleague? How does a task reach this salience, that it leads to neglecting the driving task and how might this attentional shift be prevented? For answering these questions, research efforts need to be made in basic research on attentional processes in multitasking and their modeling (as done by Salvucci and Taatgen, 2010), as well as in field studies on driver behavior. Research needs that can be derived directly from the present work are presented in chapter 5.4.

5.3. Limitations

Only a small sample of German drivers has been available for this work to get interview data on the frequency and duration of secondary task occupation. As mentioned in chapter 3.3.3, some driver groups that are suspected to be even more engaged in secondary tasks than the interviewed ones, are not represented in the sample. A validation of the method is ongoing in a study conducted at the German Aerospace Center combining the interview with a naturalistic driving scenario. Its results are expected to give hints for development needs on the method.

In the LCT studies training effects have been considered for visual-manual tasks only. Other task groups like cognitive, manual, or oral-audio tasks have not been considered here. The alcohol effects in the last study have not been compared to any secondary or reference task within the same sample, which would have been interesting in order to fully to compare effect sizes. For all LCT experiments, no gaze data have been obtained. Especially for the training study for comparison of strategies drivers used in operation of the SuRT and the CTT task, this would have been useful.

For adequate evaluation of different secondary tasks and perhaps even drivers' states, not only the operational level of driving should be tested like it is done in the LCT, but also those that measure performance at the tactical level of the driving task. At the operational level, a car-following scenario should be integrated, even if Ramaekers (2011) showed the SDLP to be the most sensitive measure for all the tested drugs in the DRUID project. Thus, data of the presented experiments are needed to be proven in appropriate settings.

5.4. Further Research Needs

Though gathering much data in a short time, the sample of the interview study was by far not representative for German drivers. Thus, further interviews are needed to collect data for the missing driver groups like small delivery vans in cities and for missing conditions as weekends, nighttime driving and driving on rural roads. It is also supposed to go deeper into the details of tasks execution in the interviews. Reasons for risk and danger estimates should be given by drivers as well as a general frequency of the tasks reported in their driving. Additionally, drivers should be asked about tasks in a way which enables researchers to do task analyses later on. Based on these task analyses, the existing and most prominent and most dangerous tasks then could be integrated in the psychological models of driving and the proposed levels of control.

Looking at this from the other side, test scenarios for impairing effects should include at least the lower two levels of control for any task or driver's state to make sure that all possible effects are inquired. Here the test scenarios of the DRUID project (Ramaekers, 2011) should be taken into consideration. For further development of the LCT, the diagnostic qualities of the different relevant measures in the tasks setting need to be further investigated. Results as found for the sensitivity of the SDLP need to be replicated. As well, other artificial tasks and their special effects on LCT metrics need to be investigated. Adjacent gaze analyses will help to interpret drivers' strategies in task operations. A study investigating and comparing measures sensitivity to visual-manual, cognitive-audio and manual tasks is currently done by the author.

To be able to investigate drivers' strategies in a more ecological valid setting, drivers need to be able to skip tasks whenever they feel not to be able to drive safe while doing them. Therefore, test scenarios including this behavior need to be developed. An attempt to this was made by Metz, Schömig & Krüger (2011) and should be further developed and investigated with other tasks as well.

As stated in chapter 2.3.7, in the long run the aim should be to bring together performance impairment and crash risk. The approach presented in the DRUID project could be an interesting way to advance on this question. Thus, it would be interesting to conduct a meta-analysis on secondary task in a comparable manner as done by Schnabel (2011). Here, all experimental work on additional tasks in driving related scenarios would be classified based on task analyses. Afterwards, these tasks effects on the driving performance related measures would be classified.

Additionally, in-depth analyses on crashes related to distracted driving are needed. Therefore, it is urgently needed to include information on drivers' inattention or their additional tasks occupation into crash reports provide by the police. For calculation of risk measures as odds ratios or relative risks, the case-control studies could be conducted.

6. References

§24a StVG. Retrieved October 25th, 2011 from http://www.gesetze-im-internet.de/stvg/__24a.html.

Af Wåhlberg, A., Dorn, L., Kline, T., 2011. The Manchester Driver Behaviour Questionnaire as a predictor of road traffic accidents. *Theoretical Issues in Ergonomics Science 12 (1)*, 66–86, doi:10.1080/14639220903023376.

Arnedt, J.T., Wilde, G.J.S., Munt, P.W., MacLean, A.W. (2001). How do prolonged wakefulness and alcohol compare in the decrements they produce on a simulated driving task? *Accident Analysis and Prevention, 33 (3),* 337-344.

Barker, C. (2007). Key findings from focus group research on inside-the-vehicle distractions in New Zealand. In: I. J. Faulks, M. Regan, M. Stevenson, J. Brown, A. Porter, & J. D. Irwin (Eds.), *Distracted Driving* (pp. 213–254). Sydney, NSW: Australasian College of Road Safety.

Bellet, T., Bailly-Asuni, B., Mayenobe, P., & Banet, A. (2009). A theoretical and methodological framework for studying and modelling drivers' mental representations. *Safety Science, 47 (9),* DOI: 10.1016/j.ssci.2009.03.014.

Bernotat, R. (1970). Operation Functions in Vehicle Control, Anthropotechnik in der Fahrzeugführung*. Ergonomics, 13*, 353-377.

Borkenstein, R.F. (1974). The role of the drinking driver in traffic accidents. *Blutalkohol, 11.*

Bortz, J. & Döring, N. (2006). *Forschungsmethoden und Evaluation für Human- und Sozialwissenschaftler (4. Auflage).* Berlin: Springer.

Bruyas, M.-P., Brusque, C., Tattegrain, H., Auriault, A., Aillerie, I. & Duraz, M. (2008). Consistency and sensitivity of lane change test according to driving simulator characteristics. *IET Intelligent Transport Systems, 2 (4),* 306-314.

Burns, P., Harbluk, J., Trbovich, P., & Lochner, M. (2006). *Evaluating Tasks with the LCT.* Paper presented at the Driver Metrics Workshop, Ottawa.

Burns, P.C., et al., 2002. *How dangerous is driving with a mobile phone? Benchmarking the impairment to alcohol.* Crowthorne, Berkshire: Transport Research Laboratory (TRL), TRL 547.

Charlton, S. G. (2009). Driving while conversing: Cell phones that distract and passengers who react. *Accident Analysis and Prevention, 41,* 160-173.

Collet, C., Guillot, A., Petit, C. (2010). Phoning while driving I: A review of epidemiological, psychological, behavioural and physiological studies. *Ergonomics, 53 (5),* 589-601.

Dawson, D., Reid, K. (1997). Fatigue, alcohol and performance impairment. *Nature, 388,* 23.

Dongens, E. (1999). A conceptual framework for active safety in road traffic. *Vehicle system dynamics, 32,* 113-128.

Drews, F. A., Pasupahi, M., & Strayer, D. L. (2008). Passenger and cell phone conversation in simulated driving? *Journal of Experimental Psychology: Applied, 14(4),* 392-400.

DRUID. (2011). Retrieved October 24th, 2011 form www.druid-project.eu.

Dynamic Research Inc. (2006). *Critical Tracking Task.* Retrieved May 30th, 2011 from http://www.dynres.com.

Engström, I., Gregersen, N.P., Granström, K., & Nyberg, A. (2008). Young drivers – Reduced crash risk with passenger in the vehicle. *Accident Analysis and Prevention 40,* 341–348.

Engström, J. (2011). *Driver distraction research priorities Input from US-EU Driver Distraction and HMI working group.* Presentation at the 2nd International Conference on Driver Distraction and Inattention, Gothenburg, Sweden, September 5th to 7th, 2011.

Erblich, J. & Earleywine, M. (2005).Distraction does not impair memory during intoxication: support for the attention-allocation model. *Journal of Studies on Alcohol, 56(4),* 444-448.

Frese, M. & Zapf, D. (1994). Action as the core of Work Psychology: A German approach. In: Triandis, H. C.; Dunnette, M. D. (Hrsg.): *Handbook of industrial and organizational psychology* (pp. 271-340). Palo Alto/Calif.: Consulting Psychologists Press.

Gawron, V.J., Ranney, T.A. (1988).The effects of alcohol dosing on driving performance on a closed course and in a driving simulator. *Ergonomics, 31 (9),* 1219-1244.

Glaze, A. L., & Ellis, J. M. (2003). *Pilot Study of Distracted Drivers.* Transportation Safety and Training Center, Center for Public Policy: Virginia Commonwealth University.

Gordon, C. (2005). *Driver distraction: An initial examination of the 'attention diverted by' contributory factor codes from crash reports and focus group research on perceived risks.* Received July 27th, 2009 from http://www.ipenz.org.nz/ipenztg/papers/2005_pdf/04_Gordon.pdf.

Gordon, C. (2007). Driver distraction related crashes in New Zealand In: I. J. Faulks, M. Regan, M. Stevenson, J. Brown, A. Porter, & J. D. Irwin (Eds.), *Distracted Driving* (pp. 299–328). Sydney, NSW: Australasian College of Road Safety.

Green, P. (1998). *Visual and Task Demands of Driver Information Systems.* Technical Report: UMTRI-98-16. Ann Arbor, Michigan, USA: The University of Michigan Transportation Research Institute.

Green, P. (2009). Driver Interface Safety and Usability Standards: An Overview. In: Regan, M.A., Lee, J.D., Young, K.L. (Eds.), *Driver Distraction: Theory, Effects and Mitigation* (pp. 445-464). Boca Raton, FL: CRC Press.

Hacker, W. (2005). *Allgemeine Arbeitspsychologie: Psychische Regulation von Wissens-, Denk- und körperlicher Arbeit. (2. Auflage).* Bern: Verlag Hans Huber.

Hanowski, R.J., Perez, M.A., & Dingus, T.A. (2005). Driver distraction in long-haul truck drivers. *Transportation Research Part F 8 (6),* 441–458.

Harbluk, J.L., Burns, P.C., Lochner, M. & Trbovich, P.L. (2007). Using the lane-change test (LCT) to assess distraction: tests of visual-manual and speech-based operation of navigation System interfaces. In: *Driving Assessment 2007.* Stevenson, Washington.

Harbluk, J.L., Mitroi, J.S., Burns, P.C., (2009). Three navigation systems with three tasks: using the lane change test (LCT) to assess distraction demand. In: *Fifth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design*. Big Sky, Montana.

Huemer, A.K. & Vollrath, M. (2010a). *Ablenkung durch fahrfremde Tätigkeiten - Machbarkeitsstudie.* Projekt FE 82.376/2009. Bundesanstalt für Straßenwesen.

Huemer, A.K. ,& Vollrath, M., (2011a). Driver secondary tasks in Germany: Using interviews to estimate prevalence. *Accident Analysis and Prevention, 43,* 1703–1712.

Huemer, A.K., & Vollrath, M. (2010b). Alcohol-related impairment in the Lane Change Task. *Accident Analysis and Prevention, 42,* 1983–1988.

Huemer, A.K., & Vollrath, M. (2011b). *Driver secondary tasks in Germany: Detailed analysis of face-to-face interviews.* Paper presented at the 2nd Conference on Driver Distraction and Inattention, September 5th to 7th, 2011, Gothenburg, Sweden. Available online at: http://www.chalmers.se/safer/ddi2011-en/program/papers-presentations

Huemer, A.K., & Vollrath, M. (2011c). Learning the Lane Change Task: Comparing different training regimes in semi-paced and continuous secondary tasks. *Applied Ergonomics.* (submitted).

ISO 26022:2010. *Road vehicles e ergonomic aspects of transport information and control systems - Simulated lane change test to assess driver distraction.*

ISO/DIS 16673.2 (2005). *Road vehicles – Ergonomic aspects of transport information and control systems – Occlusion method to assess visual distraction due to the use of in-vehicle-systems.*

ISO/DIS 26022 (2007). *Road vehicles e ergonomic aspects of transport information and control systems - Simulated lane change test to assess driver distraction.*

Jäncke, L., Musial, F., Vogt, J., Kalveram, K.T. (1994). Monitoring radio programs and time of day affect simulated car-driving performance. *Perceptual and Motor Skills, 79,* 484-486. doi: 10.2466/pms.1994.79.1.484

Johansson, E., Engström, J., Cherri, C.,Nodari, E., Toffetti A. , Schindhelm, R. & Gelau, C. (2004). AIDE IST-1-507674-IP *Review of existing techniques and metrics for IVIS and ADAS assessment.* Deliverable No. D 2.2.1. Received October 25th, 2011 from www.aide-eu.org/pdf/sp2_deliv_new/aide_d2_2_1.pdf.

Johnson, M. B., Voas, R. B., Lacey, J. H., McKnight, A. S., & Lange, J. E. (2004). Living Dangerously: Driver Distraction at High Speed. *Traffic Injury Prevention 5 (1),* 1–7.

Klauer, S.G., Dingus, T.A., Neale, V. L., Sudweeks, J.D., & Ramsey, D J. (2006). *The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data* (DOT HS 810 594). Virginia Tech Transportation Institute.

Knoche, A., Legrand, S.- A. & Verstraete, A. (2011). *How to define per se limits: a general approach.* Presentation at the DRUID Final Conference, September 27th to 28th, 2011, Cologne, Germany.

Krüger, H.-P., Kazenwadel, J. & Vollrath, M. (1995). Grand Rapids effects revisited: Accidents, alcohol and risk. *Alcohol, Drugs and Traffic Safety - T'95 - Volume 1* (pp. 222-230).

Krüger, H.-P., Kohnen, R., Diehl, M., & Hüppe, A. (1990). Auswirkungen geringer Alkoholmengen auf Fahrverhalten und Verkehrssicherheit. *Forschungsbericht Nr. 213.* Bergisch Gladbach: Bundesanstalt für Straßenwesen.

Lansdown, T.C. (2010*). Frequency and Severity of In-Vehicle Distractions – A Self-Report Survey.* Paper presented at the 1st International Conference on Driver Distraction and Inattention, Göteborg, September 28-29, 2009. Received November 9th, 2010 from http://www.chalmers.se/safer/driverdistraction-en/programme/documentation.

Lee, C. & Abdel-Aty, M. (2008). Presence of passengers: Does it increase or reduce driver's crash potential? *Accident Analysis and Prevention 40,* 1703–1712.

Lee, F. J. & Anderson, J. R. (2001). Does Learning a Complex Task Have to Be Complex?: A Study in Learning Decomposition. *Cognitive Psychology, 42(3),* 267–316.

Lee, J. D. & Strayer, D. L. (2004). Preface to the special section on driver distraction. *Human Factors, 46,* 583-586.

Lienert; G. A. & Raatz, U. (1994). *Testaufbau und Testanalyse. 5. Auflage.* Weinheim: Beltz – PVU.

Maciej, J., Nitsch, M. & Vollrath, M. (2011) Conversing while driving: The importance of visual information for conversation modulation. *Transportation Research Part F: Traffic Psychology* (in press). doi:10.1016/j.trf.2011.05.001.

Mattes, S. (2003). The lane-change-task as a tool for driver distraction evaluation. In H. Strasser, K. Kluth, H. Rausch, & H. Bubb (Eds.), *Qualitiy of work and products in enterprises of the future* (pp. 57–60). Stuttgart: Ergonomia Verlag.

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

McCartt, A. T., Hellinga, L. A. & Bratiman, K. A. (2006). Cell phones and driving: Review of research. *Traffic Injury Prevention, 7(2),* 89–106.

McEvoy, S.P., Stevenson, M.R., Woodward, M. (2006).The impact of driver distraction on road safety: Results from a representative survey in two Australian states. *Injury Prevention 12,* 242-247.

Metz, B., Schömig, N. & Krüger, H.-P. (2011). Attention during visual secondary tasks in driving: Adaptation to the demands of the driving task. *Transportation Research Part F: Traffic Psychology and Behaviour,* (in press). doi:10.1016/j.trf.2011.04.004.

Michon, J. A. (1985). A critical review of driver behaviour models: What do we know, what should we do? In R. Schwing & L. A. Evans (Hrsg.), *Human behaviour and traffic safety* (pp. 487-525). New York: Plenum Press.

Moskowitz, H., & Fiorentino, D. (2000). *A Review of the Literature on the Effects of Low Doses of Alcohol on Driving Related Skills.* (DOT HS–809–028). Springfield, VA: U.S. Department of Transportation, National Highway Traffic Safety Administration.

Owens, J.M., McLaughlin, S.B., & Sudweeks, J. (2011). Driver performance while text messaging using handheld and in-vehicle systems. *Accident Analysis & Prevention, 43 (3),* 939-947. DOI: 10.1016/j.aap.2010.11.019

Patel, J., Ball, D.J., & Jones, H. (2008). Factors influencing subjective ranking of driver distractions. *Accident Analysis & Prevention 40 (1),* 392-395.

Pettitt, M., Burnett, G. & Stevens, A. (2005). *Defining driver distraction.* Paper presented at the World Congress on Intelligent Transport Systems, San Francisco, November 2005.

Petzoldt, T., Bär, N., Ihle, C. & Krems, J.F. (2011). Learning effects in the lane change task (LCT) - Evidence from two experimental studies. *Transportation Research Part F: Traffic Psychology and Behaviour, 14 (1)*, 1-12. DOI: 10.1016/j.trf.2010.09.001

Rakauskas, M.E., Ward, N.J., Boer, E.R., Bernat, E.M., Cadwallader, M. & Patrick, C.J. (2008). Combined effects of alcohol and distraction on driving performance. *Accident Analysis and Prevention, 40 (5),* 1742-1749.

Ramaeker, J. G. (2011). *Drug effects on driving: perspectives from experimental studies*. Presentation at the DRUID Final Conference, September 27th to 28th, 2011, Cologne, Germany.

Ranney, T.A. (2008). *Driver Distraction: A Review of the current State-of-Knowledge* (DOT HS 810 787). National Highway Traffic Safety Administration (NHTSA).

Rasmussen, J. (1986). *Information Processing and Human-Machine Interaction. An Approach to Cognitive Engineering.* New York: North-Holland.

Reed, M. P. & Green, P. A. (1999). Comparison of driving performance on-road and in a low-cost simulator using a concurrent telephone dialing task. *Ergonomics, 42(8),* 1015–1037.

Regan, M., Lee, J.D. & Young, K. (2009). *Driver Distraction: Theory, Effects and Mitigation.* Boca Raton, Florida. CRC Press.

Regan, M.A., Hallett, C. & Gordon, C.P. (2011). Driver Distraction and driver inattention: Definition, relationship and taxonomy. *Accident Analysis and Prevention, 43 (5),* 1771-1781.

Rognin, L., Alidra, S., Val, C., Lescoaut, A. & Chalandon, X., (2007). Driver strategies when interacting with information and comfort systems. In: *20th International Technical Conference on the Enhanced Safety of Vehicles.* Lyon, France.

Royal, D. (2002). *National Survey of Distracted and Drowsy Driving - Volume 1: Findings* (DOT HS 809 566). National Highway Traffic Safety Administration (NHTSA).

Rueda-Domingo, T., Lardelli-Claret, P., Luna-del-Castillo, J., Jimenez-Moleon, J.J., Garcia-Martin, M. & Bueno-Cavanillas, A. (2004). The influence of passengers on risk of driver causing a car collision in Spain: Analysis of collisions from 1990 to 1999. *Accident Analysis and Prevention 36,* pp. 481–489.

Salvucci, D. D. & Taatgen, N. A. . (2010). *The Multitasking Mind.* Oxford University Press.

Sayer, J.R., Devonshire J.M., & Flannagan C.A. (2005). *The effects of secondary tasks on naturalistic driving performance* (UMTRI-2005-29). Ann Arbor, Michigan, USA: The University of University of Michigan Transportation Research Institute.

Schnabel, E. (2011). Alcohol and driving-related performance – A comprehensive meta-analysis focusing the significance of the non-significant. Unpublished Dissertation, Julius-Maximilians-Universität Würzburg, Würzburg.

Schnabel, E., Hargutt, V. & Krüger, H.-P. (2011). *Meta-analysis of empirical studies concerning the effects of the most relevant psychoactive substances on safe driving*. Retrieved October 25th, 2011 from http://www.druid-project.eu/cln_031/nn_107548/Druid/EN/deliverales-list/downloads/Deliverable__1__1__2,templateId=raw,property=publicationFile.pdf/Deliverable_1_1_2.pdf

Sdao-Jarvie, K. & Vogel-Sprott, M. (1992). Learning alcohol tolerance by mental or physical practice. *Journal of Studies on Alcohol, 53 (6),* 533-540.

Stevens, A., & Minton, R. (2001). In-vehicle distraction and fatal accidents in England and Wales. *Accident Analysis & Prevention, 33 (4),* 539–545.

Stevens, A., Burnett, G., & Horberry, T. (2010). A reference level for assessing the acceptable visual demand of in-vehicle information systems, *Behaviour & Information Technology, 29(5),* 527-540. http://dx.doi.org/10.1080/01449291003624212

Stutts, J. C., Reinfurt, D., Staplin, L. & Rodgman, E. (2001). *The role of driver distraction in traffic crashes.* AAA Foundation for Traffic Safety.

Stutts, J., Feaganes, J., Reinfurt, D., Rodgman, E., Hamlett, C., & Gish, K .& Staplin L. (2005). Driver's exposure to distractions in their natural driving environment. *Accident Analysis & Prevention 37 (6),* 1093–1101.

Stutts, J., Feaganes, J., Rodgman, E., Hamlett, C., Meadows, T., & Reinfurt, D., Mercadante, M. & Staplin, L. (2003). *Distractions in everyday driving.* AAA Foundation for Traffic Safety.

Sullman M.J.M. & Baas, P.H. (2004). Mobile phone use amongst New Zealand drivers. *Transportation Research Part F: Traffic Psychology and Behaviour 7,* 95–105.

Sullman, M.J.M. & Taylor, J.E. (2010). Social desirability and self-reported driving behaviours: Should we be worried? *Transportation Research Part F: Traffic Psychology and Behaviour 13 (3),* 215-221.

Trezise, I., Stoney, E. G., Bishop, B., Eren, J., Harkness, A., Langdon, C. & Mulder, T. (2006). *Report of the road safety committee on the inquiry into driver distraction.* Rep. No. 209. Melbourne, Victoria, Australia: Road Safety Committee, Parliament of Victoria.

VO (EG) Nr. 561/2006. Retrieved October 25th, 2011 from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:102:0001:0013:DE:PDF.

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

Vollrath, M., & Schießl, C. (2004). Belastung und Beanspruchung im Fahrzeug - Anforderungen an Fahrerassistenz. In VDI (Ed.): *Integrierte Sicherheit und Fahrerassistenzsysteme* (pp. 343-360). Düsseldorf: VDI-Verlag.

Vollrath, M., Meilinger, T., & Krüger, H.P. (2002). How the presence of passengers influences the risk of a collision with another vehicle*. Accident Analysis and Prevention 34,* 649–654.

Weir, D.H., Kwok, A.M. & Peak, J.L. (2007). *Exploratory Lane Change Test Experiments in Support of ISO WG8 LCT Task Force*. Paper presented at the ISO Task Force Meeting Calibration Task in Milano, Italy.

Wynn, T., Richardson, J.H., (2008). Comparison of subjective workload ratings and performance measures of a reference IVIS task. In: *European Conference on Human Centred Design for Intelligent Transport Systems.* Lyon, France.

Wynn, T., Richardson, J.H. & Stevens, A., (2009). *Driving whilst using in-vehicle information systems (IVIS): benchmarking the impairment to alcohol.* Presented at 1st International Conference on Driver Distraction and Inattention, September 2009, Gothenburg, Sweden.

Young K., Regan M. & Hammer, M. (2003). *Diver Distraction: A Review of Literature* (Report: 206). Victoria, Australia: Monash University Accident Research Centre.

Young, K.L. & Lenné, M.G. (2010). Driver engagement in distracting activities and the strategies used to minimise risk. *Safety Science 48,* 326-332.

Young, K.L., Lenné, M.G., & Williamson, A.R. (2011). Sensitivity of the lane change test as a measure of in-vehicle system demand, *Applied Ergonomics, 42 (4),* 611-618. doi:10.1016/j.apergo.2010.06.020

Young, M.S., Mahfoud, J.M., Walker, G.H., Jenkins, D.P. & Stanton, N.A. (2008). Crash dieting: The effects of eating and drinking on driving performance. *Accident Analysis and Prevention, 40 (1),* 142-148. DOI: 10.1016/j.aap.2007.04.012

7. Publications

In the following section the publications and submitted manuscripts are inserted. They are the core pieces of the present work. If already publicized, they are inserted in the publicized form, if submitted only; they are inserted in submitted form but with figures integrated to the text for easier reading.

Huemer, A.K. ,& Vollrath, M., (2011). Driver secondary tasks in Germany: Using interviews to estimate prevalence. *Accident Analysis and Prevention, 43,* 1703–1712. http://dx.doi.org/10.1016 /j.aap.2011.03.029.

Huemer, A.K., & Vollrath, M. (2012). Learning the Lane Change Task: Comparing different training regimes in semi-paced and continuous secondary tasks. *Applied Ergonomics, 43 (5)*, 940-947. http://dx.doi.org/10.1016/j.apergo.2012.01.002.

Huemer, A.K., & Vollrath, M. (2010b). Alcohol-related impairment in the Lane Change Task. *Accident Analysis and Prevention, 42,* 1983–1988. http://dx.doi.org/10.1016/j.aap.2010.06.005.

Alcohol-related impairment in the Lane Change Task

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Abstract

The Lane Change Task was developed to provide an objective safety criterion for the assessment of driver distraction by in-vehicle information systems (IVIS). It consists of two basic driving tasks, namely lane keeping and lane changes. The LCT has been shown to reliably detect distraction from driving. As this test becomes increasingly important for the assessment of safety the validity of the LCT is crucial. In order to examine this further, the effect of an alcohol intoxication of 0.08 g/dl on the performance in the LCT was examined in the present study as the negative effects of alcohol on driving are well-known. Twenty-three participants were tested under alcohol and placebo in a cross-over design measuring different performance indicators in the LCT. There were significant effects of alcohol during the lane keeping phase. However, these were much smaller than those typically found with distracting secondary tasks. The lane change phase was only marginally affected by alcohol. This result gives rise to some caution for interpreting effects in the LCT. The LCT is well able to detect distraction, as other studies have shown. However, our study with intoxicated participants shows, that a small effect in the LCT does not necessarily mean that this condition does not impair driving.

Keywords: *Driver distraction; Lane Change Task (LCT); Validity; alcohol effects*

1. Introduction

The Lane Change Task (LCT; Mattes, 2003) is used as a test procedure to measure distraction from driving due to secondary tasks. It is being implemented as an ISO standard with the aim to provide an objective criterion to be used to design human-machine interactions (HMI) in a way not detrimental to driving. Thus, on the one hand HMIs which distract the driver too much should be detected. On the other hand, the LCT should show which HMIs are compatible with driving. The LCT consists of a simple driving simulation that can easily be installed on any PC with a joystick steering wheel. In this task lasting for about 3 minutes the driver has to conduct 18 lane changes on a straight 3-lane road. These are cued by traffic signs indicating the direction (left or right) and width (one or two lanes) of the lane change. The performance of the driver is compared to a standard optimum behavior resulting in an index which reflects the deviation from this standard. Compared to a baseline condition without any distraction, guidelines are being developed about which deviations are detrimental to driving. The LCT has been shown to reliably detect distractions (especially visual distraction) from driving caused by secondary tasks (Mattes & Hallén, 2009).

Thus, the LCT is becoming increasingly popular in deciding about possible detrimental effects of secondary tasks while driving. Accordingly, the validity of this test with regard to traffic safety and especially the ability of the LCT to detect negative effects are of crucial importance. In order to examine this issue a study was conducted examining the effect of alcohol on the LCT. The detrimental effect of alcohol is well-documented in laboratory studies (for an overview, see e.g. Moskowitz & Fiorentino, 2000) and accident studies (for an overview, see Odgen & Moskowitz, 2004; Kelley, Darke & Ross, 2004). Alcohol effects differ depending on the type of task examined as has been shown by meta-analyses. In their meta-analysis of 109 studies published from 1981 to 1997 Moskowitz and Fiorentino (2000) describe the pattern of effects for BAC levels up to 0.16 g/dl (see Table 1). On the one hand, Moskowitz and Fiorentino stated in their review on the impairment of driving related skills that “virtually all subjects tested in the studies reviewed […] exhibited impairment on some critical driving measure the time they reached 0.08 g/dl” of alcohol. However, the BAC level required to find a negative effect depends on the type of task, as shown in Table 1. In this table, tasks were sorted with regard to the BAC level at which 50% of the studies showed a significant alcohol effect.

Table 1: Results of the Moskowitz & Fiorentino (2000) meta-analysis.

Type of task	**impairment in 50% of studies**	**lowest with impairment**	**highest without impairment**
Overall	0.030	0.001	0.160
Driving and Flying	0.001	0.001	0.070
Divided Attention	0.009	0.008	0.075
Drowsiness	0.010	0.010	0.034
Vigilance	0.020	0.021	0.028
Perception	0.040	0.037	0.080
Visual Function	0.040	0.026	0.100
Tracking	0.050	0.018	0.078
adaptive tracking		0.018	
pursuit tracking		0.054	
compensatory tracking		0.060	0.079
critical tracking		0.030	
Cognitive Tasks	0.060	0.016	0.160
Psychomotor Skills	0.060	0.014	0.120
body balance	0.040		0.080
skilled physical task		0.049	0.600
finger tapping		0.060	
Choice Reaction Time	0.060	0.020	0.063
Simple Reaction Time	0.100	0.043	0.095
Critical Flicker Function	0.100	0.100	0.790

In driving and flying-simulations, impairments could be shown at BACs as low as 0.001 g/dl. For divided attention tasks, drowsiness tests and vigilance tasks, low BAC levels from 0.009 to 0.020 g/dl demonstrated alcohol effects in more than 50% of studies. For perception and visual function, impairments were found at BAC of 0.040 g/dl and for tracking tasks at 0.050g/dl. For tracking, a wide range of tasks was used showing a wide range of impairments. For example, adaptive tracking tasks were impaired at 0.018 g/dl while some compensatory tracking tasks were not impaired at

0.079 g/dl. Cognitive tasks showed impairments in more than 50% of studies at 0.060 g/dl and had a range from 0.016 g/dl to 0.160 g/dl. A similar picture is given by psychomotor skills. Here, impairments can first be found at 0.014 g/dl. However, there are also studies with no impairment at 0.120 g/dl. Reaction time tasks were found to be impaired at a BAC of 0.060 g/dl for choice reaction tasks and 0.100 g/dl for simple reaction tasks, respectively. At last, critical flicker function was found to be impaired at high BACs of 0.100 g/dl and more.

As the LCT covers two basic driving tasks one would expect a significant effect of alcohol on performance in the LCT task. The LCT includes both tracking (keeping the lane) and choice reaction (changing the lane when signaled). As performance in the LCT is usually measured by computing an overall deviation from a standardized optimum performance, these two components are averaged. Thus, one would expect that the sensitivity of this task lies somewhere between that of tracking and choice reaction time in the area of 0.05 to 0.06 g/dl (taking the 50% impairment level from the meta-analyses presented above). In order to examine the effects of alcohol on LCT performance more closely it makes sense to compute additional performance indicators in order to distinguish between tracking performance and choice reaction in the LCT. Thus, new analysis parameters were introduced in the study presented here.

The study was also done in order to contribute to defining a cut-off value for the LCT above which a secondary task should definitely not be done while driving. As there is a well-defined relationship between BAC level and the extent of the performance decrement this can be used to assess the impact of other factors which also negatively influence driving performance. For example, one could examine the effect of sleep deprivation on driving related performance and describe which level of fatigue is comparable in effect size to certain BAC levels. Such an approach was used by Dawson & Reid (1997) who were able to find a good equivalence between hours of wakefulness and certain BAC levels. Accordingly, the results from the alcohol studies mentioned above were used to implement blood alcohol concentration (BAC) limits at levels where the alcohol-related accident risk is increased or where substantial significant effects can be found in laboratory tasks which measure aspects of performance which are relevant for driving. The idea was to find out which performance decrements in the LCT occur at different BAC levels (e.g., 0.05 g/dl like the BAC limit in Germany or 0.08 g/dl like that in other countries). These could then be used as cut-off criteria.

2. Method

In this study, subjects were tested in a within-subjects design with placebo compared to alcohol with a maximum BAC level of 0.08 g/dl. They were tested multiple times with the LCT before alcohol consumption, during rising BAC, at peak and at descending BAC with the focus to examine alcohol effects at 0.05 and 0.08 g/dl.

Design

A two factor (alcohol vs. placebo; order of conditions) cross-over-design was used including time as an additional third repeated measure. In the alcohol condition, subjects received alcoholic drinks aimed to reach an individual BAC of 0.08 g/dl. A placebo condition was introduced on the one hand to control for placebo effects and on the other hand to be able to control for effects of time on task (e.g. fatigue or vigilance-effects). In the placebo condition participants received drinks without alcohol. In both conditions they were told to receive alcohol. They were also told that different alcohol concentrations were used in the experiment but no further information was provided. The order of these two conditions was counterbalanced between subjects. Driving performance of subjects was measured nine times. Two measurements were conducted before drinking and used as baseline. Seven measurements were taken at intervals of 20 to 30 minutes beginning 20 minutes after starting to drink.

Participants

Participants were recruited through flyers at university and local supermarkets. Prior to participation, subjects were interviewed about their usual alcohol consumption and about risk factors regarding alcohol and their health. Subjects were only included when there was no risk reported. Informed consent was given about aims, procedure, risks and the possibility to quit the experiment at any time. The interview included the KFA ("Kurzfragebogen für Alkoholgefährdete"; Feuerlein et al., 1989), a brief self-assessment scale used to screen for alcohol misuse or alcohol dependence. Subjects were included only if their score was smaller than 6 which indicates no risk for alcoholism. Additionally, health risks like medication, pregnancy and cardio-vascular problems were screened in an interview. Only if none of these risks was present, subjects were included. Normal drinking behavior with respect to amount and frequency of alcohol consumption was assessed in the interview. Here, subjects were excluded if drinking less than one alcoholic drink per week. It was assumed that these subjects would have difficulty obtaining the desired BAC level of 0.08 g/dl, as pre-tests showed that these subjects are prone to get sick in the simulator by this amount of alcohol. Additionally, subjects consuming more than 300 ml pure alcohol at one occasion or more than 150 ml at more occasions a week were excluded due to excessive alcohol consumption.

With regard to these criteria, two subjects were excluded from participation. , daData of twenty-three participants, aged 19-45 (mean 25.3 years, sd 5.9), were analyzed. Twelve of them were male and eleven females. All had a valid driving license and all were of Caucasian ethnic. Mean driving experience was 6.8 years (sd 4.8), most of them (19 subjects, 79.5%) drove 5,000 to 10,000 kilometers per year. They were paid €10 per hour of the experiment.

Alcoholic drinks and BAC obtained

Alcoholic drinks were mixed of vodka and fruit juice served with ice. Based on gender, height and weight the required amount of vodka was computed in order to reach a BAC of 0.08% (modified Widmark-Formula; Widmark, 1932; Watson, Watson & Batt, 1980). Alcohol was distributed on three drinks of 0.2 l each. These were served in intervals of 20 minutes and had to be drunken in 10 minutes each. Under placebo conditions, drinks were fruit-juice and ice with a teaspoon of vodka on top, to give the smell and impression of containing alcohol. All participants in all conditions stated in a questionnaire that they believed to get alcoholic drinks in both conditions, though the amount of alcohol in placebo condition was believed to be less than in alcohol condition.

BAC was measured using a Dräger Alcotest 7410. The measurement was done once before drinking to ensure that the subjects were sober. This was repeated every 20 to 30 minutes during the experiment. As Figure 1 shows BAC was rising until about 90 minutes after beginning to drink. On average, the projected BAC of 0.08 g/dl was achieved. Afterwards, BAC slowly declined to a mean of 0.06 g/dl at the end of the experiment. In the placebo condition, the mean BAC was 0.00 g/dl at all time-points.

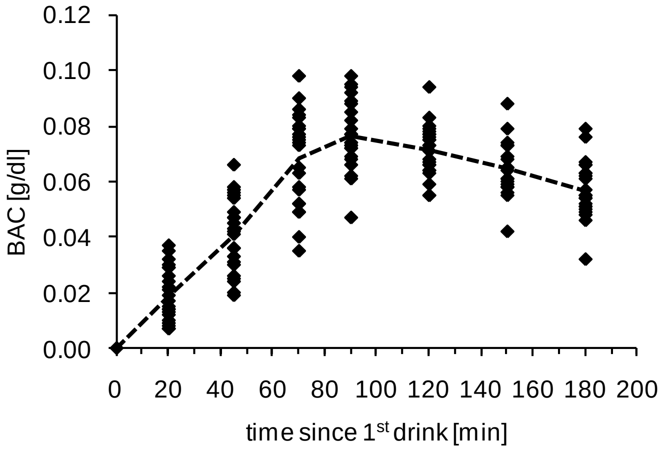


Figure 1: Participants' blood alcohol concentrations (BAC) during the alcohol session of the study. Mean BAC is displayed as a dotted line.

Driving Task: Lane Change Task (LCT)

In the LCT driving simulation, the driver sees a straight section of a three-lane road and is instructed to keep the current lane while driving at a constant speed of 60 km/h (the driver cannot drive faster than this). At some points signs are introduced which become legible at a certain distance. These indicate that the driver should change the lane (the target lane is shown) as soon as possible (see Figure 2). The distance between the signs is on average 150 m. The symbols appear on the signs at a distance of 40 m (for details see ISO/TC22/SC13/WG8, 2007). As soon as the symbols appear, lane changes are to be performed as fast and accurately as possible. One trial consists of 18 lane changes in a random order (left vs. right, movement across one lane vs. movement across two lanes) and takes about three minutes. The LCT includes both phases of lane keeping (between the signs) similar to other tracking tasks and of lane changes which can be described as choice reactions.

The lane change task has good face validity, and several studies (see Kuhn, 2005) showed that LCT can differentiate the relative distraction by several in-vehicle information systems such as navigation systems or radio, between speech and manual interfaces and between different secondary task requirements as in cognitive, visual and motor tasks, respectively.

A standard PC equipped with a joystick steering-wheel, gas and brake pedal was used to conduct the experiment. Driver behavior and car reactions were recorded with 62 Hz corresponding to a precision of 16 ms.

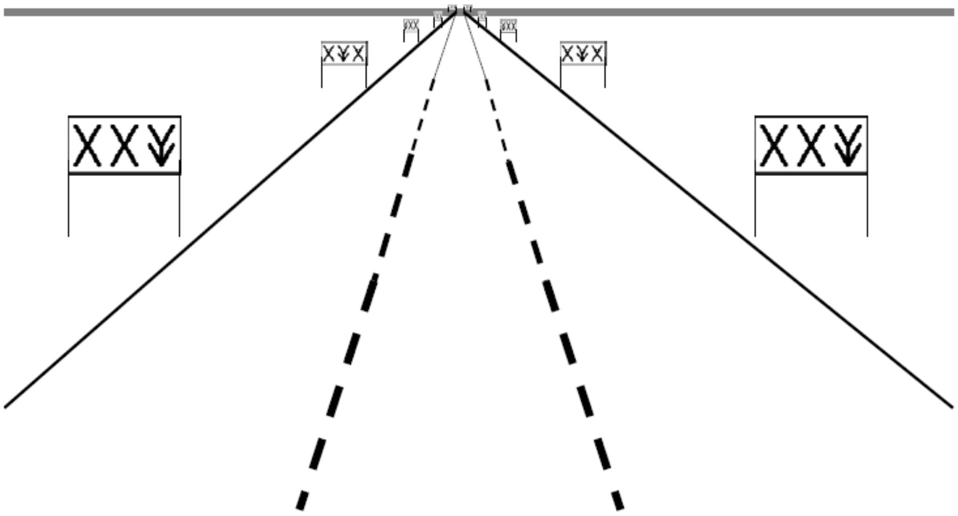


Figure 2: Lane Change Task: "Change your lane immediately as you recognize the next sign." With the symbols shown, the driver was to change to the right lane (arrow).

Dependent variables

The authors of the lane change task suggest a standard analysis procedure which is also incorporated in an ISO norm (ISO/TC22/SC13/WG8, 2007). Overall driving performance is measured by the arithmetic mean of the deviation from an ideal trajectory (see Figure 3). For this simplified ideal behavior it was assumed that during lane-keeping the car should stay in the middle of the lane. A simple linear trajectory was used to change the lane. While this is not a typical lane change behavior of a human driver, this gives an easy-to-compute standard to which the real behavior can be compared.

As we were interested in the two sub-tasks of lane keeping and lane changing, an additional analysis was developed. First, phases of lane keeping were separated from those of lane changing. The lane change was assumed to begin 30 m before each sign and to take 10 m. For both phases, the mean deviation from the ideal trajectory was computed separately. Additionally, for lane keeping phases the standard deviation of lane position (SDLP) was computed as measure of lateral control of the vehicle. For the lane changes, a reaction time was measured from the point where the sign became legible to the point where the driver started to steer. As the subjects could see the signs they knew beforehand when a lane change would be required. However, they had to wait until the sign became legible and then act accordingly. Thus, they could prepare for having to react but still had to select the appropriate action.

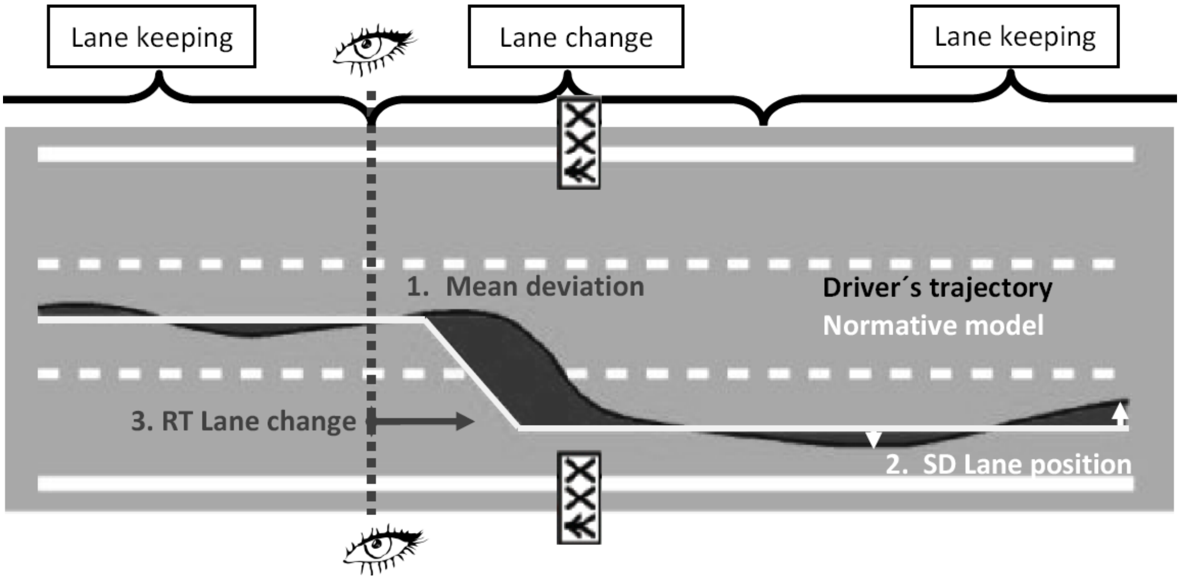


Figure 3: Driving performance measure in the LCT.

Experimental procedure

Before coming to the lab, participants were told that the testing protocol involved two sessions during which they would drink a beverage containing alcohol. Each participant signed a consent form at the beginning of the first training session and then was administered the screening and descriptive measures described above. If none of the exclusion criteria applied, participants started training the LCT for 10 trials. This first training session was followed by a second one on another day.

Test sessions were held in groups of four participants and started in the afternoon at about 4.30 p.m. Participants were instructed to eat no food for 3 hours before the appointment time and to avoid consuming any alcohol before the appointment time. Participants were assigned by random to either the alcohol-first condition or the placebo-first condition. The procedure to provide alcohol is described above. During test sessions, participants had to complete two baseline measurements on the LCT each lasting for about seven minutes before drinking and seven test measurements afterwards. After every LCT trial, their breath alcohol was measured as described above. As measurements in the LCT driving simulation and measurement of breath alcohol took about ten minutes, participants had ten to twenty minutes time to rest between measurements. Participants were not permitted to leave until their BAC was 0.03% or lower. Thus the entire experimental session lasted about five hours and test sessions were within the normal rest-wake cycles of all participants. After finishing the second test session, participants were paid and thanked for their attendance.

3. Results

For all dependent measures, differences to baseline conditions were computed. Order of conditions was examined first and found to have no effect on results. Thus, ANOVAs for repeated measures were conducted for each dependent variable separately by using the time of measurement (seven measures under alcohol; difference to baseline) as one and the experimental condition (alcohol vs. placebo) as a second factor. Due to sphericity violations, Greenhouse-Geisser corrected degrees of freedom are reported. For significant differences, η is reported as a measure of effect size. For the overall mean deviation from the ideal trajectory, both main effects were significant (see Table 2).

Table 2: Effects of alcohol on the mean deviation from the ideal driving behavior.

	effect	**df**		**F**	**p**		**η**
Mean deviation	alcohol vs. placebo	1.00	20.00	4.43	.048	*	0.43
	time of measurement	4.14	82.80	2.88	.026	*	0.35
	interaction	3.30	66.02	2.35	.074		

* significant α < 0.05

The results are shown in Figure 4. Beginning at the third time-point (peak BAC), performance was worse under alcohol as compared to placebo. However, there was no further dose-related change in the magnitude of the difference.

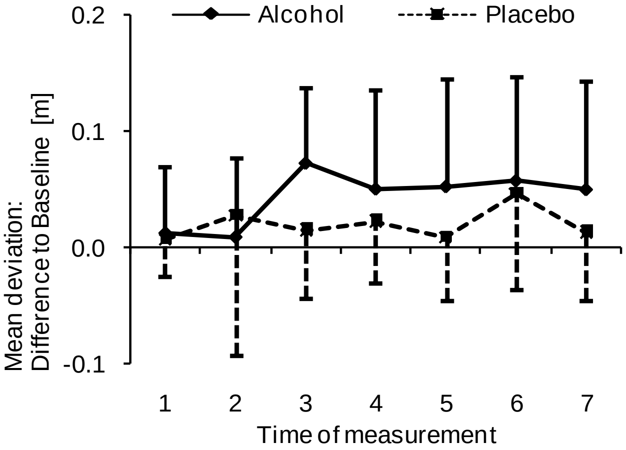


Figure 4: Mean deviation (± SD) in LCT for alcohol and placebo.

In a second step the lane keeping phase was examined using the mean deviation in this phase and the standard deviation of lane position (SDLP). For both measures there were significant main effects as well as interactions (see Table 3). As Figure 5 shows, mean deviation increased in both the placebo and alcohol condition with a somewhat larger increase under alcohol. This increase continues until the time-point before the last. The SDLP shows a clear alcohol effect. Performance is somewhat improved under placebo. Under alcohol, SDLP shows a very similar time-course as BAC with the strongest effect at T4 (peak BAC). However, the effect is quite small with 0.02 m (2 cm) at peak BAC.

Table 3: Results of the ANOVAs in the lane keeping phase (mean deviation and SDLP).

	effect	**df**		**F**	**p**		**η**
Mean deviation (lane keeping)	alcohol vs. placebo	1.00	20.00	8.93	.007	**	0.56
	time of measurement	4.32	86.34	7.09	.000	***	0.51
	interaction	4.51	90.23	3.35	.010	*	0.37
SD lane position (lane keeping)	alcohol vs. placebo	1.00	20.00	7.56	.012	*	0.52
	time of measurement	3.74	74.82	3.36	.016	*	0.38
	interaction	4.27	85.32	3.52	.009	**	0.38

* significant α < 0.05 ; ** significant α < 0.01; *** significant α < 0.001

Lane keeping phase

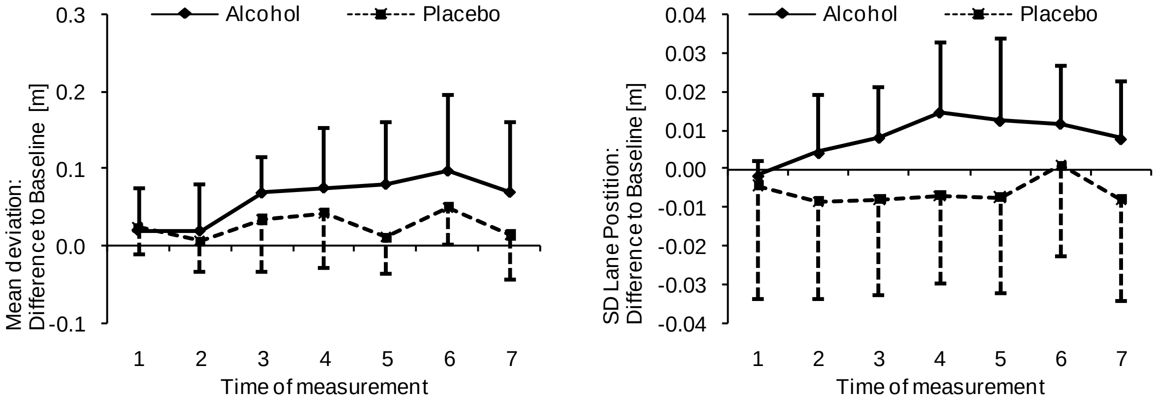


Figure 5: Effects on mean deviation and SDLP during lane keeping.

Table 4 shows the results of the ANOVAs during the lane change phase. None of the effects are significant. There is only a tendency of an interaction for the mean deviation and a tendency for the main effect of alcohol on reaction time. Thus, alcohol does not significantly influence performance during the lane change phase.

Table 4: Results of the ANOVAs in the lane change phase (mean deviation and reaction time).

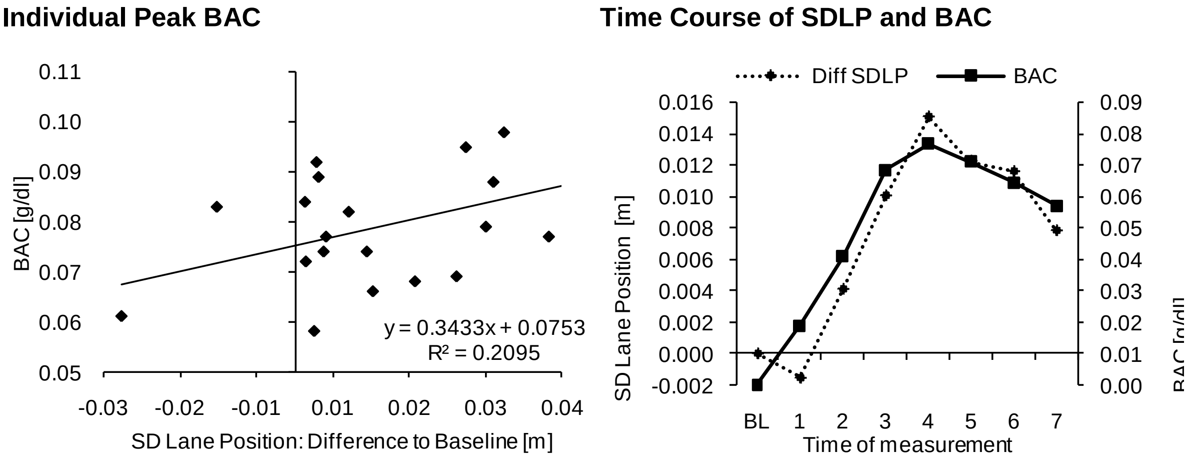
	effect	df		F	p	η
Mean deviation (lane change)	alcohol vs. placebo	1.00	20.00	1.57	.225	
	time of measurement	3.99	79.88	1.37	.251	
	interaction	3.72	74.49	2.34	.067	
Reaction time (lane change)	alcohol vs. placebo	1.00	20.00	3.99	.060	
	time of measurement	1.58	31.59	1.86	.178	
	interaction	3.33	66.65	0.72	.558	

In a second step of the analysis, the correlation between individual BAC and performance decrement was examined. To this aim only performance at peak BAC in the alcohol condition was used. Again, differences to baseline were computed. A multiple regression analysis (stepwise backwards) was computed to predict BAC including the three mean deviation measures, SDLP and reaction time. The final model (see Table 5) includes two driving parameters, reaction time and SDLP. Similar to the ANOVAs computed above, SDLP shows the stronger correlation with peak BAC. Overall, these two parameters account for 33% of the variance of the individual peak BAC level. As Figure 6 shows, BAC and SLPD are loosely related (R^2 = 0.2095) at peak BAC. More important, the time course of BAC and SDLP parallel each other demonstrating an increase in BAC and SDLP between T1 to T4 followed by a slow decline during T5 through T6. However, there is also a strong variation between the subjects.

Table 5: Regression model to predict the individual peak BAC with reaction time and SDLP.

regression model	**R²**	**F**	**df**	**p**	
	0.33	4.43	2; 18	.027	*
predictors (difference to baseline)	**β**	**T**	**df**	**p**	
reaction time (lane change)	.37	1.80	18	.089	
SD lane position (lane keeping)	.59	2.87	18	.010	*

* significant α < 0.05


Individual Peak BAC

Time Course of SDLP and BAC

Figure 6: Differences to baseline in SDLP in relation to individual peak BAC.

4. Discussion

As expected from the alcohol literature (Moskowitz & Fiorentino, 2000) a peak BAC of 0.08 g/dl significantly decreases driving performance in the LCT. The analysis of different phases (lane keeping and lane change) showed that this was especially due to degraded lane keeping behavior under the influence of alcohol. The most sensitive measure to the impact of alcohol was SDLP during lane keeping. Thus, the effect was stronger for the tracking component as compared to the choice reaction time. This is in line with the results of the meta-analysis described above (see Table 1 above). For tracking, 50% of the studies reviewed showed an alcohol effect at 0.05 g/dl. For choice reaction times, this 50% value was 0.06 g/dl. Thus, it appears that portions of the LCT as measured using SDLP are sensitive to the effect of modest levels of alcohol. There is a small relationship between LCT performance as measured using SDLP and individual BAC.

However, the pattern of alcohol effects found in this study gives rise to some caution for interpreting effects in the LCT. If a secondary task does not lead to a significant decrease in performance in the LCT, this may only be interpreted in the way that this task does not substantially withdraw (visual) attention from driving. As the standard performance measure of the LCT, the mean deviation from an ideal trajectory, is not well suited to detect performance decrement like those resulting from an alcohol intoxication, it may well be that this secondary task has some other negative effect (similar to that of alcohol) which does not show in the LCT but may become obvious if another measure of driving performance would have been used. Speech tasks or verbal human-machine-interactions may be an example of these kinds of tasks. Their effect on the LCT is much less pronounced than the effect of visual-manual HMIs (e.g., Mattes, 2003). However, there are some studies (e.g. Charlton, 2009; Drews, Pasupahi & Strayer, 2008) which indicate that these tasks may also influence driving performance negatively when appropriate driving tasks are examined.

Thus, the results of the experiment presented here show that a small or not significant effect of some task on the performance of the LCT does not necessarily mean that this condition does not impair driving. It is undisputed that BACs of 0.08 g/dl impair driving performance and increase accident risk. As this impairment results in an only small effect in the standard measure of driving performance in the LCT, this task cannot easily be used as the only benchmark for secondary tasks. Additional measures in the LCT and additional tasks covering a wider range of driving skills and abilities are needed in order to assess driving safety effects of secondary tasks.

Additionally, the experiment was aimed at defining a cut-off value for performance decrements in the LCT by using alcohol effects as a comparison. This is clearly not possible as a comparison of the magnitude of the effects show. When looking at the overall mean deviation which is usually used in evaluations of secondary tasks with the LCT, the alcohol effect at peak BAC amounts to a change of 0.1 m as compared to baseline. If this was used as a criterion for detecting distracting secondary tasks, this would result in excluding a multitude of tasks which are assumed to be safe (see Mattes and Hallén, 2009). In an overview about the effect of different tasks, a change of 0.4 m and above (from about 0.8 m to 1.2 m) is suggested in order to identify dangerous tasks.

To put it differently: While it is well in accordance with the literature on alcohol, the effect of alcohol on the LCT is substantially smaller than that of different secondary tasks. In the LCT, people seem to be very well able to react to the lane change signs even under higher concentrations of alcohol. Only their lane keeping performance deteriorates to some amount. It seems that people under the influence of alcohol are still able to manage simple, short, foreseeable tasks like the lane change of the LCT while tasks requiring continuous supervision and correction suffer from alcohol. It would be interesting to examine and understand this task-specificity of alcohol further by systematically comparing different tasks. However, this is well beyond the scope of this paper. With regard to using alcohol effects in order to define a cut-off value for the distraction due to secondary tasks, this is clearly not possible. The negative effects of alcohol on the LCT are different from those usually found with secondary tasks. Especially tasks which require eye-hand-coordination and lead to looking away from the road for a longer time lead to very strong deterioration of performance in the LCT. For the definition of a cut-off criterion it would make more sense to use a distraction task as a reference point which clearly withdraws attention from driving and for which negative effects on traffic safety have been proven. Some kind of standardized navigation task could provide a suitable candidate.

References

Charlton, S. G. (2009). Driving while conversing: Cell phones taht dristract and passengers who react. *Acident Analysis and Prevention, 41*, 160-173.

Dawson, D., & Reid, K. (1997). Fatigue, alcohol and performance impairment. *Nature, 388*(6639), 235-235.

Drews, F. A., Pasupahi, M., & Strayer, D. L. (2008). Passenger and cell phone conversation in simulated driving? *Journal of Experimental Psychology: Applied, 14(4),* 392-400.

Feuerlein, W., Küfner, H., Ringer, C., & Antons, K. (1989). *Kurzfragebogen für Alkoholgefährdete (KFA).* Weinheim: Beltz Test.

ISO/TC22/SC13/WG 8 (2007). Road vehicles - Ergonomic aspects of transport information and control systems - Simulated lane change test to assess in vehicle secondary task demand.

Kelly, E., Darke, S., & Ross, J. (2004). A review of drug use and driving: Epidemiology, impairment, risk factors and risk perceptions. *Drug and Alcohol Review, 23*(3), 319–344.

Kuhn, F. (2005). *Methode zur Bewertung der Fahrerablenkung durch Fahrerinformations-Systeme.* World Usability Day. Stuttgart.

Mattes, S. (2003). The lane-change-task as a tool for driver distraction evaluation. In H. Strasser, K. Kluth, H. Rausch, & H. Bubb (Eds.), *Qualitiy of work and products in enterprises of the future* (pp. 57–60). Stuttgart: Ergonomia Verlag.

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

Moskowitz, H., & Fiorentino, D. (2000). *A Review of the Literature on the Effects of Low Doses of Alcohol on Driving Related Skills.* (No. DOT HS–809–028). Springfield, VA: U.S. Department of Transportation, National Highway Traffic Safety Administration.

Ogden, E. J. D., & Moskowitz, H. (2004). Effects of alcohol and other drugs on driver performance. *Traffic Injury Prevention, 5*(3), 185–198.

Watson, P. E., Watson I. D., & Batt, R. D. (1980). Total body water volume for adult males and females estimated from simple anthropometric measurements. *The American Journal of Clinical Nutrition, 33*, 27–39.

Widmark, E. M. (1932). *Die theoretischen Grundlagen und die Praktische Verwendbarkeit der gerichtlich-medizinischen Alkoholbestimmung.* Berlin: Urban & Schwarzenberg.

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Learning the Lane Change Task: Comparing different training regimes in semi-paced and continuous secondary tasks

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Abstract

For road safety it is paramount that distraction by in-vehicle systems is limited. To reach this aim the Lane Change Task (LCT; Mattes, 2003) was developed. It is used as a test procedure to measure distraction due to secondary tasks in driving. The LCT is implemented as an ISO standard (ISO 26022:2010) with the aim to provide an objective criterion for designing human-machine interactions (HMI) in a way which is not detrimental to driving. As different baseline performance in the LCT could not be sufficiently explained in recent studies, comparisons of different training regimes were conducted in order to examine training influences on LCT performance. Discriminable performance improvements in LCT were found depending on the secondary task used. A training regime of at least ten runs of LCT in single-task mode is recommended for effective training. This training should be supplemented by a training of the secondary tasks examined. An additional exploration of a dual-task situation is recommended.

Keywords: Driver distraction; Lane Change Task (LCT); Surrogate Reference Task (SuRT); Critical Tracking Task (CTT); dual-task practice

1. Introduction: Assessment of driver distraction

In-vehicle information systems (IVIS) such as navigation systems or entertainment systems (e.g. audio systems) have been introduced to make driving more comfortable. As most drivers want to and do use these systems while driving (e.g. Young & Lenné, 2010), the interaction with them needs to be safe and should not distract from the primary driving task. Thus, the assessment of the amount of distraction caused by operating different devices in vehicles while driving is crucial to ensure safe driving.

There is a wide range of possibilities to test these effects, ranging from artificial laboratory setups to high fidelity motion based driving simulators (for an overview, see Regan, Lee & Young, 2008). In all these scenarios it is necessary to choose appropriate metrics for distraction effects. Some driving performance measures have been found to be sensitive to driver distraction of different types. Driving performance can be assessed by the drivers' performance in controlling the vehicle in traffic. Specific measures include longitudinal control of the vehicle (speed and distance), lateral control of the vehicle (lane keeping), and the drivers' ability to react to traffic events (e.g., other road users, as well as traffic lights and signs). An extensive review of existing measures and effects is given by Johansson et al. (2004). To summarize their findings, for the longitudinal control of the vehicle, speed and headway to the preceding vehicle were used as driving performance measures. For these conflicting effects were found with regard to secondary tasks. In the lateral control of the vehicle, direct steering metrics (e.g. steering wheel angle) or lane keeping performance (e.g. standard deviation of lane position) were used. For steering metrics, fewer but greater corrective movements were found to be made with secondary tasks. Lane keeping was found to be poorer while accomplishing visually demanding secondary tasks but was found somewhat improved with cognitive tasks. Event detection was impaired when driving with secondary tasks. Among these metrics, event detection had the strongest relation to crash risk. Although all these laboratory studies have shown that visual distraction may be detrimental to different aspects of driving, there were also huge differences in the results. These may be due to the different traffic scenarios used as well as the different metrics. It is therefore very problematic to compare different studies and, accordingly, different IVIS which were used in those studies. However, this comparison is crucial for developing and testing new IVIS, because a human-machine-interaction (HMI) concept which does not distract too much and thus is suitable to be used while driving should be implemented as early as possible in the development process. Thus easy-to-use and standardized assessments of distraction are needed. For this purpose Mattes (Mattes, 2003) developed the Lane Change Task (LCT) in the Advanced Driver Attention Metrics (ADAM) project.

1.1. The LCT: Assessment of driver distraction in a dual-task paradigm

The LCT is an ISO certified (ISO 26022:2010) standard procedure for distraction assessment. It is a tool which quantifies driver distraction in order to select between HMIs that distract the driver and those that are compatible with driving.

The LCT consists of a simple driving simulation that can easily be installed on any PC with a gaming steering wheel. In this driving simulation, the driver can see a straight section of a three-lane road and is instructed to stay in the current lane while driving at a constant speed of 60 km/h (the driver cannot drive faster than this). At some points signs are introduced which become legible at a certain distance. These signs indicate that the driver should change lanes (the target lane is shown) as soon as possible (see figure 1). The traffic signs indicate the direction (left or right) and width (one or two lanes) of the lane change. The distance between the signs is 150 m on average. The symbols appear on the signs at a distance of 40 m (for details see ISO 26022:2010). As soon as the symbols appear, lane changes are to be performed as quickly and accurately as possible. One trial consists of eighteen lane changes in a random order (left vs. right, movement across one lane vs. movement across two lanes) and takes about three minutes. The LCT includes both, phases of lane keeping (between the signs) similar to other tracking tasks, and phases of lane changes which can be described as choice reactions (probe reaction task, (ISO 26022:2010, Annex C.3, p. 21). The performance of the driver is compared to standard optimum behavior resulting in an index which reflects the deviation from this standard. Compared to a baseline condition without any distraction, guidelines are being developed about which deviations are detrimental to driving.

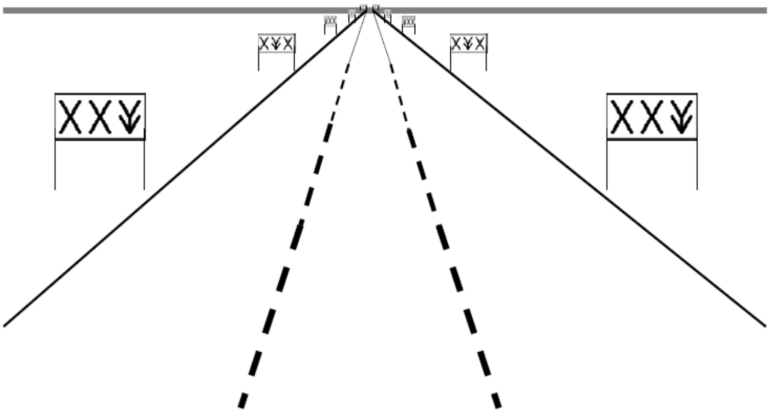

Figure 1: LCT setting (ISO 26022:20; p.5)

The LCT has good face validity. Several studies (see Kuhn, 2005) have shown that the LCT can differentiate the relative distraction caused by different in-vehicle information systems such as navigation systems or radio, between speech and manual interfaces, and between different secondary task requirements such as cognitive, visual and motor tasks (for more details, see Mattes & Hallén, 2008). However, this tool is not undisputed. Burns, Harbluk, Trbovich and Lochner (2006) criticized the unspecified information about method, metrics and criteria, the unspecified sensitivity of the performance measure and an uncertain predictive validity. One major problem is the large differences in baseline performance in the LCT. The mean deviation, which is the central measure of the LCT, differs greatly between studies (e.g. Weir, Kwok & Peak, 2007: mean deviation at baseline= 0.64 m; Rognin, Alidra, Val, Lescoaut & Chalandon, 2007: mean deviation at baseline= 1.60 m). Therefore, it is very hard to compare the results of different studies for different IVIS. Young, Lenné & Williamson (2011) also reported a rather high initial mean deviation of 1.6 m in baseline which did not decrease after training. They speculated that this might be due to the instruction, as some researchers instruct their participants to finish lane changes before reaching the signs and some do not.

One major factor influencing test performance is the level of practice. Training in general improves performance as actions are automated with practice (Lee & Anderson, 2001). This point is not clearly addressed in the ISO standard (ISO 26022:2010). The ISO standard only states that the LCT test protocol can be applied when subjects have reached a LCT baseline performance of less than 1.2 m in the central measure of this task, the so-called “mean deviation” (see below). Accordingly, the training status of subjects in the LCT is not documented very well in most studies. Generally, most of the studies on LCT metrics started testing their subjects “when comfortable” with the LCT (Burns, Trbovich, McCurdie & Harbluk, 2005), and some have used the criterion given in the ISO draft. Thus, it is necessary to clarify whether differences in baseline performance could have been caused by training effects. The same line of reasoning holds true for the secondary task. The ISO standard (ISO 26022:2010, Annex A.3, page 16) states that: “Each participant shall have at least two and up to five practice trials for each secondary task being investigated. Fewer practice trials may be used if the participant is adequately prepared for the task. For a secondary task which has no clear task duration (continuous tasks) practice should be performed for at least 30 seconds.” These weak criteria may lead to differing training status in participants in studies using the LCT. In addition to learning effects in each task alone, the question of possible interference of combined learning needs to be addressed for a dual-task test scenario. The ISO standard (ISO 26022:2010, Annex A.4, p. 16) addresses this as follows: “The participants shall experience the dual task situations. The data to be viewed or entered for the secondary task in such a trial shall be different from those used in other trials (training and test) but equal in difficulty.” It has been shown that some tasks can be operated well simultaneously if learned properly, but even then some task-switching costs are found (Gopher, 1991). It was also found by Gopher & North (1977) that in dual-task situations, subjects improve even more when experienced in the special dual-task situation. The interpretation of the authors is that optimal task switching can be learned by optimizing the time sharing between those tasks. In the field of traffic psychology, Shinar et al. (2005) examined the effect of practice on driving while operating a phone task simultaneously. They found performance improvements in the driving task as well as in the phone task over their five-day-period of testing. Participants also reported reduced workload over time. However, learning effects in single-task mode were not examined. Especially improved phone task operation in single-task mode would have been interesting for comparison to the dual-task learning. Thus, here one could also argue that it would be more efficient to learn both tasks separately because well-learned, automated tasks could be better combined, due to lower cognitive load within single-task operation.

To sum up, the effect of practice on performance is one of the core questions pertaining to test reliability. In dual-task situations, practice effects for the individual tasks and for when the two are combined need to be considered. To minimize those effects in test use, the test situation should not interfere with training. Thus, the most effective training has to be given to participants. As the LCT is a dual-task situation, in the present paper practice effects in LCT combined with different secondary tasks are examined. For comparison of dual-task and single-task training, different training regimes are compared, as well.

Effects of practice on LCT performance were examined in two previous studies. Firstly, the Japanese Automobile Research Institute (JARI) (cit. after DaimlerChrysler, 2006) found that for participants experienced in the LCT, decrements in LCT performance were smaller compared to baseline when performing it with a secondary task. A second study, recently published by Petzoldt, Bär, Ihle & Krems (2010) compared three groups of drivers at different training levels. A first group of subjects was trained in the LCT in single-task condition for 20 to 30 minutes. A second group was trained in the LCT in dual-task condition including an exploration of tasks in the beginning and afterwards completed six different secondary tasks with the LCT in balanced order between participants. A third group was not trained. Test sessions were held within one week for the trained groups. The test session procedure was almost the same as the training procedure for the fully-trained group. In addition, all participants had to familiarize themselves with the LCT until they reached a maximum mean deviation of less than 1.0 m before initial baseline was recorded and the test protocol started. In the between-group comparison of test sessions, neither a main effect of training status nor an interaction effect of training status and secondary task type was found. For the fully-trained group, data of two measurements of every condition were available. Comparisons between the training session and the test session revealed an effect of training between sessions in LCT performance for those experimental conditions in which the Surrogate Reference Task (SuRT; ISO/DIS 26022, 2007; Mattes, 2003) and the Critical Tracking Task (CTT; Dynamic Research, 2006) secondary tasks were used. For these secondary tasks, a training effect was found only in CTT performance; no effect was found in SuRT performance.

These results give useful hints for learning effects on LCT performance. For the study´s design, no conclusions can be made regarding learning patterns in either single-task LCT performance or in courses of performance in dual-task situations, as different secondary tasks had been given in the same subject´s procedure. Thus, the aim of the following studies is to clarify these effects. In the first study, the effect of practice on LCT performance in single-task situation is examined. In the second and third studies, effects of training with secondary tasks are explored. In these two studies we compared different training regimes, including practice of both, single-task practice in LCT and in the secondary task, as well as dual-task practice. In study II, we examined the effects of practice and training regime on performance on the combination of LCT and the SuRT task. In study III, these effects on combination of LCT and the CTT task were examined.

2. Study I: Single effects of training on the LCT performance measures

2.1. Method

2.1.1. Participants

Data of thirty participants (18 female and 12 male) aged between 18 and 44 years (M= 23.8 years, SD= 5.4 years) were examined in this study. Participants had a mean driving experience of 6.0 years (SD= 5.2 years). Mean annual driving distance was 8,060 km/year (SD= 9.230 km/year), which is close to the national average of 7,900 km/year if including all inhabitants from babies to the elderly (Alltagsverkehr in Deutschland, 2009). All participants were unfamiliar with the LCT prior to this experiment.

2.1.2. Design and experimental procedure

A standard PC equipped with a gaming steering wheel, and gas and brake pedals was used to conduct the experiment. Driver behavior and car reactions were recorded with 62 Hz corresponding to a precision of 16 ms. Participants were instructed to complete their lane changes as quickly and accurately as possible, according to the ISO standard (ISO 26022:2010). They were told that an efficient lane change typically is finished prior to reaching the sign, according to ISO original terms. They were not enforced to finish prior to the sign.

All participants completed forty runs of the LCT in blocks of ten runs. There were two different regimes of runs, as we were interested in any possible effects of rests between practice occasions. One group of participants (N= 11) drove one block of LCT runs a day on four successive days and the other group (N= 19) drove two blocks on two successive days. However, as there were no differences found between groups, the following results comprise pooled data.

2.2. Results

Data were examined by an ANOVA with LCT runs as a within subject factor. For significant results, η^2 is reported as a measure of effect size.

In the analysis the main effect of LCT run was significant ($F_{39;\,1131}= 18.33$; $p< 0.001$; $\eta^2= 0.387$). As shown in figure 2, participants started the first run at a mean deviation of about 1.1 m and improve rapidly in the first six runs down to about 0.8 m. Thereafter, performance improves more slowly to about 0.75 m at the end of our testing.

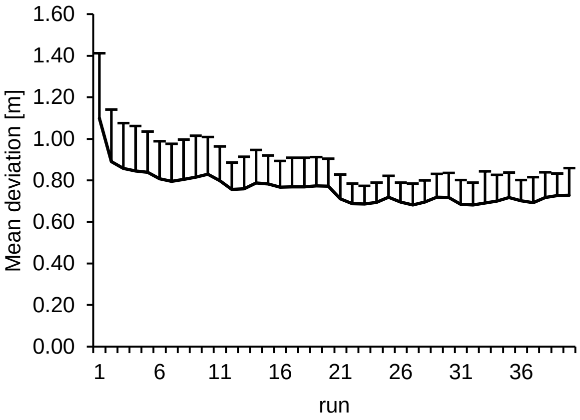

Figure 2: Mean deviations in the LCT over time

2.3. Discussion

Examination of beginners' improvement in LCT performance shows that strongest improvement in performance happens in the very first runs. For practitioners using the LCT as a tool for HMI evaluation, these findings imply that participants have to be trained in the LCT to avoid a mixing of the effects of training and secondary tasks. When looking at the results, a minimum training of at least five runs is suggested.

3. Study II: LCT and SuRT

The first study showed that there are strong training effects in the LCT which should be controlled by extended practice before obtaining the baseline measurements. The same question arises for the dual-task performance. As shown in some studies cited above, dual-task performance also changed with practice. It is always a question which kinds of effects represent the dangers of IVIS better, when doing these IVIS tasks for the first time (unpracticed) or after having gotten used to them. With respect to real driving, people will often operate different IVIS and will get quite used to them. Thus, on the one hand one could argue that measuring the effect of well-learned IVIS handling is more comparable to real driving. On the other hand, one could also argue that the initial handling might be the more dangerous and thus is more relevant to traffic safety. Regardless of how this puzzle is solved, it is useful to know the magnitude of these training effects and how to improve best dual-task performance. These objectives were addressed in the second study.

3.1. Method

3.1.1. Secondary task SuRT

The SuRT secondary task (ISO/DIS 20622, 2007; Mattes, 2003) is a visual search task in which participants have to find a slightly larger target circle within a display of distracters. In the most difficult setting used here, the target is to be found in a display of fifty circles and has to be marked manually with a cursor-ruled bar. When the circle has been marked, the selection has to be confirmed. After each confirmed selection the next display is shown. Performance in this task is measured by computing the mean time from the presentation to the confirmation. The SuRT task was presented on a 17” PC monitor that was located on a table to the right of the driver, approximately 45° to the right and 30° down, within the visual field when looking at the LCT monitor (for illustration see figure 3). The screen resolution was set at 600 x 800 pixels. The target size was 7.5 mm in diameter, with a line thickness of 1 mm, resulting in a 0.54° viewing angle at a distance of 80 cm. The distracters were 6.5 mm in diameter, resulting in a 0.42° viewing angle. A standard keyboard´s cursor pad was used for responding. The keyboard was located to the right of the participants, which corresponds to the position of the gear shift in a car. A more detailed description of the experimental setup of SuRT and LCT can be found in the ISO draft (ISO/DIS 20622, 2007).

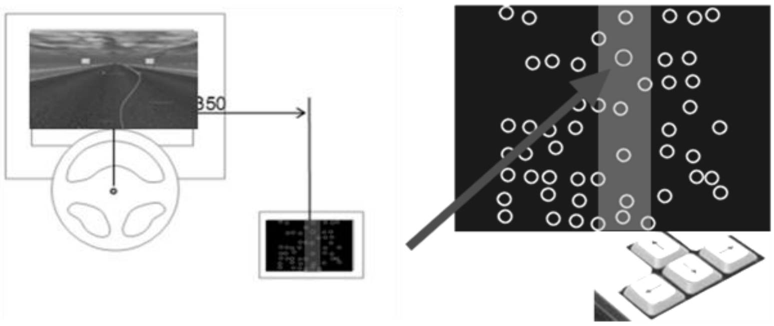

Figure 3: The SuRT secondary task setting and display example.

3.1.2. Participants

Twenty-eight participants aged between 21 and 43 years (M= 25.8, SD= 4.6) took part in the study. Thirteen of them were male and fifteen female. Annual driving distance was between 3,000 and 50,000 km/year (M= 12,192 km/year; SD= 11,798 km/year). They had had a driving license for M= 7.9 (SD= 4.9) years. None of the participants had prior experience with LCT or SuRT prior to this study.

3.1.3. Design and Experimental procedure

Data collection was divided in two steps. First, participants were trained in their specific training regime and afterwards, a test session was held. In the first step, there were three different types of training:

(1) Blocked training, in which participants practiced either LCT only or SuRT only for five runs each (a run comprising of two LCT runs or 2 minutes of SuRT) and then changed the task to practice the other (e.g., 2x LCT - 2x LCT - 2x LCT - 2x LCT - 2x LCT - 2 min SuRT - 2 min SuRT - 2 min SuRT - 2 min SuRT - 2 min SuRT - 2 min SuRT and so on).
(2) Alternated training, in which participants practiced one run of each task and changed the task afterwards (e.g., 2x LCT - 2 min SuRT - 2x LCT - 2 min SuRT - 2x LCT - 2 min SuRT - 2x LCT - 2 min SuRT and so on).
(3) Simultaneous training where both tasks were practiced simultaneously from the beginning (e.g., 2x LCT & SuRT - 2x LCT & SuRT - 2x LCT & SuRT and so on).

Each of these training regimes comprised twenty runs administered on two successive days. Thus, after these training sessions, regardless of the condition, each participant had practiced twenty runs of the LCT and at least 20 minutes of the SuRT task. In the second step, a “test session” was held. In these test sessions, participants had to operate both tasks simultaneously. Here, six runs of the LCT with simultaneous operation of the SuRT task were administered. To make sure that participants knew how to operate the two tasks and, according to the results of the first study for elimination of the strong learning effects in lane change initiation, participants were able to explore both tasks prior to measurement. This exploration lasted for about one minute for each task.

3.1.4. Results

Data were analyzed in two steps. Driving performance and performance in the secondary task were analyzed separately for the test session and the training sessions. For the test sessions, a 3 (type of training) x 6 (single LCT runs) ANOVA with repeated measures was conducted for the driving performance as well as 3 (type of training) x 3 (SuRT runs) ANOVA for the SuRT performance. For the training sessions, a 3 (type of training) x 20 (single LCT runs) ANOVA was conducted for the driving performance as well as 3 (type of training) x 10 (SuRT runs) ANOVA with repeated measures for the SuRT performance. If sphericity was violated, Greenhouse-Geisser corrected degrees of freedom were used. For significant results, η^2 is given as a measure of effect size.

The ANOVA for the training sessions showed a main effect of the training regime ($F_{2;\,24}= 10.59$; $p= 0.001$; $\eta^2= 0.469$), of the runs ($F_{2.76;\,66.19}= 5.50$; $p= 0.003$; $\eta^2= 0.186$) but no interaction. For SuRT performance both main effects (training regime: $F_{2;\,25}= 4840$; $p< 0.001$; $\eta^2= 0.795$); runs: $F_{3.39;\,84.77}= 22.71$; $p< 0.001$; $\eta^2= 0.476$) and the interaction effect ($F_{6.78;\,84.77}= 5.42$; $p< 0.001$; $\eta^2= 0.301$) were significant.

In the test sessions, neither main effects nor an interaction was found in driving performance. However, for the SuRT a main effect of run was found indicating an improved performance over time regardless of the group ($F_{1.13;\,28.30}= 7.48$; $p= 0.009$; $\eta^2= 0.230$).

Figure 4 shows the effects of the training regimes on performance in the LCT as well as on SuRT performance. When looking at the overall mean deviation, performance improved in all three groups during the first five to ten trials in a very similar manner as in the first study. Only the initial peak from the first to the second run was smaller, which may be due to the fact that the participants were able to accommodate themselves to the LCT for about a minute before the first measurement. Additionally, the mean deviation was larger in the group with simultaneous practice in both tasks and this difference remained quite similar until the end of the practice trials.

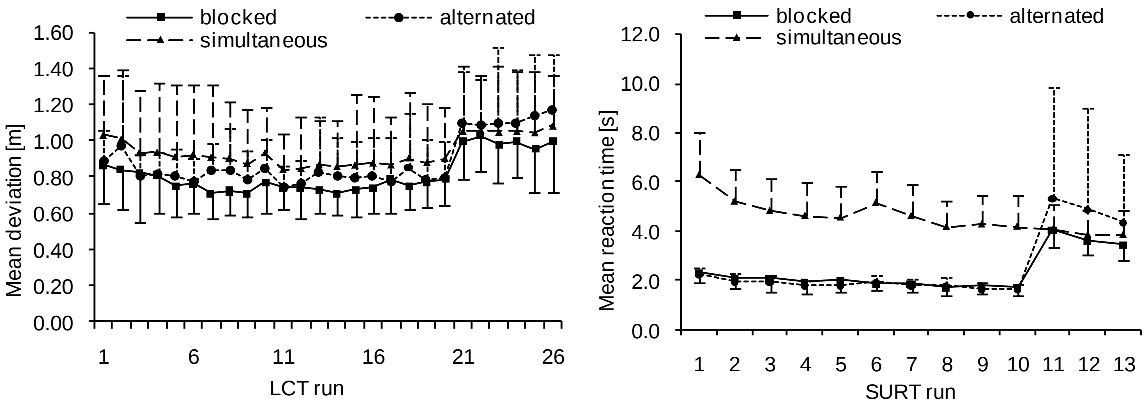

Figure 4: Mean deviations in the LCT and SuRT performance for the different training regimes over time

As also shown in figure 4, huge differences between training regimes could be found in SuRT performance. The simultaneously trained group showed threefold longer reaction time to SuRT stimuli compared to the other two groups which operated the SuRT in training in single-task condition. When looking at the test session performance when every participant operates under dual-task condition, SuRT performance for the “blocked” and the “alternated” groups dropped. Here, performance of the “blocked” training group dropped to the “simultaneous” groups´ level; performance of the “alternated” group was even worse. After at least 27 min (1 min + 13 * 2 min) of SuRT practice, participants’ reaction times to stimuli decreased even in the last trials.

3.2. Discussion

The results confirm the findings of the first study which showed that a training of at least five runs of the LCT alone is needed to get a stable performance, and a training of ten runs results in even more stable performance. Other than the LCT performance, performance in the SuRT is not stable even after the extensive training administered here. SuRT performance improves more slowly and continuously than LCT performance. No advantages of simultaneous training could be shown. In contrast, LCT performance seems to improve more slowly when done with secondary task training. In blocked training learning seems to be more homogeneous compared to alternated training. Additionally, it could be shown that the negative effect of the SuRT task on LCT performance is found even after this extensive training. Thus, training in dual-task performance does not negatively influence the sensitivity of the LCT.

Overall, for an effective training of the participants it seems to be best to practice LCT and any secondary tasks alone until performance is stable. In the LCT, an absolute minimum of five runs is needed, but taking into consideration the improvement thereafter in this experiment, ten trials in LCT are recommended for training. For other secondary tasks like the SuRT, even ten trials may not be enough. In order to examine this, different secondary tasks were examined in a third study.

4. Study III: Combining LCT and CTT

In contrast to the SuRT which is a task that does not need continuous monitoring, many secondary tasks need this continuous operation. As learning to handle two continuous tasks may be different to learning to handle the control of one continuous task and an interruptible secondary task, we also examined the effects of training arrangements combining LCT and the Critical Tracking Task (CTT). Specifically, we wanted to know if in this task participants profit from a simultaneous training. Like SuRT, the CTT is recommended as a reference task in the ISO draft of 2007.

4.1. Method

4.1.1. Secondary task CTT

The visual-manual control task CTT needs the continuous attention of the participants. On a light grey screen a horizontal line is presented in the center of the display. At the beginning of the task, this horizontal line starts to move upwards and downwards, away from the center of the display in an unstable manner (for illustration, see figure 5). Participants have to keep the moving horizontal line in the center of the display by pushing the up and down arrow keys of a keyboard. The level of instability sets the difficulty of the task. In this experiment, instability was fixed to a lambda of 1.0. The CTT was presented at the same position as the SuRT in study II, in accordance to the ISO draft (ISO/DIS 20622, 2007). A standard keyboard cursor pad was used for input.

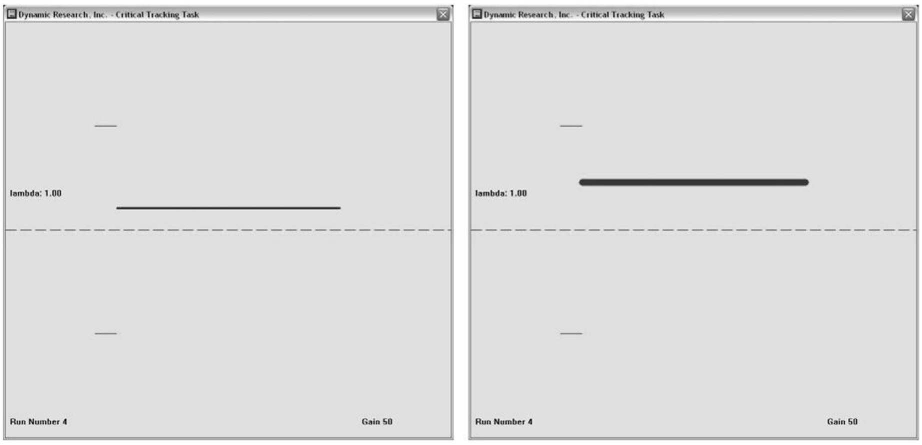

Figure 5: CTT secondary task display. In the right display, the instable bar is under control of the participant; in the left it is not and thus turns thicker and red.

4.1.2. Participants

Ten female and ten male participants aged between 19 and 49 years (M= 24.1, SD= 8.2) took part in the experiment. They had had their driving licenses for M= 7.3 (SD= 8.3) years, and most of them drive fewer than 20,000 km/year (M= 15,476 km/year; SD= 11,616 km/year). All participants were unfamiliar with both LCT and CTT before experimental procedure of this experiment.

4.1.3. Design and experimental procedure

Design and procedure were similar to study II, using ten practice trials and three test trials. However, as the alternated training was shown to be not effective, only the blocked training and the simultaneous training were compared.

4.2. Results

Data analysis procedure was parallel to that for study II. In the training sessions, no effects were found for LCT driving performance measures. For CTT performance, the main effect for training regime ($F_{1;\,18}$= 9.20; p= 0.007; η^2= 0.338) as well as the main effect for LCT runs ($F_{2.52;\,45.29}$= 4.08; p= 0.016; η^2= 0.185) and the interaction was significant ($F_{2.52;\,45.29}$= 4.26; p= 0.014; η^2= 0.191)).

In the test sessions as well, no effects on driving performance were found. Only CTT performance showed main effects of run ($F_{1.87;\,33.64}$= 5.86; p= 0.008; η^2= 0.246) as well as of training regime ($F_{1;\,18}$= 62.53; p< 0.001; η^2= 0.776).

Results of study III are illustrated in figure 6. Quite contrary to expectations, the CTT seemed to be able to be performed without disturbing the driving performance in the LCT. However, as figure 6 shows, this is due to the drivers focusing on the driving task which resulted in a performance decrement in the simultaneous group while performance was stable in the single-task blocked group.

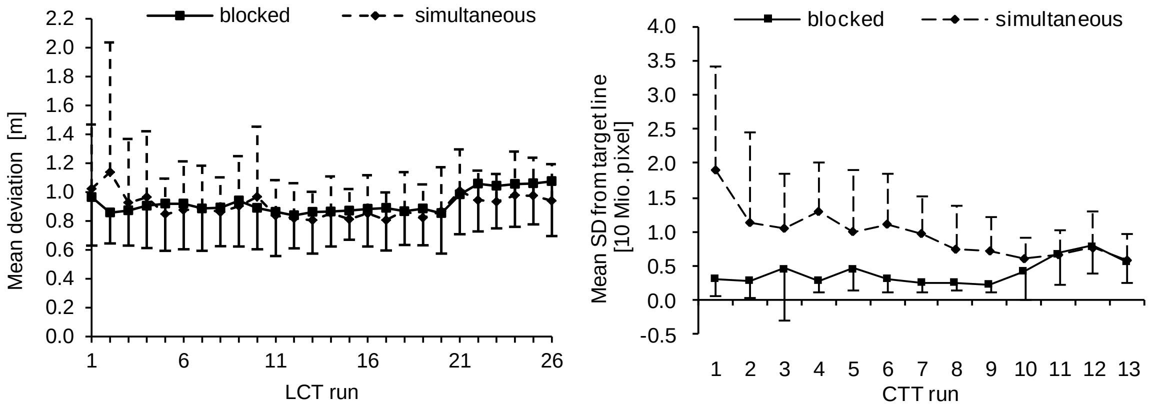

Figure 6: Mean deviations in the LCT and CTT performance for the different training regimes over time

4.3. Discussion

In the third study no training effects were shown in LCT performance at all. CTT performance improved under simultaneous training. In blocked training, practicing the CTT alone, no effects were found as CTT performance is quite good from the beginning in this group. Thus, during the first ten trials participants seem to learn how to integrate this CTT within the driving task so that the performance keeps improving. However, this seems to be some kind of an implicit learning process as later on, under dual-task conditions in CTT trial 11, the blocked learning group performed comparably as well as the simultaneous learning group. Thus, if one examines the CTT without much training one will come to the conclusion that it does not impair driving. This lack of training in the CTT is at the cost of LCT performance. However, after some training, both tasks can be performed in parallel quite well.

Prior to the experiment, we expected the CTT to be more difficultly integrated in the dual-task setting compared to the SuRT task. We expected poorer LCT performance in the simultaneous training group while learning as well as greater negative performance effects in the blocked group in test sessions. However, the opposite effect was demonstrated. This may be due to different strategies of task operation. In the SuRT, one search has to be done until the target has been found. When this is interrupted, one probably has to start orientation and cognitive processing anew. This will lead to relatively long gazes as well as “mind away from the road”. In the CTT, a short glance is sufficient to see the deviation of the target from the middle of the screen and the reaction can be done without visual control. Thus, less distraction due to gazes away from the road as well as due to motor program selection would result. Of course, this should be tested by means of gaze recording which was not done here.

5. General discussion of studies on training

5.1. Training effects and implications for LCT use

In the first of the three presented studies we found a training effect on LCT performance. This effect was strongest within the first five LCT runs, but still an improvement was found until the tenth run. This result of performance improvements with practice were supported by studies II and III. Here, task exploration before the beginning of performance measurement substantially reduced training effects in the first recorded runs of the studies. However, even if reduced, training effects still were found in study II in the first ten runs.

For the SuRT task in single-task mode in study II no strong initial learning effect was found, yet a gradual improvement over a long range of time was found until the last trials. No learning effects were found in single-task mode for the CTT in study III. In dual-task conditions, LCT performance showed the same pattern as in single-task performance over time, but without the initial rapid learning. This may, on the one hand, be due to the initial exploration. On the other hand, specific effects of different (secondary) task types on dual-task learning seemed to occur. When LCT was performed simultaneously with the CTT, dual-task performance was at same level as single-task performance; no learning effects were found in this study. When performing the LCT together with the SuRT, the level of LCT performance was slightly worse than in single-task learning; its improvement over time was similar, resulting in a nearly same level of performance in the test sessions. Therefore, the performance patterns of secondary tasks need to be considered, too.

For secondary tasks, for SuRT as well as for CTT, learning patterns changed when performed with the LCT simultaneously compared to single-task learning. For both tasks under dual-task conditions, a large learning effect was found within the first three trials, which was not found in single-task learning, followed by a steady improvement. Task performance in the test sessions for both secondary tasks was at the level of single-task learning groups in the end. From this point of view, there seems to be no advantage for the one or the other training regime.

As the main concern of this paper is to provide information about dual-task learning in LCT-related settings, the most interesting question is how to provide training leading to efficiently learned dual-task performance. Comparing different training regimes in particular, a blocked training seems to be the most efficient way to do this in both studies II and III, as a stable performance could be achieved relatively quickly in each task. Most important, the dual-task performance is quite similar regardless of whether dual-task performance was practiced beforehand or just the single-task blocked training. In contrast, an alternated training practicing one trial of LCT and one of the secondary tasks seems to slow down the learning in study II.

Based on the strength of performance improvement found in our first study, we suggest supplying a training of at least five, or even better ten, LCT runs prior to baseline performance data collection. Results from the second study confirm that a training of at least ten runs of the LCT alone is needed to get stable performance. In addition, the present training studies showed that participants have to be practiced in all used tasks, the LCT as well as in the reference tasks SuRT and CTT. For an effective training of participants it seems to be best to practice LCT and secondary tasks alone in a blocked regime at least until a stable performance is found in all tasks. This is also recommended from a very practical point of view, as single-task training is easier to do for participants.

From a theoretical point, it is interesting to note that single-task practice is sufficient to achieve a good dual-task performance. Dual-task training did not, in our studies, provide any advantage in performance. Thus, it seems that one has to practice tasks in order to perform them automatically, but does not have to learn how to switch between these tasks. Additionally, it is interesting to see how the different reference tasks differ in their effect. When SuRT and LCT are combined, both tasks are performed worse in the beginning (compared to single-task performance). LCT and SuRT performances improve, but small differences to single-task performance are even found in the end of the extensive trainings. When LCT and CTT are combined, performance decrements are found in CTT only, but these vanish over time. Drivers thus seem to be able to coordinate CTT and LCT quite well. This is somewhat surprising because the CTT is a task which demands continuous monitoring. Therefore, it was assumed to interfere more with the LCT compared to SuRT, which is a self-paced task. However, drivers seemed to use different strategies in task operation resulting in stronger distraction from the LCT when operating the SuRT. We believe drivers in the SuRT tend to finish a search which has been started already before looking back at the LCT. This behavior results in longer periods of visual distraction from the road, leading to decrements in the LCT driving performance. It may be assumed to be the best strategy for finishing the SuRT display, as a visual search may have to be started again after looking away. In contrast to this, in the CTT task, short glances seem to be sufficient to assess the bar´s deviation from the target, and corrections can be done with hardly any visual control. Thus, here only short glances would be necessary, resulting in smaller decrements in LCT performance. Comparing these presumed patterns of operating secondary tasks, the LCT seems to be sensitive to visual distraction by means of glance duration away from the driving task. This suggestion, of course, has to be confirmed with studies including gaze-analysis.

5.2. The LCT as a psychological test: implications from the present studies

Unfortunately, the training effects on LCT performance which were shown in the present studies cannot explain the different mean deviations found in the different laboratories. Even in the first trials the performance in our laboratory was much better than compared to other laboratories. The instructions given to participants are likely to play a major role here, as Young et al. (2011) have pointed out. They state: “Unlike the instructions adopted in other LCT experiments (e.g., Harbluk, Burns, Lochner, Trbovich, 2007; Harbluk, Mitroi & Burns, 2009), the current participants were *not instructed to have completed* their lane change by the time they reach the lane change sign.” (Young et al., 2011, p.616) [emphasis added] In the ISO standard (ISO 20622:2010), guidelines for the instruction of participants are given as follows: “Instruct participants to complete the lane change quickly and efficiently. Mention to the participant that an efficient lane change *typically is finished before* the sign is reached.” (ISO 20622:2010, Annex A, page 15) [emphasis added] In our studies, the ISO instruction was used. This may explain why even in the first sessions 1.15 m was the worst deviation found in the initial training session and deviation went down to 0.78 m in the last training sessions. Even in training sessions starting in dual-task mode (LCT and SuRT, first run in simultaneous training), the mean deviation was only 1.05 m. Thus, the instruction to finish the lane change quickly may explain these differences. Moreover, providing no clear instructions may also lead to larger deviations between the subjects as some participants change their lane quite slowly while others do it quickly. Thus, one would recommend using this ISO instruction in order to obtain stable behavior between the different participants.

Using the LCT as a test method for safety-critical situations with new in-vehicle systems, the strong trainings effects found here could be used for testing. If participants in such a test scenario were inexperienced in LCT as well as in the new system´s operation, these factors could resemble a worst-case scenario to test the most distracting effects of a system. On the other hand, if usual use of a system and its effects on driving should be evaluated, participants should be trained well in both operations, to give a realistic picture of distraction effects of the system without mixing these effects with LCT practice deficits. An additional advantage in test methodology is the higher test sensitivity in testing trained drivers, as variability between participants is substantially reduced during practice. Thus, error variability of the test is reduced as well.

6. Conclusions and implications for LCT use

What do these results imply for the evaluation of secondary task demands with the LCT? As LCT performance should not be interpreted alone, but rather compared to reference tasks in order to be comparable between tests sites, performance in dual-task situations with reference tasks should be comparable first. Thus, participants have to show stable performance in all used tasks.

To use the LCT as a sensitive tool to measure performance degradation effects of any added task and to compare effects of different systems, it has to be used with the same test protocol. Here, some points have to be considered. First of all, the same instructions concerning the lane change have to be delivered to participants to obtain comparable driving patterns. Second, the LCT and any secondary task have to be practiced. Additionally, to be on the safe side, we recommend letting participants practice the dual-task situation for at least two LCT runs to minimize any potential distraction effect of the new situation on performance.

References

Alltagsverkehr in Deutschland (2009). Paper presented at the Anwenderworkshop, September 2nd, 2009, Berlin. available online from http://www.mobilitaet-in-deutschland.de/pdf/ Projektpraesentation_MiD2008_WorkshopSeptember2009_FassungMaerz2010.pdf [May, 30th 2011].

Burns, P.C., Trbovich, P.L., McCurdie, T., Harbluk, J.L. (2005). Measuring distraction: task duration and the lane-change test (LCT). In: Human Factors and Ergonomics Society 49th Annual Meeting.

DaimlerChrysler AG. (2006). The Lane Change Test. Paper presented at the Driver Metrics Workshop, Ottawa.

Dynamic Research Inc. (2006). Critical Tracking Task. Available from http.//www.dynres.com. [May, 30th 2011].

Gopher, D. (1991). The skill of attention control: Acquisition and execution of attention strategies. In D. Meyer & S. Kornblum (Hrsg.), Attention and performance IVX. Hillsdale, NJ: Erlbaum.

Gopher, D, & North, R. (1977). Manipulating the conditions of training in time- sharing performance. Human Factors, 19(6), 583-593.

Harbluk, J.L., Burns, P.C., Lochner, M., Trbovich, P.L. (2007). Using the lane-change test (LCT) to assess distraction: tests of visual-manual and speech-based operation of navigation System interfaces. In: Driving Assessment 2007. Stevenson, Washington.

Harbluk, J.L., Mitroi, J.S., Burns, P.C. (2009). Three navigation systems with three tasks: using the lane change test (LCT) to assess distraction demand. In: Fifth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design. Big Sky, Montana.

ISO/DIS 26022 (2007). Road vehicles - Ergonomic aspects of transport information and control systems - Simulated lane change test to assess driver distraction.

ISO/DIS 26022: 2010. Road vehicles -- Ergonomic aspects of transport information and control systems -- Simulated lane change test to assess in-vehicle secondary task demand.

Johansson, E., Engström, J., Cherri, C.,Nodari, E., Toffetti A. , Schindhelm, R. & Gelau, C. (2004). AIDE IST-1-507674-IPReview of existing techniques and metrics for IVIS and ADAS assessment. Deliverable No. D 2.2.1 from http://www.aide-eu.org/pdf/sp2_deliv_new/aide_d2_2_1.pdf

Kuhn, F. (2005). Methode zur Bewertung der Fahrerablenkung durch Fahrerinformations-Systeme. World Usability Day. Stuttgart.

Lee, F. J., & Anderson, J. R. (2001). Does Learning a Complex Task Have to Be Complex?: A Study in Learning Decomposition. Cognitive Psychology, 42 (3), 267–316,

Mattes, S. (2003). The lane-change-task as a tool for driver distraction evaluation. In H. Strasser, K. Kluth, H. Rausch, & H. Bubb (Eds.), Qualitiy of work and products in enterprises of the future (pp. 57–60). Stuttgart: Ergonomia Verlag.

Mattes, S., & Hallén, A. (2008). Surrogate Distraction Measurement Techniques: The Lane Change Test. In M. A. Regan, J. D. Lee, & K. L. Young (Eds.), Driver distraction. Theory, effects, and mitigation (pp. 107–122). Boca Raton, Fla.: CRC Press.

Petzoldt, T., Bär, N., Ihle, C., Krems, J.F. (2010).Learning effects in the lane change task (LCT)-Evidence from two experimental studies.Transportation Research Part F: Traffic Psychology and Behaviour, Article in Press.

Rognin, L., Alidra, S., Val, C., Lescoaut, A., Chalandon, X. (2007). Driver strategies when interacting with information and comfort systems. In: 20th International Technical Conference on the Enhanced Safety of Vehicles. Lyon, France.

Shinar, D,, Tractinsky, N., & Compton, R. (2005). Effects of practice, age, and task demands, on interference from a phone task while driving. Accident Analysis and Prevention, 37, 315–326.

Weir, D.H., Kwok, A.M. & Peak, J.L. (2007). Exploratory Lane Change Test Experiments in Support of ISO WG8 LCT Task Force. Paper presented at the ISO Task Force Meeting Calibration Task in Mailand.

Young, K.L., Regan, M.A., Lee, J.D., (2008). Measuring the effects of driver distraction: direct driving performance methods and measures. In: Regan, M.A., Lee, J.D., Young, K.L. (Eds.), Driver Distraction: Theory, Effects and Mitigation. CRC Press, Boca Raton, FL, pp. 85-106.

Young, K.L. & Lenné, M.G. (2010). Driver engagement in distracting activities and the strategies used to minimise risk. Safety Science 48, 326-332.

Young, K.L., Lenné, M.G., & Williamson, A.R. (2011). Sensitivity of the lane change test as a measure of in-vehicle system demand, Applied Ergonomics, 42 (4), 611-618.

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Driver secondary tasks in Germany: using interviews to estimate prevalence

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Abstract

Secondary tasks while driving are commonly found in different types of driving distraction studies all over the world. For profound understanding of secondary tasks impact on road safety it is essential to know in detail what kind of task drivers are doing in which situations. Despite of resource consuming observational studies, interviews may be a suitable access to these data if reporting biases are minimized. In 2009, 289 drivers were interviewed in face-to-face interviews on German motorway service areas as well as in the city of Braunschweig about their secondary task engagement in the last 30 minutes of driving. Five groups of drivers were examined: (1) Truck drivers at the motorway (N= 90), (2) car drivers on private trips at the motorway (N= 71), (3) car drivers on business trips at the motorway (N= 29), (4) car drivers on private trips in town (N= 85), (5) car drivers on business trips in town (N= 12). The pattern and frequency of engagement in secondary tasks differed between these groups. Overall, about 80% of all drivers conducted one to three secondary tasks. Secondary task engagement in Germany thus is a serious issue and accident studies here are needed to estimate drivers´ risk.

Keywords: Driver distraction; secondary tasks; frequency; face-to-face interviews

1. Introduction

The 100car naturalistic driving study (Klauer et al., 2006) and its analyses concerning driver distraction showed in a new and comprehensive way the importance of research in the field of driver distraction and drivers occupation with secondary tasks. By means of the observation of drivers´ behavior in a one-year period it was shown how often some secondary tasks are carried out while driving at least in the USA. Additionally with their analysis of crashes and critical event, the authors were able to show the increased crash risks for the drivers occupied with more complex secondary tasks. By analysis of the circumstances under which tasks were carried out, relative frequency of different tasks could have been assessed and in combination with the crash analysis that delivered estimations of risk-enhancement, authors were even able to calculate population attributable risks for some group of secondary tasks.

Effects of specific secondary tasks on driving performance can be examined closely in driving simulator studies. Here changes in driving parameters and behavioral observations can be made in controlled settings. With this method causal influences of secondary tasks on driving performance can be shown. For an overview of experimental studies, please refer to Ranney (2008), for studies especially dealing with the use of phones while driving, refer to Caird et al. (2008). While experimental studies are able to show changes in driving behavior due to secondary task involvement, it is not possible to directly use these effects to predict changes in crash risk. One important reason is that participants in these studies are usually instructed to carry out secondary tasks. In this situation, secondary task involvement is probably larger than in real traffic and will probably also be shown when it would not in real traffic. Additionally, a simulator setting is always some kind of an artificial setting and the external validity (transferability to real driving) is questionable. For these reasons, experimental studies are not included in the following overview.

Information on secondary task frequency can be gathered by different types of interview-studies, as it has been done in telephone surveys by McEvoy et al. (2006) in Australia and by Royal (2002) in the US or in online surveys, as done by Lansdown (2010), Sullman & Baas (2004), and Young & Lenné (2010).There are two basic limitations of these types of data. First, it is questionable whether the sample really represents the driver population. More specifically, online data collection restricts the sample to those drivers who have access to the internet. Second, the answers may be participant to self-reporting biases, such as social desirability effects (e.g., under-reporting) and inaccurate recall. For example, af Whålberg et al. (2011) found substantial correlations between self-reported accidents and self-reported risk-behavior, but not with objectively recorded accident frequency. While this gives rise to some caution about self-reported accidents, research that has directly investigated the degree of correspondence between self-report and observed driving behavior has generally supported the accuracy of self-report (e.g., see Sullman & Taylor, 2010). This may be due to the fact that secondary task behavior not regarded as being socially unacceptable.

The second type of studies on exposure to secondary tasks is observation studies. Here exposure data in normal driving is gathered. By observation rather than questioning, most reporting biases are eliminated. In naturalistic driving studies (e.g. Klauer et al., 2006; Stutts et al., 2005) in which drivers are observed while normal driving in equipped cars, frequency of secondary tasks as well as critical events or even accidents in real driving situations can be observed. As accidents are rarely found in these studies, risk estimates are mostly not possible. An exception here is the 100-Car Naturalistic Driving Study (Klauer et al., 2006) in which a number of accidents as well as near-accidents or critical events were analyzed. It is thus the only source of data for actual risk of specific secondary tasks, here given in Odds ratios as well as population attributable risks. To give appropriate estimates of risk naturalistic driving studies need to include a significant amount of accidents as cases to be compared to non-accident control driving. For this and as accidents are rare events, a high number of observations resulting in a high number of equipped cars and/or a long observation time is needed. Together with the time-consuming data analysis naturalistic driving studies are a resource consuming approach.

Crash risk due to driver distraction is estimated from accident studies as well as exposure (e.g. Glaze & Ellis, 2003; Gordon, 2005; Hanowski et al., 2005; Stevens & Minton, 2001; Stutts et al. 2001). Here, accidents where a specific task had been carried out are compared to the same type of accidents while the driver was not distracted by this task. In this way, odds ratios as a measure of altered crash risk can be given. However, as long as exposure is not taken into account (e.g., by examining secondary task involvement in crash-free driving) these odds ratios are a mixture of exposure and risk. Additionally, data are mainly collected by police officers at crash scenes. As officers do not have any direct information on secondary task engagement and as drivers in crashes are often not able or willing to report those engagement it can be assumed that the accident risk due to secondary tasks is mostly underestimated in these studies. Finally, accident studies are based on crash data from different countries. As culture as well as traffic differs largely between countries, results from one country cannot easily be transferred to another.

In order to give an overview about the existing studies about secondary task engagement in traffic, a literature search was conducted. To summarize the results, the secondary task types were integrated into one system following a classification of Stutts et al. (2001). The resulting nine different task types are shown in table 1. The first group of tasks here are all task concerning eating and drinking, the second type are all smoking related tasks. The third group comprises all tasks concerning clothing and body care like taking off the jacket or snubbing the nose. The next group includes all tasks related with any device integrated in the vehicle, from positioning of mirrors to manipulation of in-car-telephones. All manipulation of non-integrated devices like mp3-players is found in the fifth group. Passenger-related tasks are summarized in the sixth group. Any other task carried out in the vehicle concerning any other item is found in the group “other tasks”. Tasks not concerning any items are found in the group “self-initiated tasks”, here singing or daydreaming are grouped. In the last group all outside the vehicle distractions are found.

Table 1 Secondary task types in literature. Secondary tasks are grouped after a complemented nomenclature first found in Stutts et al. (2001).

	Secondary task type	**Description**
1	Eating / Drinking	-
2	Smoking related	-
3	Clothing & body care	▪ Snub nose ▪ Change clothes
4	Integrated devices	▪ All adjustments necessary for driving (mirrors, seat etc.) ▪ Manipulation of integrated devices
5	Other devices	▪ Manipulation of non-integrated devices (mobile phone, mp3 player)
6	Passenger related tasks	▪ Talking ▪ Gestures and Touching ▪ Receiving and Giving any device
7	Other tasks	▪ Animal related ▪ Searching things ▪ Reading and writing ▪ Cleaning up
8	Self-initiated tasks	▪ Talking to oneself, daydreaming ▪ Singing ▪ Thinking about something
9	Outside distraction	▪ Track related (construction sites) ▪ Looking at something. (pedestrians, advertisements) ▪ Listening to something (e.g. music from outside, sirens)

Five interview studies were found concerning secondary tasks while driving. While Sullman & Baas (2004) asked about phone use only, the other four studies asked about secondary task engagement in general. Sullman & Baas (2004) asked 287 drivers in Victoria, New Zealand about their phone use while driving and about their personal estimation of its riskiness. 43% of participants reported never to use the phone while driving, another 43% reported occasional use and the remaining 14% reported to use it often or all the time. The results of the other interview studies are summed up in table 2. McEvoy et al. (2006) asked in a telephone survey 1374 drivers of New South Wales or Western Australia in Australia to report all distracting activities during their last driving trip lasting longer than five minutes. Royal (2002) analyzed data of 4010 drivers surveyed in the USA in 2002 showing that most drivers engage in secondary tasks while driving. Drivers here were also asked to indicate the riskiness of secondary tasks. Lansdown (2010) developed an online survey in the United Kingdom and analyzed data of 483 respondents. Young & Lenné (2010) used an internet survey of 287 drivers in Victoria, Australia. Here drivers were asked to report about their general activity in a wide range of secondary tasks and to indicate how often they are engaged in them. In a next section of the survey driver were also asked to indicate the perceived riskiness of engagement in secondary tasks while driving as well as the riskiness of other driving behaviours. In these surveys, as summed up in table 2, drivers reported high rates of engagement while driving at least some times. It can be assumed that at least 90% of drivers operate in-car-systems; most of them listen to music. Most drivers (more than 80%) talk to passengers; half of the drivers (up to 80%) eat or drink at least sometimes. Between 40% and 60% operate other than in-car devices, and, as found by Young and Lenné (2010), high proportions of drivers engage in internal tasks (72%) or pay attention to outside distractions (58%).

Table 2 Overview of secondary task types contributing to crashes in different interview data. The percentages give the number of drivers admitting the secondary tasks shown in the rows.

	Royal (2002)	McEvoy et al. (2006)	Lansdown (2010)	Young & Lenné (2010)
Data Source	telephone survey	telephone survey	online survey	online survey
Secondary Task	drivers engaged [%]	drivers engaged [%]	drivers engaged [%]	drivers engaged [%]
Eating / Drinking	49	18	51	80
Smoking related		10	2	
Clothing & body care	8	3	3	
Integrated devices		100	91	94
Other devices	66	7	1	41
Passenger-related	81	40	81	
Other tasks	16	25	1	23
Internal tasks		69		72
Outside distraction		55	3	58

Besides differences of the samples of the studies, the large variation of the results may also be due to a different methodology of the questions. Royal (2002) and Young & Lenné (2010) asked about driving in general which may be difficult for the participants to remember and to estimate. McEvoy et al. (2006) asked only about the last trip which may have helped to get more precise data but here as well, remembering may be poor if the trip was long before the interview call.

Four driver observation studies dealing with all types of driver distraction were found. The first of these studies was carried out by Stutts et al. (2005), videotaping 70 drivers during one week of their normal driving in 2000 to 2001. Videos were taken by cameras in the vehicle, watching the driver, the front seats and out of the windscreen. Afterwards, the drivers´ activity was rated according to the categories of the secondary tasks described above. Sayer et al. (2005) rated videotapes of drivers taken during a field operational test in a non-assisted phase of driving in 2004 and 2005. They rated a total of 1140 video clips of 5 seconds of driving time taken of 36 drivers of six driver age groups ranging from 20 to 70 years. The videos had been taken over a period of four weeks per driver. For these video clips secondary task type was rated and driving parameters with secondary tasks were compared to driving without a secondary task. Johnson et al. (2004) analyzed 40 000 photographs taken in July 2001 at the New Jersey Turnpike and rated secondary task occupation of the randomly photographed drivers. Klauer et al. (2006) finally reported the part of the 100 car naturalistic driving study concerning driver distraction and inattention and its relation to crashes, near crashes and incidents. In the 100 car naturalistic driving study 109 drivers were driving equipped cars for a one-year-period between 2001 and 2004. Here, drivers and their surrounding were observed by video recording. Driving parameters were also collected. Klauer et al. (2006) filtered the large amount of data by using a combination of driving parameters, to be able to find critical situations in their data. By this filtering process, 82 crashes, 761 near crashes and 8295 critical incidents were found. They were analyzed and compared to 6000 randomly selected noncritical situations. Drivers´ attention status and secondary task occupation were analyzed for critical and non- critical situations. Thus, odds ratios for different secondary task types were calculated.

To summarize these studies, for observational studies in accident free driving, about 30% of driving time with secondary tasks is found. Interaction with passengers is common and therefore should be a major relevant topic in research. Dealing with devices in the car, infotainment tasks as well as driving related tasks are equally common and thus equally important. Outside distractions are rarely found in these studies. This may be due to the observation method as this type of distraction is difficult to observe in video tapes. An overview of different secondary task type frequencies found in the existing studies is displayed in table 3.

Table 3 Overview of secondary task types contributing to crashes in different observational data. The percentages give the number of the secondary tasks shown in the rows related to driving time involving any secondary task ("distracted driving time") and to the total driving time.

	Klauer et al. (2006)		Stutts et al. (2003)		Sayer et al. (2005)		Johnson et al. (2004)	
Data Source	video data		video data		video data		photographs	
Secondary Task	distracted driving time [%]	total driving time [%]	distracted driving time [%]	total driving time [%]	distracted driving time [%]	total driving time [%]	distraction photos [%]	total photos [%]
Eating / Drinking	14.83	4.61	7.63	1.90	7.16	0.26	10.00	3.85
Smoking related	4.99	1.55			10.81	0.40	0.00	0.00
Clothing & body care			26.10	6.50	0.07	0.00	0.00	0.00
Integrated devices	16.10	5.13			5.83		3.33	1.28
Other devices	4.18	1.30	21.29	5.30	38.27	1.41	23.33	8.97
Passenger-related	52.12	16.20	26.10	6.50	15.24	0.56	23.33	8.97
Other tasks	2.16	0.67	10.04	2.50	8.14	0.30	16.67	5.11
Internal tasks							30.00	11.54
Outside distraction	5.21	1.62					0.00	0.00
Total	**100.00**	**31.08**	**91.16**	**22.70**	**85.53**	**3.14**	**106.67**	**41.03**

If no numbers are found in a cell, this may have two reasons: no observations were made in this category or they may not be correctly identified here, as the data was not reported by authors in this detail. For the same reason, the sum of distracted driving time may differ from 100%.

Finally, six accident studies concerning driver distraction were found. The first of these studies was carried out by Stutts et al. (2001) who analyzed the data of the Crashworthiness Data System of the National Accident Sampling System of the US between 1995 and 1999. Here, data of 5000 representative accidents per year were analyzed. Glaze & Ellis (2003) analyzed police crash reports of 2792 distraction crashes in Virginia, USA. Crashes were analyzed regarding crash type, distraction type, roadway and number of vehicles. In New Zealand, presence of driver distraction and type of distraction is recorded for every crash reported to the police. Gordon (2005) transferred the distraction types used in the national coding system (Crash Analysis System, CAS) into the coding system used by Stutts et al. (2001) and reported crash data of the years 2002-2003. British data was reported by Stevens & Minton (2001), using 5740 crash reports of England and Wales of the years 1985-1995. These authors do not report the total number of crashes in the region within this time period, thus the data sample cannot be drawn to the population of crashes and thus not been entirely interpreted. Crash data of truck drivers was analyzed by Hanowski et al. (2005). Their data was based on a national survey of truck crashes with injuries and fatalities at 24 sites in 17 States in 2001 through 2003. From those crashes, data of drivers, co-drivers, vehicles, roadway, and driver state were recorded and the most likely crash causation was estimated.

Integrating the results of these accident studies, the frequency of secondary tasks in accidents is found to be between 10% and 30%, depending on the definition of secondary tasks used in these studies. An exception is the study of Stevens & Minton (2001) with frequencies below 2% which may be due to the crash reporting system. Including internal tasks such as thinking, singing or talking to oneself, this portion reaches 40% of crashes. In table 4 a summary on crash data studies on driver distraction is found. In this table, the percentages of the nine secondary task types are given with respect to all distraction crashes and to all crashes. Within the distraction crashes, outside the vehicle distractions are the most common source of distraction accounting for 30%-40% of distraction crashes. Interaction with passengers are also commonly found (in about 10%-25% of distraction crashes) followed by operations on in-vehicle devices, integrated as well as non-integrated ones (15%-35% of distraction crashes). These data show that driver distraction is quite frequent in crashes. However, it remains unclear whether this is the results of a large exposure (driving with secondary tasks) or distraction related crash risk.

Table 4 Overview of secondary task types contributing to crashes in different accident studies. The percentage give the number of the secondary tasks shown in the rows related to all crashes which involve distraction ("distraction crashes") and to all crashes.

Data Source	Stevens & Minton (2001)		Stutts et al. (2001)		Glaze & Ellis (2003)		Gordon (2007)		Hanowski et al. (2005)	
	Crash Data Cars		Crash Data Cars		Crash Data Cars		Crash Data Cars		Crash Data Trucks	
Secondary Task	Distraction crashes [%]	analyzed crashes [%]	Distraction crashes [%]	all crashes [%]	Distraction crashes [%]	all crashes [%]	Distraction crashes [%]	all crashes [%]	Distraction crashes [%]	all crashes [%]
Eating / Drinking	16.83	0.30	1.70	0.22			7.63	1.90	3.00	0.33
Smoking related			0.90	0.12					2.00	0.22
Clothing & body care					2.30	0.50	26.10	6.50	6.00	0.66
Integrated devices	34.65	0.61	16.90	2.18	0.40	0.10			10.00	1.10
Other devices	2.97	0.05	1.50	0.19	0.00	0.00	21.29	5.30	5.00	0.55
Passenger-related	25.74	0.45	10.90	1.41	7.10	1.40	26.10	6.50	12.00	1.32
Other tasks	19.81	0.35	29.90	3.85		1.00	10.04	2.50	7.00	0.77
Internal tasks					35.60	7.50			5.00	0.55
Outside distraction			29.40	3.79	42.40	27.50			44.00	4.84
Total	**100.00**	**1.76**	**91.20**	**11.76**	**87.80**	**38.00**	**91.16**	**22.70**	**94.00**	**10.34**

If no numbers are found in a cell, this may have two reasons: no crashes were found in this category or they may not be correctly identified here, as the data was not reported by authors in this detail. For the same reason, the sum of crash type portions in distraction crashes may be lower than 100%.

To sum up literature findings from observational, interview and accident studies, secondary task occupation while driving is commonly found and reported by accident-free drivers as well as in accidents. Distractions by passengers as well as distractions by in-vehicle devices seem to play an important role. However, as frequencies found in observation studies do not differ that much from accident involvement, it is hard to say whether distraction really increases accident risk. Case-Control studies of distraction based accident risk are needed to clearly show the influences of these tasks on driving performance and safety. Furthermore, it is not possible to combine the information about exposure and risk from these different studies as the sample differences as well as the definition and recording of secondary tasks differs too much between the studies.

As culture and traffic differ between countries there is no easy way of transferring these data to other contexts. As Germany has a high traffic density, secondary task engagement as well as its influences on crash risk may differ from the referred studies. To estimate hazardousness for secondary tasks here, all data mentioned above is needed: At first, exposure rates have to be gathered to be able to compare them to detailed crash data in the following. To get these exposure data in an effective way, we developed an interview method for German drivers. As an advantage of these interviews we here were able to get information on secondary tasks that cannot be recorded by outside observers, e.g. daydreaming as well as subjective evaluation on riskiness of tasks. To avoid drawbacks of the interview studies like problems with remembering or underestimation biases, we conducted interviews with drivers directly after driving in face-to-face interviews in summer 2009.

2. Method: Interviews about secondary tasks while driving

Driver interviews were used as they provide an effective and fast means to get an overview about the frequency and types of secondary tasks. Additionally, some secondary tasks like daydreaming cannot be observed from outside but are easy to report by the drivers themselves.

2.1. Interview protocol

For these interviews a semi-structured standardized protocol was developed to gather information on frequency and duration of every secondary task type in the first part and to get more detailed information on the tasks carried out in the second part. Additionally, subjective risk estimations were obtained. In order to reduce forgetting, interviews were conducted instantly after the trip at parking sites in the same environment and context where the trip had taken place. To enhance response rate, face to face interviews were chosen. Additionally, the first part of the interview was kept very short including only the most basic questions about different secondary tasks. Afterwards, the second part was conducted for only one secondary task with in-depth questions. Thus, the overall time needed for the interview was abbreviated while at the same time the basic information was obtained from all drivers. In this paper, only the data of the first part are presented as this gives the information about frequency and perceived risk of all drivers.

In the first part of the interview, demographical data was gathered. Afterwards, drivers were asked to report every secondary task of the last 30 minutes of driving. In order to support remembering, they were asked where they had been 30 minutes ago and were encouraged to remember the trip from this time-point onwards. If the actual trip was shorter, the whole trip was to be reported. To gather a complete report of all tasks, the different task types were explained to the drivers. For every task reported, task type according to the categories described above and duration was given. This part of the interview took about 5 minutes. In the next part driver were asked to report one of their tasks in detail. Here, they should report circumstances and course of action of the task. Afterwards they were asked to estimate the distracting effect of this task in the actual situation and in general as well as to rate the risk of conducting this task while driving for the actual situation and in general. This part of the interview took about 10 additional minutes. Afterwards drivers were thanked for their patience and help and were given an information brochure on the project aims. All interview data were audio-recorded and transliterated afterwards.

2.2. Sample

Interviews were carried out at four parking areas at the motorway and three parking areas in the city of Braunschweig, Germany. The parking areas at the motorway are situated at the E30, one of the most used road transport motorways crossing Europe from east to west, these parking areas are almost exclusively used by drivers on the motorway. Here, drivers who are travelling the E30 take rests or refuel their vehicles. The parking areas in the city are situated in suburban area near radial highways within shopping areas with supermarkets, do-it-yourself stores etc. Around those parking areas, roadways were surface streets. Data collection was from July to August 2009, from Monday to Friday between 8.00 a.m. and 5.00 p.m. This gives some restrictions to the sample. On motorway, almost all types of drivers are represented, as commercial drivers on transit operate at all daytimes, as commuters are represented at least in the afternoon and as occupational drivers could be asked within their working hours. In the specific city area one groups of drivers is missing in the sample, as families with working parents are unlikely to do their shopping within the interview times. The time of data collection was vacation time in Germany, thus a untypical amount of families on vocational trips may be found on motorway. A total of 135 hours of interview time was recorded. Six trained psychologist interviewers carried out the interviews in teams of two. Every vehicle driver arriving at one of the parking areas was asked to take part in the study. Out of 343 drivers, 289 agreed to give the interviews. This corresponds to a responder-rate of 84.3%. Of the non-responders, age (estimated), sex, vehicle type, the location of the interview and the presence of passengers was recorded and compared to the responders. There was no difference with regard to sex, vehicle type, location of interviews, passengers present in the vehicle. Non-responders were estimated to be a bit younger (39 years) than the responders (45 years). However, this may also be due to an estimation bias. Thus, there is no strong evidence that the non-responders differ systematically from the responders. In particular, it does not seem likely that they avoided the interview because of a special engagement in secondary tasks.

3. Results

3.1. Driver types

In the first step it was examined which characteristics of the trip or the drivers could lead to a different amount of engagement in secondary tasks. Drivers differed with regard to the purpose of the trip (occupational or private). There were cars and trucks and the trip took place either in the city or on the motorway. Table 5 gives the number of drivers according to these characteristics. 287 of the 289 drivers of the sample were assigned to one of five groups of drivers, differentiating them on vehicle type, location of the interview and driving purpose. A total of 197 drivers were car drivers. Out of them, 41 were on occupational trips and 156 on private trips. 12 of the occupational car drivers were interviewed in the city and 29 at the motorway. 85 of the private car drivers were interviewed in the city and 71 at the motorway. 90 of the truck drivers were interviewed at the motorway and they were on occupational purpose. There was one truck driver on a private trip and one truck driver interviewed in the city. These were not taken into the following analyses, which are all based on these five driver groups.

Table 5 Driver group characteristics and demographic data of the sample. Drivers are grouped after (1) driving purpose, (2) location of interview and (3) vehicle type. The five driver groups that were analyzed comprised 287 of the total 289 drivers interviewed. Demographic data is given only for the analyzed drivers.

Vehicle type	Location	Driving purose	N	Gender		Age		Driving expiereince [years]		Mileage [1000 km /year]		Actual trip length [km]		Passengers	
				m	f	M	SD	M	SD	M	SD	M	SD	without	with
Car	**City**	**Private**	**85**	**40**	**45**	**46.6**	**15.4**	**26.8**	**14.2**	**19.2**	**18.9**	**17.0**	**18.2**	**48**	**37**
		Occupational	**12**	**7**	**5**	**39.1**	**11.5**	**20.1**	**12.0**	**32.9**	**27.8**	**14.5**	**13.4**	**10**	**2**
	Motorway	**Private**	**71**	**53**	**18**	**51.1**	**13.8**	**30.4**	**12.9**	**20.6**	**18.3**	**235.2**	**113.4**	**15**	**56**
		Occupational	**29**	**23**	**6**	**41.0**	**12.5**	**23.1**	**13.7**	**51.4**	**34.5**	**161.6**	**136.8**	**24**	**5**
Total Car			197												
Truck	City	Private	0												
		Occupational	1												
	Motorway	Private	1												
		Occupational	**90**	**89**	**1**	**42.2**	**10.5**	**23.1**	**10.6**	**128.9**	**54.9**	**222.4**	**147.5**	**85**	**5**
Total Truck			92												
Total City			98												
Total Motorway			191												
Total Private			157												
Total Occupational			132												
Total analysed			**287**	**212**	**75**	**45.4**	**13.7**	**25.9**	**13.0**	**58.0**	**60.8**	**149.9**	**146.1**	**182**	**105**

Table 5 also shows the demographical data of the drivers´ groups. Car drivers on private trips in the city had a nearly equal distribution of gender, were middle-aged, and had the longest driving experience but the smallest annual mileage. They were on short trips and one third of them carried passengers. Occupational car drivers in the city were also of both genders, were the youngest driver group in the sample with the shortest driving experience but with a medium annual mileage. They were also on short trip and had few passengers. Private car drivers on the motorway were mostly male, mostly older with the longest driving experience but with a low annual mileage. They were on the longest trips and carried the most passengers. Occupational car drivers on motorway were mostly male, younger, with a shorter driving experience but with high annual mileage. They were currently on long trips and most of them drove alone. Occupational truck drivers were almost exclusively male, middle-aged with a medium driving experience but a very high annual mileage. They were on very long trips and almost all of them were alone in the truck.

3.2. Engagement in secondary tasks

In the first step of the analyses, the frequency and duration of secondary task engagement was computed regardless of the specific type of distraction. As displayed in figure 1, more than one third of the drivers (37.3%) reported to have been engaged in two different secondary tasks. About one fifth reported one task (20.6%) or three tasks (22.0%). About one sixth (16%) reported four or more different secondary tasks. Only 3.8% of drivers reported no secondary task engagement.

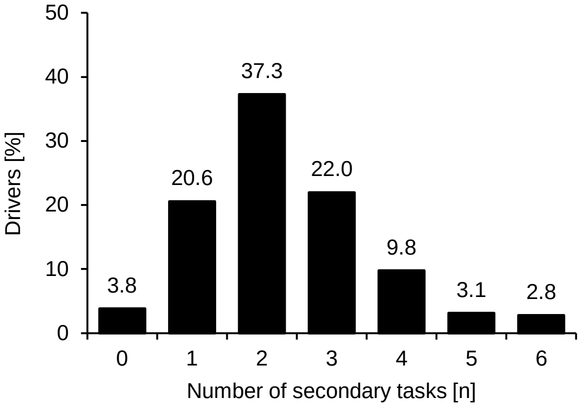

Figure 1 Number of reported secondary tasks within the last 30 minutes of driving. Up to six tasks were reported by drivers. Percentage of drivers who reported each sum of tasks is shown.

In figure 2 secondary task engagement is displayed separately for the five driver groups. Additionally, besides the average number of secondary tasks (left) also the overall duration of secondary task engagement is given. Car drivers in the city on occupational trips reported the largest number of tasks (M= 3.2, SD= 1.4 tasks), lasting for about 40% of their driving time. Private car drivers in the city do less tasks (M=1.9, SD= 1.0 tasks) and these are the shortest with about one third of the driving time. Car drivers on motorway, on private as well as on occupational trips are doing about 2.2 (SD=1.2) and 2.3 (SD=1.1) tasks, respectively, lasting for about 41% to 42% of driving time. Truck drivers carry out about 2.7 (SD= 1.4) tasks, lasting the longest with about 54% of driving time.

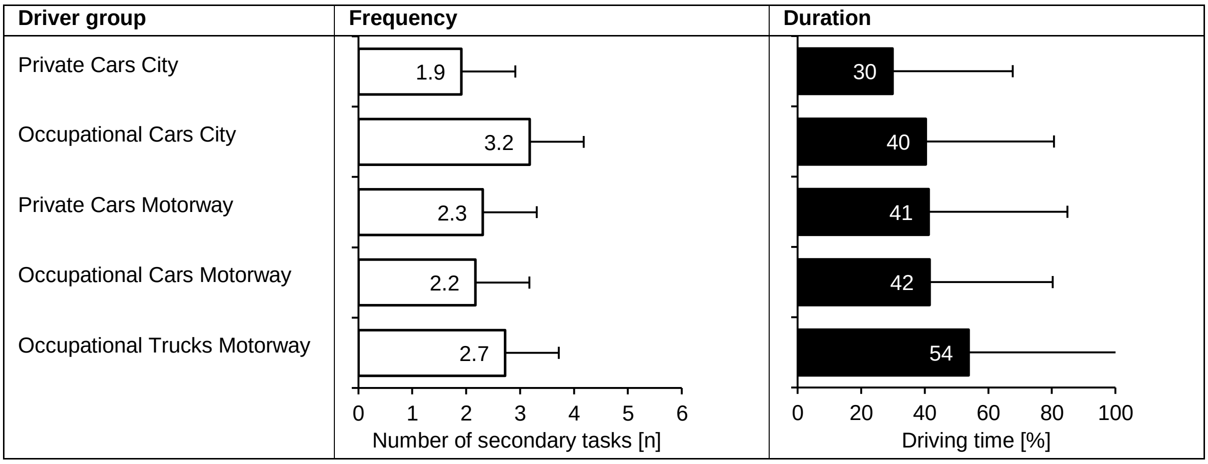

Figure 2 Frequency and Duration of secondary task occupation in driver groups. For each driver group, mean number of tasks (white bars, whiskers represent SD) and mean duration of occupation with tasks (black bars, whiskers represent SD) is given.

In the second step, different types of secondary tasks were examined. Figure 3 gives the frequency and amount of time spent with different tasks sorted by the frequency. The mean duration was only computed for those drivers who had conducted this task. Figure 3 shows, that using integrated devices is the task most frequently reported by the drivers (about 58% of all drivers). These tasks are relatively short as they account for only about 5% of the driving time. Tasks related to passengers are also quite frequent with about 38% of drivers, but last substantially longer (about 39% of driving time). Self-initiated tasks were done by about 30% of drivers, also lasting long with about 37% of driving time. Outside distractions are found in 23% of drivers and about 10% of driving time. Dealing with other, non-integrated devices in the car is a less common task found in 18% of drivers. But this task last quite long with about 35% of driving time. Eating and drinking is less common with only 9% of all drivers However, if they eat or drink this takes about 30% of their driving time. Smoking is found in 24% of drivers taking about one fifth of the driving time (23%). Clothing and body care is found in 10% of drivers lasting only about 3% of driving time. Any other tasks are found in 4% of drivers for about 5% of driving time.

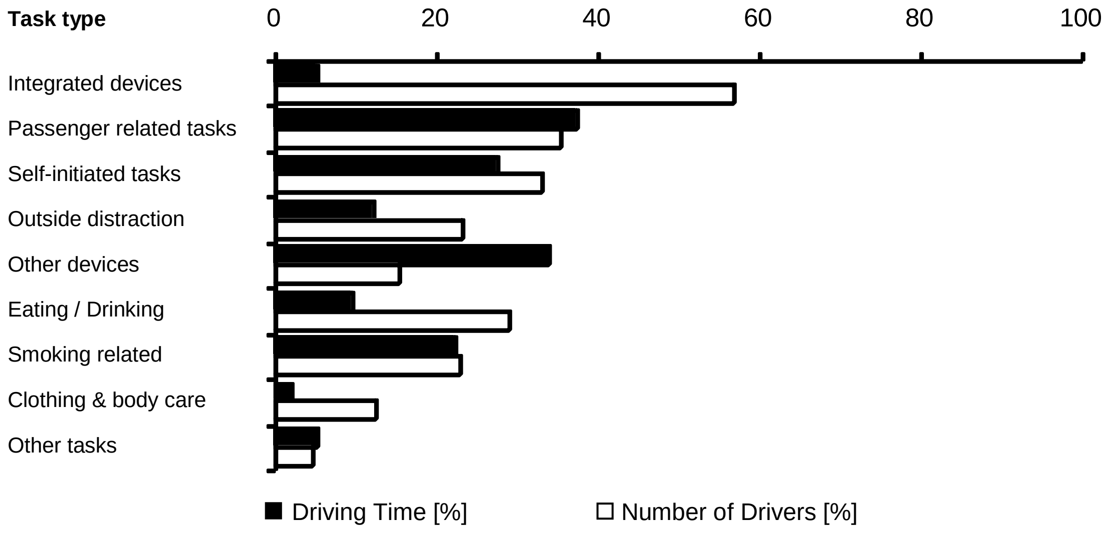

Figure 3 Frequency and Duration of specific secondary task types. Frequency (white bars) and driving time (black bars) of the specific secondary task types are given for all drivers. Frequency is given relative to sample, duration relative to driving time.

In the next step of the analyses differences between the five driver groups were examined with regard to frequency and duration of the tasks. The following figures 4 to 7 show the comparisons of task occupation profiles for drivers in an urban area, drivers on private purpose, occupational car drivers and occupational trips on motorways, respectively.

In figure 4 the profiles of drivers in the city are displayed. What can be seen here is that in general drivers on occupational trips do more tasks, except of passenger related tasks. However, the duration of these tasks (if done) is quite similar in both groups. The most frequent tasks are using integrated devices followed by passenger related tasks in private vehicles, and self-initiated tasks and outside distraction. The tasks with the longest duration are passenger-related tasks, self-initiated tasks and smoking.

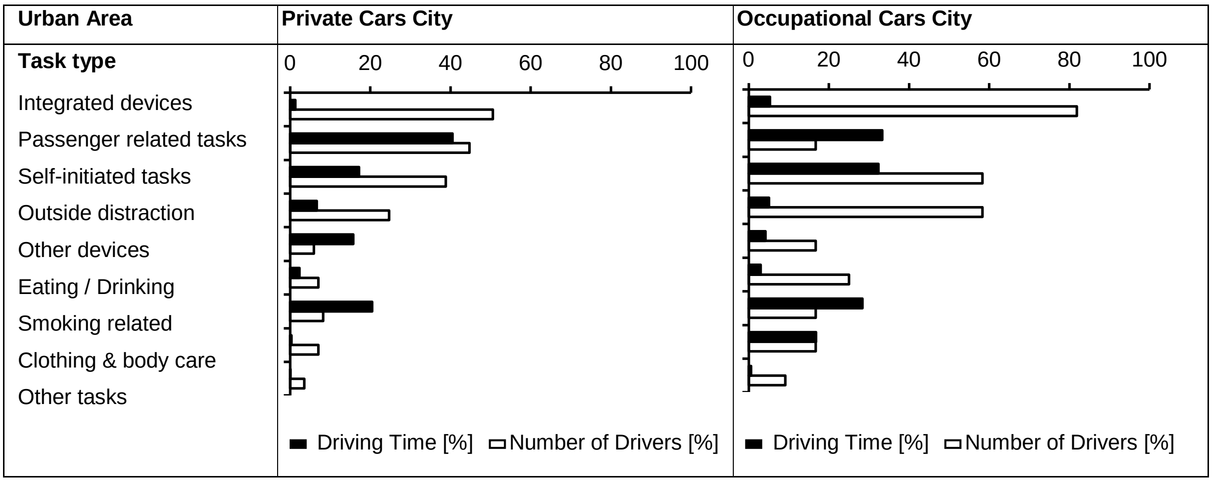

Figure 4 Profiles of secondary task occupation in urban trips. Frequency (white bars) and driving time (black bars) of the specific secondary task types are given for private (on left) as well as occupational (on right) car drivers in city. Frequency is given relative to sample, duration relative to driving time.

In figure 5 private trips on motorways and in the city are compared. On motorways more passenger-related tasks are found. This might be because of vacations time in Germany where more families were driving on longer trips. In the city also less eating and drinking as well as clothing & body care tasks are found. For self-initiated task it is found, that they are more frequent in the city but of longer duration on motorways.

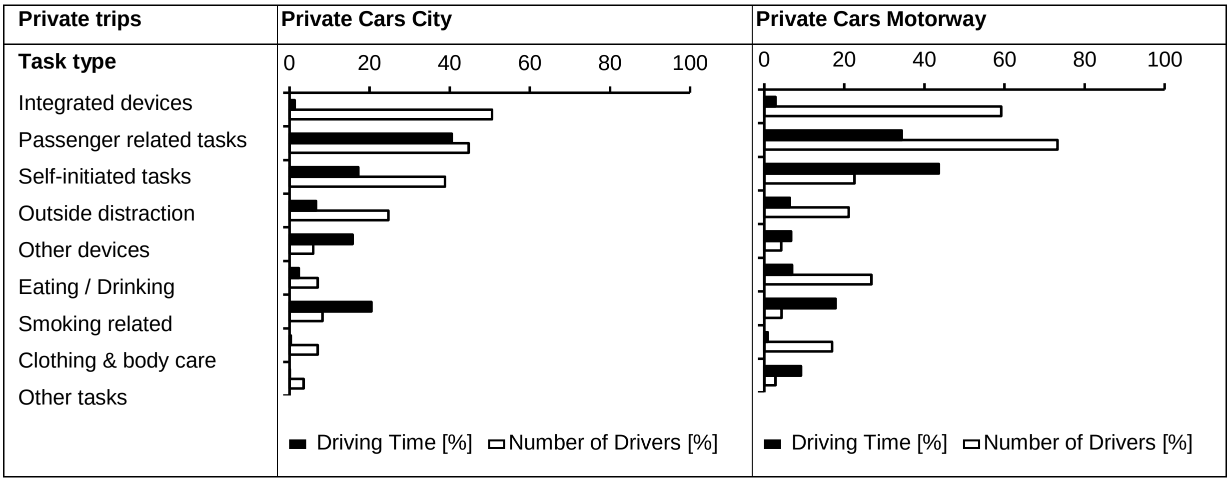

Figure 5 Profile of secondary task occupation in private trips. Frequency (white bars) and driving time (black bars) of the specific secondary task types are given for private car drivers in city (on left) as well as on motorway (on right). Frequency is given relative to sample, duration relative to driving time.

In figure 6 car drivers on occupational trip in the city are compared to those on motorways. In cities, more self-initiated tasks as well as more outside distractions are found, on motorways dealing with other devices and eating/ drinking is more frequent. The secondary tasks in the city are generally of shorter duration, except of clothing & body care tasks, if they occur.

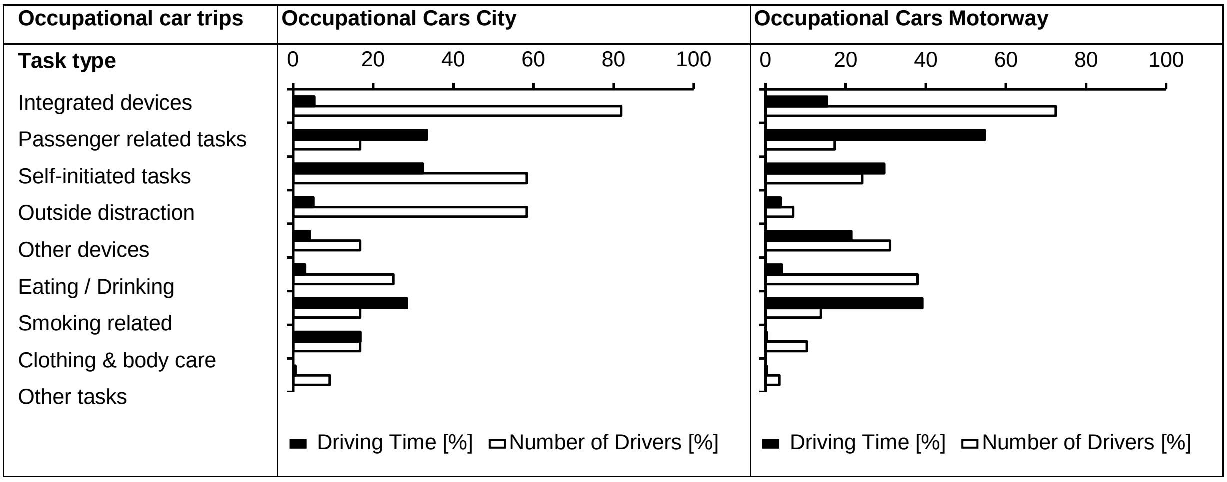

Figure 6 Profile of secondary task occupation in occupational car trips. Frequency (white bars) and driving time (black bars) of the specific secondary task types are given for occupational car drivers in city (on left) as well as on motorway (on right). Frequency is given relative to sample, duration relative to driving time.

Figure 7 finally compares occupational truck and car drivers´ secondary task behaviour on motorways. On motorways, car drivers are more and longer occupied with passengers. They eat less frequently and for shorter time and are less and for shorter time distracted from outside the vehicle and from other tasks. In car drivers more smokers are found and they smoke a greater part of their driving time.

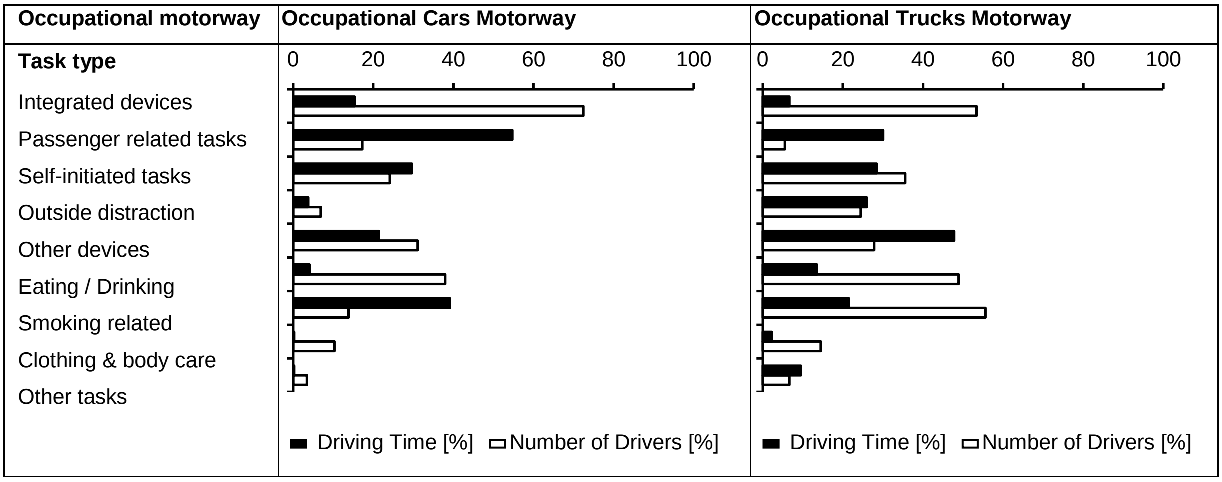

Figure 7 Profile of secondary task occupation in occupational trips on motorway. Frequency (white bars) and driving time (black bars) of the specific secondary task types are given for occupational car drivers (on left) as well as occupational truck drivers (on right) on motorway. Frequency is given relative to sample, duration relative to driving time.

These analyses show that secondary task engagement depends on driving purpose, vehicle type and road type. On motorways, passenger related tasks are the most frequent secondary tasks, if passengers are present in the vehicle. If not, operating devices not integrated in the vehicle is a frequent activity of the drivers. In the urban area, outside distractions and self-initiated tasks are the most frequent tasks, followed by passenger related tasks. Over all, operating integrated devices is the most frequent tasks with the shortest length, whereas operating other devices is not found so often but has the longest duration if it is done.

3.3. Subjective evaluation

At the end of the Interview drivers were asked to rate one of the tasks that they reported to have been engaged in with regard to the distraction caused by the task and the danger the task presents. For the danger, drivers were asked whether they believed that the tasks were danger in general and if they thought it had been dangerous when they engaged in these tasks. Figure 8 gives the results. As the white bars indicate, most drivers believe most tasks to be potentially dangerous (ratings between 90% agreement for outside distractions and 40% for smoking), but far fewer rated the current task as being possibly distracting (27% agreement for clothing & body care down to 11% for self-initiated tasks) or dangerous when they had conducted them (18% agreement for outside distractions down to 3% for smoking).

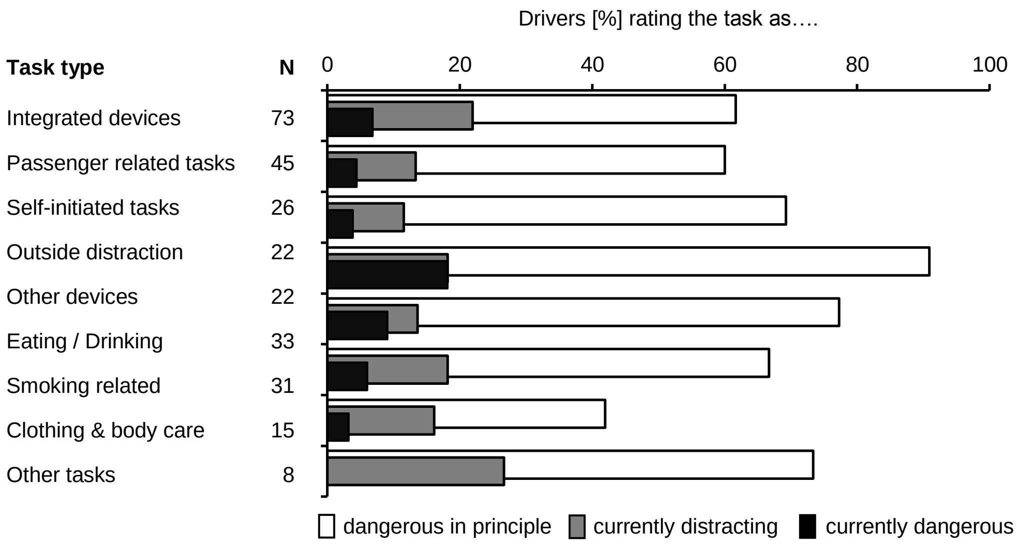

Figure 8 Subjective evaluations of secondary task distraction and danger. Each driver was asked to rate one of his reported task types, considering general danger, actual distraction and actual danger of task. Number of drivers rating each task is given in the second column. Ratings are agreements to influence of task given relative to this sample.

4. Discussion and conclusions

This interview study on secondary tasks while driving shows that German drivers engage in secondary tasks quite frequently. Two to three secondary tasks per 30 minutes are carried out by the drivers, lasting for about 30-50% of the driving time. The most common task types are operating devices, passenger related tasks, and distractions from outside the vehicle as well as self-initiated, internal distractions. These estimations are hard to compare with those of the international interview and online studies described above because the latter did not obtain information on a trip basis but in a more general manner (e.g., “do you telephone while driving?”). The estimations are very similar to those from the international observation studies (see chapter 1), but a little higher in frequency. This may be due to the different method as self-initiated tasks and outside distractions are hard to observe, but easy to report. It may also be due to difficulties to give good time estimation about the duration of the task. Finally, it could also be cultural differences. In order to examine this more closely it would be valuable to have a direct comparison between observation and report data by interviewing observed drivers directly after their trip in a comparable manner as it was done here.

Reported secondary task engagement differed between the five driver groups that were found in the sample. Different patterns of engagement were found in overall frequency and duration as well as between specific secondary task types. Private (in our sample only car-) drivers are doing in general fewer secondary tasks than those on occupational trips. Here, different concepts of driving time may be an important factor, as occupational drivers are primary working and only in the second sense driving a vehicle. Thus, for these special drivers as higher amount of workload should be suspected. Occupational drivers are more often occupied with integrated as well as non-integrated devices in the car, which may resemble work tasks. They are also more often occupied with self-initiated task, which may be work-related planning. Occupational drivers eat and drink more often while driving which may be interpreted in a sense of intended time-saving. Overall, those drivers are doing more task but with shorter relative duration. This result may be due to longer trips of occupational drivers (in cities, most private trips were less than 30 minutes) or, may be due to optimized multitasking performance. In this line of interpretation the finding may resemble the different pattern of accident data presented by Hanowski et al. (2005), showing occupational drivers´ accident risk by secondary task at least not to be higher, than car driver´s risk in the other studies. Passenger related tasks do not show the same pattern here as the other task groups do. They are less frequently found in occupational trips as there are less frequent found any passengers. Looking at the accident data, this task group has a higher accident risk in commercial truck drivers than in car driving samples. This, too, may be an indicator of lower risk for well-trained task (driving + secondary task) combinations. On motorway, drivers are engaged relatively longer in secondary tasks than in the city area. Self-initiated tasks and outside distractions were reported less frequent for motorway-trips; this may be due to less stimulation outside the vehicle on motorways to be distracted by. The longer smoking, passenger related tasks like chatting and operating integrated devices may from this point of view be interpreted as an active search for distraction, or better diversion from a driving task that may causes fatigue by lacking stimulation. It can be assumed that different driver types have specific roles while being a driver. Occupational drivers seem to work additionally to driving; drivers on longer trips seem to have needs that they want to fulfill while driving (eating and drinking, smoking) and strategies to keep their performance. In contrast, on short city trips, outside distraction is more prominently found and self-initiated tasks, like planning or daydreaming are more often found.

From the drivers´ perspective, these secondary tasks are dangerous in principle but the task currently done was estimated to be not so distracting and not so dangerous. The overall estimation of the danger posed by the different tasks is very similar to the danger ratings found in other interview studies (Patel et al., 2008; Young & Lenné, 2010). The low ratings for the current danger could, on the one hand, be interpreted as an underestimation of the danger by the drivers. On the other hand it could also be seen as an indicator for the drivers´ ability to engage in secondary tasks in situations where driving demands are quite low and it is assumed to be safe to engage in these tasks. Or engagement in secondary tasks could also be used to counteract boredom and fatigue as according to the line of interpretation for the differences between city and motorway trips. Thus, the large frequencies found here should not be interpreted as being dangerous per se. As far as the drivers are well able to select safe phases of their trip for their engagement in secondary tasks, this might not be dangerous but even increase wakefulness and alertness.

These specific patterns of drivers´ engagement in secondary tasks and these evaluations have some implications. When planning activities to reduce distraction crashes are conceptualized, these differences and the underlying motives and needs need to be taken into account. As only case-control accident studies are able to contribute to establishing an increased accident risk due to secondary tasks, those are clearly required not only for Germany. Afterwards, it has to be evaluated for which tasks as well as which driver groups countermeasures are needed and how they have to be implemented to be most powerful. As an example, commercial drivers´ behavior is to large amounts determined by their companies’ demands. Here, legislation enforcement on companies is far more promising than encouragement of drivers´ to act safer.

An interesting point found in the data is that devices integrated in cars are operated quite frequently, but the duration of this activity is quite short. It may be that this reflects at least in some part the effort spent in designing the human machine interface in a way which leads to a minimal distraction during driving. In contrast, the operation of non-integrated devices is done less frequently but with a much higher duration. At least some part of this may be due to the fact that these are not optimized for the operation in cars. Again, a closer examination and comparison of these tasks would be valuable.

In this study only a small sample of German drivers was examined. More exhaustive studies need to be done in order to achieve a representative picture of distracted driving in Germany. Thus, the frequencies and durations reported here should clearly be viewed with caution and are restricted to the circumstances and samples described above. On the other hand, as the results are quite similar to those of the observation studies from other countries, it seems that these results are not so far from the overall German reality. The sample collected in this study did not include non-German speaking drivers (Eastern European truck drivers) as well as any nighttime driving (especially relevant for truck drivers), trips at weekends and on other road types than large highways and urban areas, to name the most important factors. We did not get information und any rural driving as there are short-distance commuters, young drivers on their way to school or to leisure activities. Craftsmen, on working trips are missing, if these trips are short. In the city sample, no inner-city driving is found, mostly missing here short-distance commercial deliverers. As there are some special driver groups with accident high risk (e.g. young drivers) or high workload (short-distance commercial deliverers) this data should clearly be obtained in following studies. The high frequency of secondary tasks found in this study clearly shows the need for specific accident studies in Germany in order to evaluate a possible increase in accident risk due to secondary task involvement.

From a methodological point of view, using face-to-face interviews directly after the trips can be evaluated as a success. Drivers are well able to report their tasks and thus it is possible to get an assessment of driver secondary task engagement quite fast and with much less time than it is required by naturalistic driving studies. Additionally, the self-report enables the assessment of internal distraction which cannot be seen in video observations. The high responder rate and the similar results as compared to other studies support the impression that drivers honestly report their engagement in secondary tasks to their best knowledge. However, the ability of the drivers to accurately report the tasks and estimate their duration should be further assessed by comparison studies as mentioned above. Further studies with this approach are being planned.

References

Caird, J.K., Wilness, C.R., Steel, P. & Scialfa, C. (2008). A meta-analysis of the effects of cell phones on driver performance. Accident Analysis and Prevention 40, 1282–1293.

Glaze, A. L., & Ellis, J. M. (2003).Pilot Study of Distracted Drivers. Trasnportation Safety and Training Center, Center for Public Policy, Virginia Commonwealth University.

Gordon, C. (2005). Driver distraction: An initial examination of the ‘attention diverted by’ contributory factor codes from crash reports and focus group research on perceived risks. (Online paper, available: http://www.ipenz.org.nz/ipenztg/papers/2005_pdf/04_Gordon.pdf [July 27th 2009]).

Hanowski, R.J., Perez, M.A., & Dingus, T.A. (2005). Driver distraction in long-haul truck drivers. Transportation Research Part F 8 (6), 441–458.

Johnson, M.B., Voas, R.B., Lacey, J.H., McKnight, A.S., & Lange, J.E. (2004). Living Dangerously: Driver Distraction at High Speed. Traffic Injury Prevention 5 (1), 1–7

Klauer, S.G., Dingus, T.A., Neale, V. L., Sudweeks, J.D., & Ramsey, D J. (2006). The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data (DOT HS 810 594). Virginia Tech Transportation Institute.

Lansdown, T.C. (2010). Frequency and Severity of In-Vehicle Distractions – A Self-Report Survey. paper presented at the 1st International Conference on Driver Distraction and Inattention, Göteborg, September 28-29, 2009. (Online paper, available:

http://www.chalmers.se/safer/driverdistraction-en/ programme/documentation [November 9th, 2010]).

McEvoy, S.P., Stevenson, M.R., Woodward, M. (2006).The impact of driver distraction on road safety: Results from a representative survey in two Australian states. Injury Prevention 12, 242-247.

Ranney, T.A. (2008). Driver Distraction: A Review of the current State-of-Knowledge (DOT HS 810 787). National Highway Traffic Safety Administration (NHTSA).

Regan, M. A., Lee, J., D., & Young, K. L. (2008). Driver distraction theory, effects and mitigation: CRC Press.

Royal, D. (2002). National Survey of Distracted and Drowsy Driving - Volume 1: Findings (DOT HS 809 566). National Highway Traffic Safety Administration (NHTSA).

Patel, J., Ball, D.J., & Jones, H. (2008). Factors influencing subjective ranking of driver distractions. Accident Analysis & Prevention 40 (1), 392-395.

Sayer, J.R., Devonshire J.M., & Flannagan C.A. (2001). The effects of secondary tasks on naturalistic driving performance (UMTRI-2005-29). Ann Arbor, Michigan, USA: The University of University of Michigan Transportation Research Institute.

Stevens, A., & Minton, R. (2001). In-vehicle distraction and fatal accidents in England and Wales. Accident Analysis & Prevention, 33 (4), 539–545.

Stutts, J., Feaganes, J., Reinfurt, D., Rodgman, E., Hamlett, C., & Gish, K., et al. (2005). Driver's exposure to distractions in their natural driving environment. Accident Analysis & Prevention 37 (6), 1093–1101.

Stutts, J. C., Reinfurt, D., Staplin, L., & Rodgman, E. (2001). The role of driver distraction in traffic crashes. AAA Foundation for Traffic Safety.

Sullman M.J.M. & Baas, P.H. (2004). Mobile phone use amongst New Zealand drivers. Transportation Research Part F: Traffic Psychology and Behaviour 7, 95–105.

Sullman, M.J.M. & Taylor, J.E. (2010). Social desirability and self-reported driving behaviours: Should we be worried? Transportation Research Part F: Traffic Psychology and Behaviour 13 (3), 215-221.

Young, K.L. & Lenné, M.G. (2010). Driver engagement in distracting activities and the strategies used to minimise risk. Safety Science 48, 326-332.

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International Association of Applied Psychology (IAAP), Divison 13 Traffic Psychology

Deutsche Gesellschaft für Psychologie (DGPS)

Wissenschaftliche Publikationen

Peer-Reviewed Journals

Huemer, A.K. & Vollrath, M. (2011c). Learning the Lane Change Task: Comparing different training regimes in semi-paced and continuous secondary tasks. *Applied Ergonomics.* accepted

Huemer, A.K, & Vollrath, M. (2011a). Driver secondary tasks in Germany: Using interviews to estimate prevalence. *Accident Analysis and Prevention, 43,* 1703–1712.

Huemer, A.K. & Vollrath, M. (2010b). Alcohol-related impairment in the Lane Change Task. *Accident Analysis and Prevention, 42,* 1983–1988.

Huemer, A.K. & Vollrath, M. (2010a). Ablenkung durch fahrfremde Tätigkeiten - Machbarkeitsstudie. Projekt FE 82.376/2009. Bundesanstalt für Straßenwesen.

Huemer, A.K. & Vollrath, M. (2008). Alkoholstandard für die Lane Change Task? - Wirkung von Alkohol auf die Leistung der Fahrer. In VDI (Hrsg.) *Integrierte Sicherheit und Fahrerassistenzsysteme* (S. 253-261). Düsseldorf: VDI Verlag GmbH.

Weitere Zeitschriften

Lang, T., Göres, T., Jünemann, D., Vollrath, M., Werneke, J. & Huemer, A. K. (2009). Untersuchung von „Human Factors“ bei Landmaschinen*. Landtechnik, 64 (1),* 58-60.

Beiträge zu Konferenzbänden

Huemer, A. & Vollrath, M. (2008). Alkoholstandard für die Lane Change Task? - Wirkung von Alkohol auf die Leistung der Fahrer. In VDI (Hrsg.) *Integrierte Sicherheit und Fahrerassistenzsysteme* (S.253-261). Düsseldorf: VDI Verlag GmbH.

Vollrath, M. & Huemer, A. (2007). Anpassung von Warnungen an die Fahreraktivität – ist adaptive Assistenz sinnvoll? In VDI (Hrsg.), *Prospektive Gestaltung von Mensch-Technik-Interaktion* (S. 215-220). Düsseldorf: VDI Verlag GmbH.

Tagungsbeiträge

Huemer, A.K. & Vollrath, M. (2011b). *Driver secondary tasks in Germany: Detailed analysis of face-to-face interviews.* Paper presented at the 2nd International Conference on Driver Distraction and Inattention, Göteborg, 05.-07.09.2011, available online at: http://www.chalmers.se/safer/ddi2011-en/program/papers-presentations

Huemer, A.K. & Vollrath, M. (2010d). *Alcohol effects on driving performance: Compensation may protect controlled actions.* Paper presented at the T2010 Conference on Alcohol, Drugs and Traffic Safety. Oslo, 22.-26.09.2010.

Huemer, A.K. & Vollrath, M. (2010e). *Sicher ist es gefährlich, während der Fahrt SMS zu schreiben, aber ich hab doch nur.....* Vortrag beim 47. Kongress der Deutschen Gesellschaft für Psychologie, Bremen, 26.09.-30.09.2010.

Huemer, A.K. (2010c). *Germans think secondary tasks while driving are not dangerous at all.* Paper presented at the 27th International Congress of Applied Psychology (ICAP2010), Melbourne, 11.-16.07.2010.

Werneke, J., Huemer, A. K., Vollrath, M., Lang, T., Göres, T. & Jünemann, D. (2009). *Was macht denn der Häckslerfahrer da?* Human Factors bei Landmaschinen. Vortrag bei der 6. Tagung der Fachgruppe Arbeits- und Organisationspsychologie, Wien, 09.09.-11.09.2009.

Huemer, A.K. & Vollrath, M. (2009). *Trag mich zum Auto, dann fahre ich... - Alkoholwirkung bei automatischen oder kontrollierten Handlungen.* Vortrag bei der 51. Tagung experimentell arbeitender Psychologen, Jena, 29.03.-01.04.2009.

Nowak, P., Huemer, A.K. & Vollrath, M. (2009). *LCT und Nebenaufgaben – welches Training trainiert was?* Vortrag bei der 51. Tagung experimentell arbeitender Psychologen, Jena, 29.03.-01.04.2009.

Huemer, A.K. &Vollrath, M. (2008). *Lane Change Task unter Alkohol-Einfluss.* Vortrag bei der 24. VDI/VW-Gemeinschaftstagung Integrierte Sicherheit und Fahrerassistenzsysteme, Wolfsburg, 29.-30.10.2008.

Vollrath, M. & Huemer, A.K. (2008). *Adapting lane keeping assistance to driver activity does not increase acceptance.* Paper presented at the 4th International Conference on Traffic and Transport Psychology, Washington DC, USA, 03.09.2008.

Huemer, A. & Vollrath, M. (2008*). Wer passt sich an wen an? - Wirkung adaptiver Fahrerassistenz.* Vortrag bei der 50. Tagung experimentell arbeitender Psychologen, Marburg, 3.-5.3.2008.

Vollrath, M. & Huemer, A. (2007). *Anpassung von Warnungen an die Fahreraktivität – ist adaptive Assistenz sinnvoll?* Vortrag bei der 7. Berliner Werkstatt Mensch-Maschine-Systeme „Prospektive Gestaltung von Mensch-Technik-Interaktion“, Berlin, 10.-12.10.2007.