A holistic approach for measuring Driver Distraction and Inattention

Dipl.-Ing. Melanie Ganzhorn, Dipl.-Psych. Frederik Diederichs and Dipl.-Ing. Harald Widlroither

Fraunhofer IAO and University of Stuttgart IAT, Germany

Abstract

The research about inattention and distraction is still struggling to answer all questions coming up from the automotive industry and politicians. A major reason for this is the partial approach in measuring driver inattention and distraction. Therefore a holistic approach with a reference model for driver distraction and inattention was developed. It includes under investigated fields like driver under-stimulation, individual driver traits and driving task. This leads into a holistic theoretical model on driver attention, inattention and distraction. Within this paper the new holistic approach to classify and judge the hazard potential of the driver-driving task-distraction (DDD) interrelation is described. The methodology includes all driver states from under-stimulation to over-stimulation considering factors to classify driver capability, driving tasks and tertiary tasks. In addition a holistic definition of distraction is given. Based on this definition a standardized rating scale was developed and validated which is based on empirical social research methods, driver cognitive workload models and empiric data. Based on the analysis of each variable out of the DDD interrelation a holistic approach is presented to calculate the hazard potential of this interrelation. Finally this approach is for the first time empirically reviewed within an initial driving simulator experiment. Results are presented and discussed in this paper as well.

Introduction

To reduce accidents the research of driver condition detection has gained an important tradition. For example advanced driver assistance systems (ADAS) with drowsiness detection are now common practice in the automotive market (bester-beifahrer.de, 2012). Driver distraction and inattention is under research since the 1970ths, however it is up to date one of the most attended and discussed topics in driver state research.

The most popular method used to detect distraction is eye- and head tracking to measuring driver’s visual distraction and inattention. This approach can be considered as functional, but not sufficient enough. In addition auditive, manual and cognitive distraction should be analysed beside the visual distraction.

For such a holistic analysis it is indispensable to include driver’s performances due to the driver’s individual characteristic of each resource. For example the increased probability of reduced cognitive performance of elderly drivers is well known. Therefore each driver has his/her own set and characteristic of available resources for driving and additional tasks, the so called tertiary tasks. This individual values result also in different individual limitations for each driver. Therefore some drivers are faster overstrained by the driving task then others. That means that the hazard of distraction and inattention is depending on the individual driving performance and limitations of each driver.

Common approaches do not include the influence of different workload caused by the driving tasks. The hazard of distraction and inattention however depends strongly on the difficulty of the driving task. A more difficult driving task, e.g. driving in urban areas, requires more resources of the driver than easy driving tasks, such as driving on a highway without high traffic. Due to the limitation of these resources a hazard can occur if the driving task or the driving task and a tertiary task exceed the resource limitations. Consequently common approaches have to be extended by the factors driver performance and driving task.

Analysing the interrelation between distraction, driver performance and driving task makes it apparent that it is not enough to observe only the hazard due to upper limitations of resources. Moreover it is necessary to include the lack of activation due to the missing workload of the resources. This under-stimulation can also lead to hazards. It can be expected that under-stimulation will increase within the next years along with the change to (semi) autonomous driving.

Obviously a new holistic approach is necessary, which is not limited to singular events and demands for resources. An analysis and judgement of the current hazard potential due to the interrelation of driver performance, driving task and distraction is necessary. This paper describes this holistic approach to classify and judge the hazard potential of driver-driving task-distraction (DDD) interrelation. The aim is to keep the driver in the loop according to the Yerkes-Dodson-Modell (1908) and avoid under or over-stimulation.

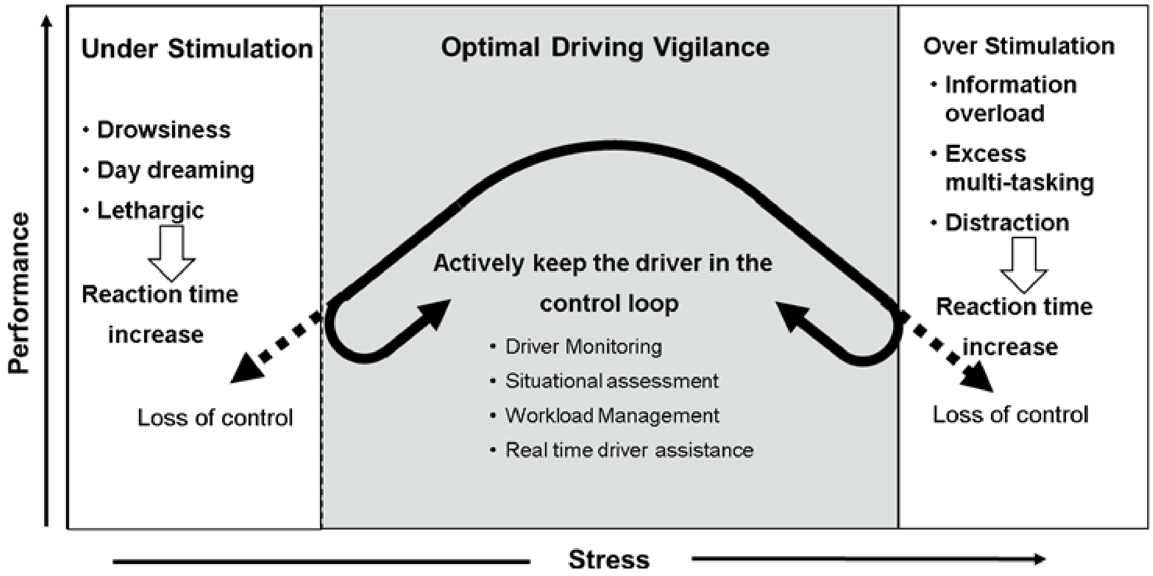

Figure 1 Driver in the loop (adapted form Yerkes and Dodson, 1908).

First each of the DDD factors will be described and analysed. A classification of each variable by objective factors is the basis for the review of this approach within a driving simulator study.

Driver Performance

The driver is the most important factor within the interrelation of driver, driving task and distraction (Bernotat, et al., 1985). He has to handle the car and perform the driving task. According to the Vienna Convention from 1968 the driver has to control the car in every situation as well as he needs skills and knowledge required to perform the driving task (Bundesrepublik Deutschland, 1968).

Within the driver-car-system the driver has the task to regulate and control the vehicle which requires a permanent information processing (Abendroth, et al., 2012). Summing up the driver is responsible for his action and his vehicle as well as for avoiding the hazard of other road users (Bundesrepublik Deutschland, 1968).

To perform the driving task the driver has different possibilities and resources at his disposal. Based on these individual differences groups of drivers with a similar hazard potential can be generated.

Classification of Drivers

The classification of drivers is based on the S-O-R-(C) - Modell (Hacker, 1978). It describes the whole process from the environmental perception to the realization of the driving task.

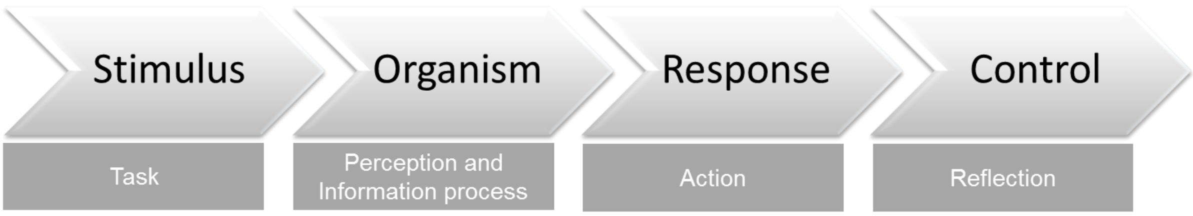

Figure 2 S-O-R-C model (adapted from Hacker, 1978).

During the driving task different stimuli affect the driver. They can be classified into: visual, auditive, olfactory, tactile and vestibular. They are percept and processed within the organism to generate actions.

The quality and time of perception and information processing as well as the following action and control depend on a high number of individual factors, e.g. cognition, physical abilities and so on. These are highly correlated with the general ability to perform (defined by stress and strain). This ability is not reflected in the S-O-R-C model, but highly relevant. Therefore it was added as an additional factor for the DDD interrelation approach.

Based on this model and the stress-strain-correlation an accident analysis and literature study about factors influencing organism, response, control and performance (e.g. Abendroth, et al. 2012, Kaiser 2010, Weidemann, et al. 2010, Vivell 2007, Donges 2012, Fastenmeier et al. 2005, Statistisches Bundesamt 2012, Schlick, et al. 2010) was made to classify the drivers. The results are summarized in Table 1.

Table 1 Classification of drivers.

Term	Factor \ Age	18-24		25-34		35-44		45-54		55-64		65+	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Long	Perception	++	++	++	++	+	+	○	○	-	-	--	--
Long	Cognition	++	++	++	++	+	+	○	○	-	-	--	--
Long	Experience	--	--	○	○	+	+	++	++	++	++	++	++
Long	Reaction time	++	+	+	○	○	-	-	--	--	--	--	--
Long	Physical mobility	+	++	○	+	-	○	--	-	--	--	--	--
Long	Motion speed	++	+	+	○	○	-	-	--	--	--	--	--
Long	Numbers of accidents	--	--	○	○	++	++	++	++	○	○	--	--
Long	Mortality risk	--	-	-	○	+	++	++	++	○	○	--	--
Long	Risk behaviour	--	-	-	○	○	○	○	○	+	+	++	++
Middle	Alcohol or drug misuse	--	+	--	+	-	+	-	+	-	-	+	++
Short	Performance	+	○	++	+	+	○	○	-	-	--	--	--
	Σ	**0**	**3**	**4**	**7**	**5**	**6**	**1**	**1**	**-7**	**-8**	**-11**	**-11**
	Driver Group	**3**	**1**					**2**		**3**			

++ very good (2) + good (1) ○ neutral (0) - bad (-1) -- very bad (-2)

According to the factors in Table 1 drivers can be classified in different groups. The drivers with the highest driving performance capability are between 25 and 45. The middle capable drivers are between 45 and 55. The most dangerous hazard potential has the group of drivers over 55 years and young male drivers. .

Driving task

According to Rasmussen (1983) the driving task can be classified by the required cognitive effort:

- Driving task without experience: knowledge based performance is required. These actions require the highest cognitive effort.
- Known driving task: action patterns are well known, memorized actions are used within this rule based behaviour.
- Automated driving task: based on highly automated sensor motoric stimulus-response-mechanism.

Most of the lane keeping and stabilization tasks are performed automatically under normal conditions on a (well) known road (Schweigert 2002). This enables a fast and save performance. Complexity of the task is rising, when sudden and unexpected changes occur. Then the driver must react rule-based or without experience. Both require a higher cognitive effort.

Beside the cognitive effort the urgency is influencing the resources required by the driving tasks. Stabilization has the highest urgency followed by controlling the car and navigation tasks.

In addition to cognitive effort and urgency the driving situation also influencing the driving task. The higher the complexity of the situation, the higher the difficulty of the driving task (Schweigert 2002) Based on existing driving task analysis (e.g. Fastenmeier, 1995) factors for the DDD interrelation approach were defined by an accident analysis and literature study (e.g. Schneider 2009, Reichart 2001, Bernotat, et al. 1985, Schweigert 2002, Fastenmeier 1995, Statistisches Bundesamt 2013, Walter, et al. 2012, Spacek 1999, Khanh, et al. 2012, Hargutt, et al. 2007, Vollrath, et al. 2011). These factors are summarized in Table 2.

Table 2 Classification of the driving task.

Difficulty / **Factor**	**easy**	**middle**	**difficult**
Cognitive effort	Automated driving	Rule-based	Without experience
Urgency	Navigation	Controlling	Stabilization
Road type	highway	countryside road	urban
Road condition	very good	middle	bad
Lane width	wide	middle	closely
Lane condition	straight	curves with big radius	curves with closely radius
Lane grade	without grade	low grade	high grade
Intersection	none	with clear rules	difficult ROW rules
Weather conditions	try	bit rainy or snowy	heavy rain, fog, hail, heavy snow, ice storm
Light conditions	daylight without dazzling	dawn	darkness or dazzling
Traffic	low, without oncoming traffic	middle with and without oncoming traffic	high with oncoming traffic
Length of the trip	short	< 4h	>4h
Speed	rather low	middle	high
Speed consistency	constant	light variable	high variable
Vehicle and driver assistance systems (DAS)	brand new with high number of DAS	middle-age car with standard DAS	old car without DAS

Depending on the variation of factors out of the classification (easy, middle, difficult) driving tasks performed on simulated or real roads can be classified.

Due to the higher accident risk of drivers performing a difficult driving task the hazard potential rises from easy to difficult driving tasks.

Distraction

According to Lee (2009) distraction is defined as "the diversion of attention away from activities critical for safe driving toward a competing activity" and can be classified into visual, acoustic, cognitive and manual distraction (Ranney 2000, Schneider 2010, Baumann 2006).

Driving is a multiple task which requires dividing the attention between several driving related and non-driving related tasks. The criticality of spending attention to non-driving related tasks is depending on the interference with the driving task. The more resources the non-driving task requires the higher is the criticality of this task.

These non-driving tasks, the so called tertiary tasks, can require different resources at the same time, e.g.:

- Navigation input: manual, visual and cognitive resources
- Talking to passenger: acoustic, cognitive and (sometimes) visual resources
- Writing text message: manual, cognitive and visual resources.

Beside the different combinations of resources, these tasks are carried out individual and the resources used differ highly. Thus this individuality has an influence of the distraction. This means that different strain of the driver leads to different stress and individual distraction due to individual shifting of resources. E.g. the interference of some non-driving tasks with the driving task can be reduced by training, which enables an automated performance of the non-driving task. Lower interference means lower distraction from the driving task. Thus an individual driver related rating of driver distraction, which is rating the distraction based on the concrete individual behaviour, is needed.

Based on these requirements a standardized rating scale was developed and validated which is based on empirical social research methods, driver cognitive workload models and empirical which are dealing with driver distraction and inattention. This rating scale is the so called “**B**ewerterbasierte **Ab**lenkungs**S**kala” (BABS) (Ganzhorn, 2013) method and can be used for video as well as real time analysis. The new classification criteria of driver state are hereby based on relevant driver condition factors as proposed e.g. by Trefflich (2010) and Kopf (2005). In Table 3 a schematic overview of the categories and criterion of the BABS is given. Details and validation results are to be published within 2013 by Ganzhorn et.al.

Table 3 Schematic overview of the BABS (Ganzhorn, 2013).

Distraction	none	low	middle	high
Visual	No interference - view to the road		Middle interference - interrupted view on the road	High interference - highly interrupted view on the road
Manual	No interference - both hands on wheel	Low interference - low manual interruption	Middle interference - middle manual interruption controlling the car	High interference - high manual interruption controlling the car
Auditive	No interference - just listen to music		Middle interference - not able to perceive all auditive information	
Cognitive	No interference - full cognitive resources for driving task	Low interference - low cognitive interruption	Middle interference - middle cognitive interruption	High interference - high cognitive interruption

The Driver-Driving Task-Distraction (DDD) interrelation

As defined above the driver and his performance in the driving task is grouped into three categories (high capability, middle capability and low capability). The driving task is also divided into three categories (easy, middle and difficult). Finally a new approach to rate driver distraction was presented. Within this scale distraction is divided into four categories: no, low, middle and high distraction. A hazard potential was defined for all of these factors. Nevertheless this separated point of view is not enough to detect the complete hazard potential of distraction. To detect how dangerous distraction is, it is necessary to analyse also the DDD interrelation.

For the analysis of this interrelation the workload performance diagram according to Yerkes-Dodson (1908) can be used. It describes the optimum state of the driver as the “optimal vigilance level”, which depends on the relation between stress and performance. Stress is the individual outcome of strain and depends on the different capability of the driver groups. For this approach strain, as a set of objective factors form the environment, is defined by the combination of driving and tertiary task.

For an analysis of the interrelation the diagram has to be interpreted for each of the three driver groups in a different way.

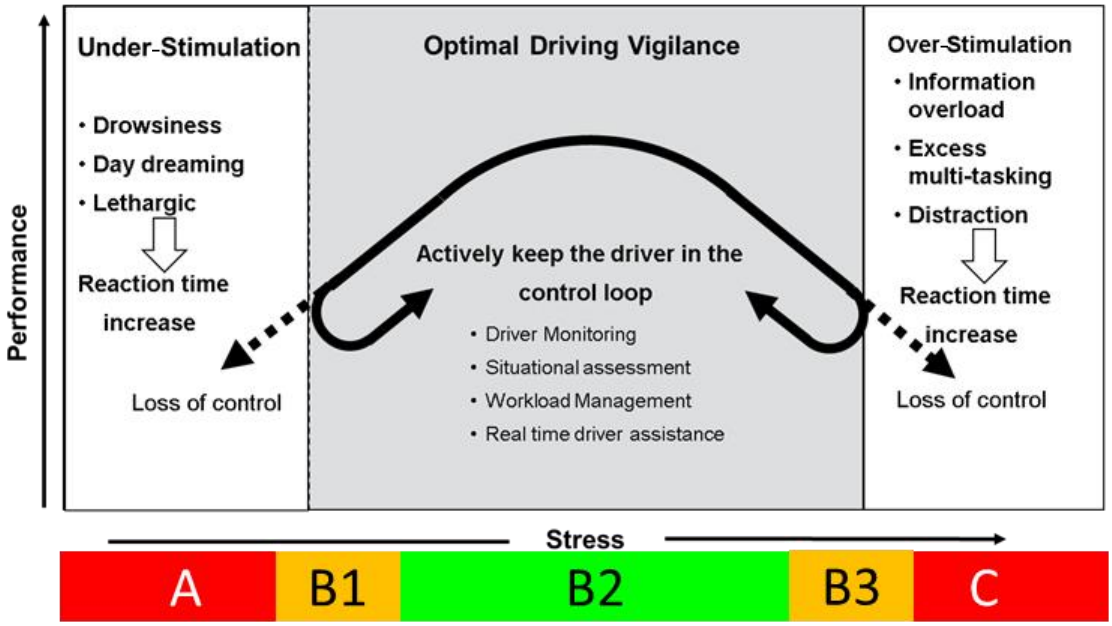

Figure 3 Stress performance correlation adapted from Yerkes-Dodson-Diagram (1908).

Nevertheless for all driver groups the areas of the diagram can be classified according to Kircher (2012):

- Under-stimulation by driving task (A, B1)
- Under-stimulation by driving and tertiary task (A, B1)
- Optimal stimulation by driving task (B1-B3)
- Optimal stimulation by driving and tertiary task (B1-3)
- Over-stimulation by driving task (B3, C)
- Over-stimulation by driving and tertiary task (B3, C)

This classification represents the hazard level of the DDD interrelation. The areas A and C are highly critical, areas B1 and B3 are of a middle criticality and area B2 is the area with optimal driver performance and low criticality due to the driver-driving task-distraction interrelation.

The different capability of the driver groups (stress level) as well as the height of demand out of the driving task and distraction (strain) influences the attribution to these five hazard levels. This attribution is shown in Table for interrelation for all kinds of distractions, driver capability and driving tasks.

The aim is to analyse the driver state with this approach and to implement systems to prevent under or over-stimulation or to get the driver back to the optimal driving performance and keep the driver in the loop of an optimal vigilance.

Table 4 Hazard level of driver-driving task-distraction interrelation.

Driver group	Driving task		
	Easy	Middle	Difficult
No distraction			
1	A	B1	B1
2	B1	B1	B2
3	B2	B2	B3
Low distraction			
1	B1	B1	B2
2	B1	B2	B3
3	B2	B3	C
Middle distraction			
1	B1	B2	B3
2	B2	B3	C
3	B3	C	C
High distraction			
1	B2	B3	C
2	B3	C	C
3	C	C	C

Without distraction only drivers out of group 1 are at risk due to the under-stimulation. Within this situation it would be possible to activate the drivers with a stimulating, but not or low distracting tertiary task.

For drivers of the group 3 already a low distraction in a difficult driving task is risky, at the same time the same situation and distraction is the optimal stimulation for drivers out of group 1. For these drivers the risk to be under-stimulated is higher than the over-stimulation due to their high capability.

As Table 4 shows it is indispensable to regard the driver-driving task- distraction interrelation when talking about the hazard due to distraction. Moreover this holistic approach shows the danger due to under-stimulation for special driver groups.

To review and validate this approach an initial driving simulator experiment was conducted in the driving simulator. Due to the complexity of the whole DDD approach only a part of it was covered within this experiment. The factor driver was chosen as a constant with drivers out of group 1. Results are described in the next chapter.

Driving Simulator Experiment

The aim of this simulator experiment was to test the impact of different driving tasks with high distraction and without distraction. Due to the complexity of the whole DDD approach only a part of it was covered within this experiment. Therefore the factor driver was chosen as a constant with drivers out of group 1, with n=23 male persons 25-34 years old. According to the definition in Table 2 the scenarios were chosen. The drivers had to perform an easy driving task on a highway (HW) and a middle driving task on a countryside road (CS). Each driving task had to be performed once without distraction and once with high distraction. So the following hazard potential was expected:

Table 5 Expected hazard levels of DDD interrelation within the simulator experiment.

Driver group	Driving task	
	Easy	Middle
No distraction		
1	A	B1
High distraction		
1	B2	B3

Hypotheses

To review this part of the DDD approach the following hypotheses were compiled:

- H1: The chosen tertiary task leads to a high distraction.
- H2: The driving performance is correlated to the performance in the tertiary task.
- H3: The participants have the same capability and perform in the same way (the stress level out of the strain is equal).
- H4: (Driving) Performance depends on the complexity of the driving task and the height of distraction (strain) according to Table 5.

H1 was chosen to validate the distraction of the tertiary task.

H2 tests if there is a correlation between the performance in driving and in solving the additional task. E.g. neglecting the tertiary task is one compensation strategy to show a better driving performance.

H3 states that the participants out of the same driver group have an equal stress level out of the same strain. This hypothesis therefore validates the classification of drivers of the DDD approach on the one hand and enables the assumption of H4 that the performance is only depending on strain (and not on individual capability) on the other hand.

By testing these hypotheses the experimental design is controlled and it can be assumed that the driving performance is only influenced by the driving task and the level of distraction as stated in H4. As Table 5 shows a different influence of the distraction should only be measured within the highway scenario, for the countryside equal performance is expected. So H4 is the core of this simulator experiment, because this hypothesis testing the different hazard levels of the DDD approaches. Therefore the results for the H1-H3 are shortly summarized to focus on H4.

Dependent variables

To test the hypotheses dependent variables were measured: speed, steering angle, rated driving performance, mistakes in tertiary task, subjective ratings. The participants were pretend to drive 80km/h on the countryside road and 100km/h on the highway. Driving performance was rated by the experimenter according to the definition of Schweigert (2003) with the categories: speed constancy, vehicle control and lane keeping. The tertiary task was designed in the way mistakes could be measured easily: Participants had to count all red crosses between blue crosses and red circles. The difference to the existing red crosses to the counted is the number of mistakes. Subjective ratings about driving performance and complexity of the driving task were asked by questionnaires.

Results

The results of H1-H3 are shortly summarized to show the controlled design of the experiment:

- H1: Results do not refute this hypothesis, for example the variance shows relevant differences: without distraction on countryside 3,09 and on highway 2,80 in opposite to variance with distraction on countryside 6,27 and on highway 3,28.
- H2: no significant correlation between driving performance and performance in tertiary task were found (highway p=0.93 and countryside p=0.79). So results do refute this hypothesis. The assumption is that the distraction level was that high that no significant differences could be measured any more.
- H3: The variance of speed without and with distraction is less than 5% for both driving tasks. The steering wheels show also homogeneity with standard deviation of 2,8° on the highway (max. 11,9°) and 3,8° on countryside (max. 47,86°). So the chosen participants are a group of drivers with homogeneous capacity.

For the analysis of H4 the results of the dependent variables: speed, steering angle, rated driving performance and mistakes in tertiary task are shown below for the highway scenario with distraction (HW+D), the countryside road (CS), countryside road with distraction (CS+D) and highway without distraction (HW).

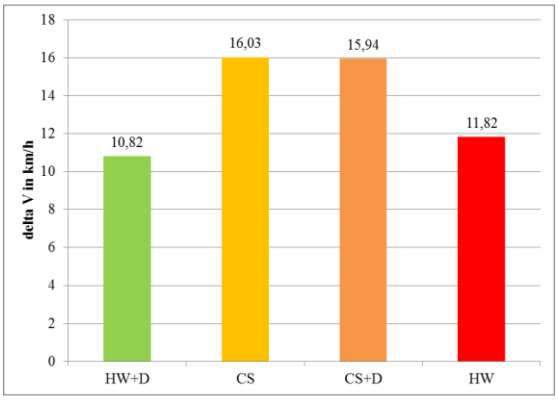

Figure 4 Mean of delta V for each scenario.

Figure 4 shows clearly the differences between the CS and HW scenario, delta V differs about 6km/h between these scenarios. Between the highway scenario with and without distraction no clear difference is shown.

Due to the curves within the countryside scenario it is not possible to compare highway and countryside results. However the results show clear differences between the tasks with and without distraction (see figure 5). The difference between the CS scenarios is with 7° clearly lower than the difference between HW with 12°.

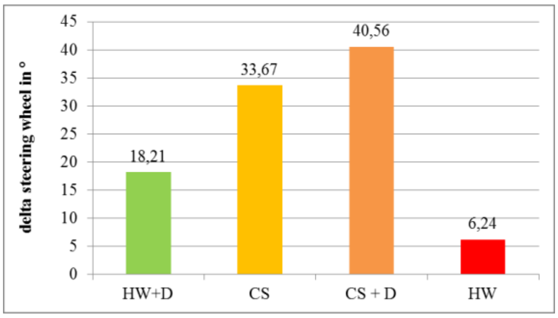

Figure 5 Delta of the steering wheel for each scenario.

Measuring the errors in driving performance show differences between tasks with and without distraction as well as differences between HW and CS with distraction. Fewer errors were rated on the HW than on the CS.

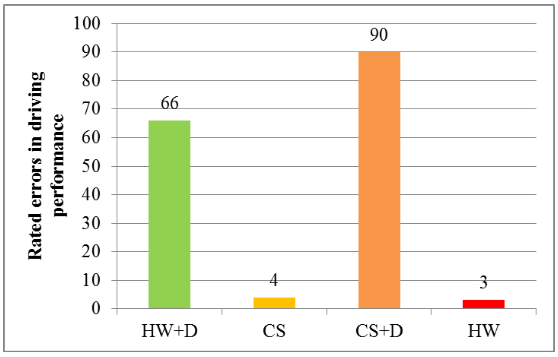

Figure 6 Errors in driving performance rated by experimenter.

As figure 7 shows fewer mistakes in the tertiary task were counted within the highway scenario, also.

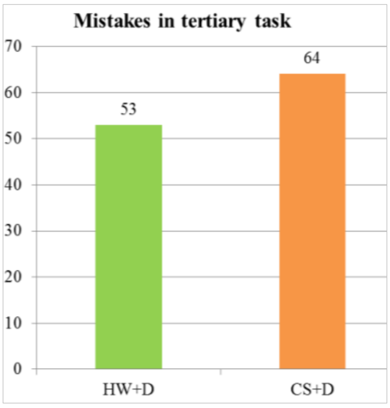

Figure 7 Mistakes in tertiary task.

The results of the dependent variables show, that there are clear differences in the difficulty of driving tasks. Speed and steering wheel also show similar results for both countryside road scenarios as it was expected according to the DDD approach (see Table 5). However the expected differences between highway with and without distraction were not found. Delta V is nearly the same and the delta of the steering wheel indicates a higher hazard for the highway with distraction due to higher steering moves on a straight lane.

Conclusion

This paper showed the need of a new approach to rate distraction. It is not enough to judge distraction or distracting tasks detached from driver state and driver trade and the demand of the driving task the driver performs while being distracted.

The influence of the driver is given due to the individual capability and therefore to the different stress resulting from the same strain. Driving task is influencing the rating of distraction, because distraction interference with the driving task. The sum of driving task demand and distraction defines the strain, which affects the driver and leads to stress. Therefore driving tasks and distraction were also classified. Driving tasks were classified according to their complexity. For the classification of distraction a new approach and rating of distraction was presented, which is needed to calculate the interference with the driving task.

The definition of hazard levels was made according to Kircher (2012) and Yerkes, Dodson (1908). This creates a new holistic approach to calculate the risk out of the driver-driving task-distraction (DDD) interrelation and enables the development of systems to keep the driver in the loop of bring him back to the loop of optimal driving performance.

Finally the approach was testes in a simulator experiment with a reduced and controlled experimental design. The results showed that the approach seems to be the right way, because most of the assumptions were found in the results. Nevertheless the differences between under-stimulation and optimal stimulation were not shown by the results. Moreover the experiment was conducted with only a few participants. So these are some weak points which should be regarded within the further research. Therefore a next simulator experiment is planed with different driver groups and more driving tasks to review the approach more detailed.

References

Abendroth, B. und Bruder, R. 2012. *Die Leistungsfahigkeit des Menschen fur die Fahrzeugfuhrung*. [Hrsg.] Hermann Winner, Stephan Hakuli und Gabriele Wolf. Handbuch Fahrerassistenzsysteme. Wiesbaden : Vieweg + Teubner Verlag, Springer Fachmedien Wiesbaden GmbH, 2012, S. 4-10.

Baumann, M.R.; Petzold, T. (2006). *Situation Awareness beim Autofahren als Verstehensprozess*. MMI-Interaktiv „Aufmerksamkeit und Situation Awareness im Fahrzeug" Bd. Nr. 11, S. 43-57.

Bernotat, R. und Käppler, W.-D. 1985. *Wirksystem Fahrer - Fahrzeug - Umwelt. [Buchverf.]* Institut für Verkehrssicherheit. [Hrsg.] Klaus Rompe. Verkehrssicherheit und Wirksystem Fahrer - Fahrzeug - Umwelt. Köln : TÜV Rheinland GmbH, 1985, S. 13-46.

Bester-beifahrer.de (2005) [Online] http://www.bester-beifahrer.de/fahrerassistenzsysteme/muedigkeitswarner/

Bundesrepublik Deutschland. 1968. *Wiener Abkommen über den Straßenverkehr*. Wien : s.n., 1968.

Donges, E. 2012. *Fahrerverhaltensmodelle.* [Hrsg.] Hermann Winner, Stephan Hakuli und Gabriele Wolf. Handbuch Fahrerassistenzsysteme. Wiesbaden : Vieweg + Teubner Verlag; Springer Fachmedien Wiesbaden GmbH, 2012, S. 15-22.

Eberhard Ulrich. Berlin : VEB Deutscher Verlag der Wissenschaften, 1978. S. 76-87.Hargutt, V., et al. 2007. *Nicht krankheitsbedingte psychologische Determinanten der Fahreignung und Fahrsicherheit*. [Buchverf.] Burkhard Madea, Frank Mußhoff und Günter Berghauns. [Hrsg.] Burkhard Madea, Frank Mußhoff und Günter Berghauns. Verkehrsmedizin. Köln : Deutscher Ärzte-Verlag GmbH, 2007, S. 599-606.

Fastenmeier, W. 1995. *Situationsspezifisches Fahrverhalten und Informationsbedarf verschiedener Fahrergruppen. Autofahrer und Verkehrssituation*. Köln : Verlag TÜV Rheinland GmbH, 1995, S. 141-179.

Fastenmeier, W., et al. 2005. *Der ältere Patient als Autofahrer*. Münchner Medizinische Wochenschrift. 2005, 40, S. 40-43.

Ganzhorn, M., et.al. 2013. *Eine bewerterbasierte Ablenkunkgsskala (BABS) zur objektiven Beurteilung von Unaufmerksamkeit*. Submitted for the 7th VDI conference Fahrer im 21. Jahhundert, Braunschweig, November 2013.

Hacker, W. 1978. *Allgemeine Arbeits- und Ingenieurpsychologie*. [Hrsg.]

Kaiser, H. J. 2010. [Hrsg.] Deutscher Verkehrssicherheitsrat e.V. (DVR). *Fit und Automobil*. [Broschüre]. Bonn : s.n., 2010.

Khanh, T. Q. and Huhn, W. 2012. *Sichtverbesserungssysteme*. [Hrsg.] Hermann Winner, Stephan Hakuli und Gabriele Wolf. Handbuch Fahrerassistenzsysteme. Wiesbaden : Vieweg + Teubner Verlag; Springer Fachmedien Wiesbaden GmbH, 2012, S. 448-470.

Kircher, K. 2012. *Situationsgerechte Fahreraktivierung statt Überforderung*. Unpublished speech on the Fraunhofer IAO VI Summit 2012 in Stuttgart.

Kopf, M. 2005. *Was nützt es dem Fahrer, wenn Fahrerinformations- und -assistenzsysteme etwas über ihn wissen?* [Hrsg.] Markus Maurer und Christoph Stiller. Fahrerassistnezsysteme mit maschineller Wahrnehmung. Berlin, Heidelberg : Springer-Verlag, 2005, S. 119-120.

Lee, J.D.; Young, K.L.; Regan M.A. (2009). *Defining Driver Distraction, in Driver Distraction: Theory, effect and mitigation*. CRC Press, Taylor & Francis Group London, S. 31-40.

Ranney, T.A.; Mazzae, E.; Garrott, R.; Goodman, M.J. (2000). *NHTSA Driver Distraction Research: Past, Present, and Future.*

Rasmussen, J (1983). *Skills, rules and knowledge; signals, signs, and symbols and other distinctions in human performance models*. IEEE Trans. Systems, Man, Cybernetics, Vol. SMC-13, S. 257-266.

Reichart, G. 2001. *Menschliche Zuverlässigkeit beim Führen von Kraftfahrzeugen*. Düsseldorf : VDI Verlag, 2001. S. 43-44.

Schlick, Chr., Bruder, R. und Luczak, H. 2010. *Arbeitswissenschaft.* Berlin, Heidelberg : Springer-Verlag, 2010. S. 87; 127-227; 360-414.

Schneider, J. H. 2009. *Modellierung und Erkennung von Fahrsituationen und Fahrmanövern für sicherheisrelevante Fahrerassistenzsysteme*. Chemnitz : s.n., 2009. S. 13.

Schweigert, M. 2002. *Fahrerblickverhalten und Nebenaufgaben*. München : s.n., 2002. S. 21.

Spacek, P. 1999. *Spurverhalten und Unfallgeschehen in Kurven*. Straßenverkehrstechnik. 1999, 2.

Statistisches Bundesamt. 2012. *Verkehr*. Wiesbaden : s.n., 2012. Fachserie 8 Reihe 7.

Statistisches Bundesamt. 2013. *Unfälle (polizeilich erfasste): Deutschland, Jahre, Unfallkategorie, Ortslage*. [Online] 24.05.2013. https://www.genesis.destatis.de/genesis/online;jsessionid=34BAFB709D0D901DE4D174EBE72D809A.tomcat_GO_1_2?operation=previous&levelindex=2&levelid=1361800342579&step=2.

Trefflich, B. 2010. *Videogestützte Überwachung der Fahreraufmerksamkeit und Adaption von Fahrerassistenzsystemen*. Techn. Univ., Diss., 2010--Ilmenau.

Vivell, P. 2007. *Sehvermögen*. [Buchverf.] Burkhard Madea, Frank Mußhoff und Günter Berghaus. [Hrsg.] Burkhard Madea, Frank Mußhoff und Günter Berghaus. Verkehrsmedizin. Köln : Deutscher Ärzte-Verlag GmbH, 2007, S. 217-219.

Vollrath, M. and Krems, J.. 2011. *Verkehrspsychologie*. [Hrsg.] Marcus Hasselhorn, Herbert Heuer und Frank Rösler. Stuttgart : W. Kohlhammer GmbH Stuttgart, 2011. S. 155; 169-172.

Walter, M., et al. 2012. *Lane Departure Warning*. [Hrsg.] Hermann Winner, Stephan Hakuli und Gabriele Wolf. Handbuch Fahrerassistenzsysteme. Wiesbaden : Vieweg + Teubner Verlag; Springer Fachmedien Wiesbaden GmbH, 2012, S. 543-553.

Weidemann, J., et al. 2010. *Fahrzeugentwicklung für eine Gesellschaft im demografischen Wandel.* [Buchverf.] Heinz Häfner, Konrad Beyreuther und Wolfgang Schlicht. [Hrsg.] Heinz Häfner, Konrad Beyreuther und Wolfgang Schlicht. Altern gestalten. Berlin, Heidelberg : Springer-Verlag, 2010, S. 109-119.

Yerkes R.M.; Dodson J.D. 1908. *The relation of strength of stimulus to rapidity of habit-formation*. Journal of Comparative Neurology and Psychology 18: 459–482.