Can talking on the phone keep the driver awake? Results of a field-study using telephoning as a countermeasure against fatigue while driving.

Nina Jellentrup, German Aerospace Center, Institute of Transportation Systems, Braunschweig, and **Barbara Metz,** Interdisciplinary Center for Traffic Sciences (IZVW) at the University of Wuerzburg and **Siegfried Rothe**, Daimler AG, Böblingen

ABSTRACT

In recent studies, negative consequences of distraction while driving, especially of telephoning are highlighted and discussed. Besides negative short term effects of telephoning, also other, more positive effects are thinkable. Fatigue is an important risk factor especially in the field of driving platoon. Long distance drives under monotonous conditions lead to diminished attention and alertness. Then asked, drivers report that they actively apply countermeasures against fatigue in monotonous driving situations. One of the countermeasures that are mentioned is engaging in conversation either with the passenger or on the phone.

The presented field study investigated whether talking on the phone can help to improve drivers' condition during monotonous rides. The participants drove for 3 hours in the morning and 3 hours in the afternoon on a test track with a mean speed of 40 km/h. During the drives, the participants received phone calls after defined time intervals. With the help of physiological recording methods (EEG and eyelid measures), CAN-Bus-data, reaction times and psychological questionnaires, the condition of 18 subjects was measured. The analysis shows that the drivers were more alert and awake during the telephone conversation and up to twenty minutes afterwards. The alpha spindle rate diminished and data of eyelid-behaviour showed a decline in the relative blink duration. The results support the subjectively reported impression that talking on the phone is a possibility to stay alert in monotonous driving conditions. The reported findings are discussed in the light of a prospective application in vehicles.

INTRODUCTION

Fatigue is considered to be a severe risk in driving. Several studies estimate that micro sleep is responsible for 24% to 33% of all traffic accidents on German streets (e.g. Anselm & Hell, 2002; Evers & Auerbach, 2003). Episodes of micro sleep occur more frequently after long drives without any rest. Furthermore, the likelihood of near misses and accidents is quadruple to six fold increased for drowsy drivers (Ji, Zhu & Lan, 2004). Rothe (1995) even assumes that approximately one-third of all fatal traffic accidents on German motorways can be attributed to sleep and distraction. Most fatigue-related accidents happen between 2 a.m. and 6 a.m. and between 3 p.m. to 4 p.m.. These periods are also well known in chronobiology as the time of the day where activation level is the lowest (Garbarino, Nobili, Beelke, De Carli & Ferrillo, 2001; Horne & Reyner, 1995; Maycock, 1997; Zulley, Crönlein, Hell & Langwieder, 1995). According to Krüger

(2005), drivers' performance decreases especially on long rides are caused by overload in only 1% of driving errors but in more than 40% by underload.

It is known that fatigued drivers often hesitate to take a break; instead they try to influence their state with various activities to keep awake, e.g. playing loud music or opening the window for fresh air. Such countermeasures only help temporarily (Sagberg, Jackson, Krüger, Muzet & Williams, 2004). Different measures against fatigue were - partly theoretical and partly experimental - investigated by Popp (2005).

The experimental field study presented in this paper examines the effect of talking on the phone as one potential countermeasure against fatigue in driving. In the literature, phone calls are mainly discussed as one cause for distracted driving which leads to a higher risk of driving errors. In their meta-analysis, Horrey and Wickens (2004) analyzed a series of studies investigating telephoning during driving: All 42 publications lift out the distractive effects of telephoning (e.g. Alm & Nilsson, 1994; Horrey & Wickens, 2004; McKnight & McKnight, 1993). For instance, in a driving simulator study Burns, Parkes, Burton, Smith and Burch (2002) found effects of phone calls on vehicle control which resemble effects of a blood alcohol level of 0.8 per mill. The risk of serious accidents is estimated to be four times higher when using a mobile phone while driving (McEvoy, Stevenson, McCartt, Woodward, Haworth, Palamara, Cercarelli, 2005). Many studies show no difference between hands-free phone calls and phoning via handset (Abdel-Aty, 2003; Consiglio, Driscoll, Witte, Berg, 2003; Kircher, Vogel, Tornros, Bolling, Nilsson, Patten, Malmstrom, Ceci, 2003; McCartt, Hellinga & Braitman, 2006; Shinar, Tractinsky & Compton, 2002; Strayer, Drews & Crouch, 2003; Strayer & Johnston, 2001; Strayer, Drews, Crouch & Johnston, 2005). Based on those results, some authors conclude that phone calls do not only interfere with driving because of their motor activity (dialing, answering calls, etc.) but also because of the cognitive demands of talking on the phone (Horrey & Wickens, 2004; Rakauskas, Ward, Bernat, Cadwallader & De Waard, 2004). Beside the reported experimental results that highlight the potential distracting effect of telephoning, some naturalistic driving studies draw a more complex picture. Olson, Hanowski, Hickman, & Bocanegra (2009) and Hickman, Hanowski, & Bocanegra (2010) report that distraction through dialling a cell phone or texting a message is related to a serious increase in incident rate. At the same time, the analysis of the naturalistic driving data implies that talking and listening to a hands free phone reduces the risk of having an incident. Based on those results it can be concluded that handling a phone (e.g. dialling) increases the risk of having an accident but talking on the phone actually improves driving safety.

Most studies focusing on the distracting effects of phone calls assume that handling and talking on the phone add extra load on the driver in an already demanding driving situation. In that case, the extra-load caused by telephoning might lead to overload and then as a consequence might cause driving errors. Like already described, driving is not always a demanding task during which overload of the driver might cause accidents. Especially during long drives the danger of errors due to underload of the driver is way more pronounced than the danger of overload. Longer periods of underload can first lead to a state of reduced vigilance of the driver and then, even to fatigue. In such situations, adding some extra load, e.g. through conversation with a passenger or on the phone might be more helpful than dangerous. In the present study it is assumed that talking on the phone has a positive effect on driver's attention in monotonous traffic situations and thus makes a contribution to road safety. The results originate from one part of a study dealing with countermeasures in monotonous driving situations.

METHODS

Procedure

In the experiment, three vehicles were driving in a convoy for 6 hours on a test track. Therefore, three drivers participated in each experimental session. Two truck drivers drove on position one and two of the driving platoon. The car drivers were located in the third position (figure 1 left).

Each experimental day started with an explanation of the coming experiment. This included instruction regarding the driving task, the test procedures, the possible occurrence of fatigue due to the monotonous driving situation and the cabling of EEG, EOG and ECG electrodes as well as eye-closure coils (see figure 1 right). While the electrodes were attached, the subjects filled in questionnaires dealing with the subjective perception of their sleep quality and with the evaluation of their own chronotype. Afterwards the subjects drove a training round of 36 km on the test track to get an impression of the course, the test vehicle and the exact test conditions. The experiment consisted of two blocks of three rounds each. Between the blocks there was a break of 45 minutes. Each round took roughly one hour. The first truck driver was instructed to hold a speed of 40 km/h, with acceptable fluctuation of +/- 3 km/h. The participants driving behind should keep a distance of half the speedometer stand to the lead vehicle.


Figure 1: Vehicle arrangement in the convoy: The trucks drive in first and second position, the G-Class moves in third position behind the trucks (left). Subject with attached EEG, ECG (covered) and EOG electrodes and eye-closure coils (right).

The driver in the G-Class was over the entire experiment (seven laps – including test round) in third position. Within this experiment different countermeasures were investigated in two sub-studies. For the sub-study "Overtaking" an overtaking manoeuvre was performed in the middle of the second round of each block by the driver at the second position.

In the sub-study "Communication" which is described in this paper, phone calls were used as a potential countermeasure. The driver of the G-Class received three telephone calls per block (morning and afternoon session). Each call lasted five minutes and was presented in a clocked manner. At the beginning of each conversation, the driver rated his fatigue with the help of the nine-stage Karolinska Sleepiness Scale (KSS) (Akerstedt, 1990). Then, an interactive interview was performed by the experimenter. The questionnaire used for the interviews contained six different categories of general and personal issues. Five to nine questions were asked at each phone call. The questions had been developed in four pre-tests using eight to eleven participants from different educational levels. No knowledge was queried; instead it was asked for a personal opinion. The aim was to reclaim the participants moderately by encouraging them to think and talk but without causing overload. The topics were history, geography, politics, technology, sports and everyday experiences. Both - the topics and the questions - were used in the same order for all participants.

Figure 2 illustrates the sequence of the vehicles and the timing of the studied countermeasures. After seven rounds of 36 km and a total mileage of 252 km, the drivers went back to the starting point where the test drive ended.

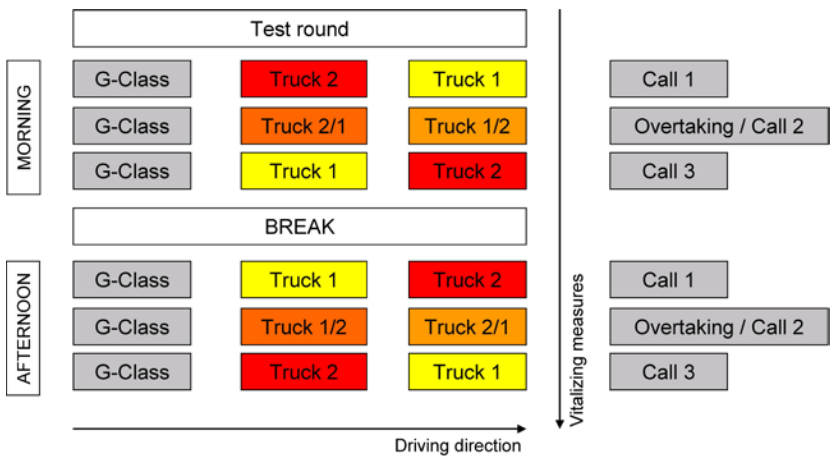

Figure 2: Schematic representation of the experimental design: The order of vehicles, the number of driving sessions (morning and afternoon) and the timing of the countermeasures "overtaking" and "phone calls" are shown.

Participants

In the experiment a total of 60 subjects participated. Twenty subjects took part as a car driver in the sub-study "Communication", which is presented in this paper. Due to adverse weather conditions, two days of test drive had to be cancelled. Therefore, the final sample size is composed of 18 drivers including 8 women and 10 men between 18 to 41 years (M = 25.61; SD = 6.29).

Drivers with a low and a high annual mileage were selected to get a wide spread of expertise in driving. The average mileage was 19759 km per year (SD = 14062; range: 500 – 50000). All participants were German native speaker.

Materials and Apparatus

Test vehicle and test track. On each experimental day, three subjects drove in a driving platoon. Two of them drove a truck of a total weight of 40 tons and took the first and second positions of the convoy. In last position, the third driver drove with an off-road vehicle (G-Class). Two identical Mercedes-Daimler Benz trucks (Actros series 1860, year: 2007, 16 litre V8 engine: 440 kW / 598 hp) and a Mercedes-Benz off-road vehicle from Type G-Class models V463 (built 2000) with a 5 litre V8 petrol engine (225 kW / 306 hp) were used. The test track is part of a former military area. It is a round course of about 36 km with hilly and curvy sections. There is no regular traffic on the test track.

Psychophysiological measures. During the experiment, EEG, EOG and ECG were recorded. For EEG and EOG, the data of all recorded channels were sampled at a rate of 500 Hz. For EEG, 32 electrodes were recorded in accordance with the 10/20-system. Furthermore, eyelid opening level was measured with two metal coils which were attached to the upper and lower lid of one eye. Because of induction between the two coils, the distance between the upper and lower lid (the eyelid opening level) can be measured (Hargutt, 2003). The eyelid opening level was recorded with 100 Hz.

Data analysis

The influence of the six phone calls on drivers' state is analysed. The calls occurred in both driving blocks after 60, 120 and 150 minutes of driving time. The duration of each conversation amounted at maximum five minutes.

Different parameters reflecting the state of the driver are used as dependent variables. Various objective and subjective measurement methods were applied. The objective parameters include the EEG, EOG, ECG and the eye-closure method, a continuous reaction time measurement and the analysis of vehicle data. As subjective measures, standardized estimation scales and questionnaires were used.

For the analysis, the objective data is divided into time intervals relating to the beginning and the end of the calls. In this paper only the results of the EEG and eye-lid opening measure will be discussed. Results for the P300, EOG and ECG, steering wheel angle, reaction times and questionnaires are not presented.

EEG. An increase in alpha EEG spindle rate indicates increased fatigue (Markand, 1990), and a decrease in attention (Torsvall & Akerstedt, 1987). With the help of the recorded EOG, artefacts due to eye movements were filtered in order to analyze only the signals caused by the brain waves. Then, the data of all recorded channels were analyzed using an algorithm developed by Daimler AG. The algorithm calculates the average number of alpha spindles in a specified time interval, i.e. the alpha spindle rate for a specific time frame. To determine the frequency of the alpha band, a fast Fourier transformation (FFT) is applied by the algorithm. Individual mean differences are suppressed by using a z-transformation. Alpha spindles are characterized by their duration, spectral amplitude and peak frequency. The moving average of these parameters is used over larger time windows to obtain continuous measures. The occurrence of alpha spindles within the moving window is counted and the alpha spindle rate is calculated (Schmidt, 2010). The analysis of the EEG includes the records of 17 drivers because one participant had to be excluded because of problems with the EEG recording.

Eye-lid opening level. A trigger signal was used to synchronise the eye-closure data with the other measuring methods. In the analysis, a baseline (first ten minutes of the morning session) is used to determine a reference value reflecting the eye-lid opening level of a driver being awake. Based on that baseline, the eye-closure data is evaluated regarding driver state and fatigue. The calculated parameters of the eye-closure are standardized individually in relation to the baseline. It is important to standardize individually as subjects differed in their eye-closure behaviour. The parameter presented in this analysis is the relative blink duration (Hargutt, 2003; Gradenegger, Kenntner-Mabiala, Hargutt & Krüger, 2008). Lower values indicate that the driver is more awake. Before analysing the eye-lid opening level, all recorded datasets were controlled manually to select data with good recording quality. In that process, some datasets were classified as not evaluable since there was for instance no trigger signal or no baseline. In the end, 83% of the recorded datasets were analysed.

RESULTS

Subjective measures

After the experimental drive, participants evaluated the telephone calls and their effect on driver's state. All subjects declared that the phone calls had a vitalizing effect on their condition and even 83% of the subjects said that the phone calls were very important to them during driving. One third of drivers stated that without the calls they would have terminated the experiment. In the next step the drivers estimated the duration of the activation: 28% of subjects said that the activation lasted 00-10 minutes, 22% spoke of 10 to 20 minutes, 22% from 20 to 30 minutes, and 28% estimated the length of the effect to last 30 to 60 minutes.

EEG

The assumption 'phone calls have an activating effect' is investigated. The alpha spindle rate during the phone call is expected to be lower than in the 20-minute interval before the phone call. A 2x2 ANOVA shows that the alpha spindle rate varies depending on the interval ($F(1,16) = 6.90$, $p = .02$) but not depending on the time of day ($F(1,16) = 1.37$; $p = .26$). The Alpha spindle rate is lower during the phone call (red) than before (blue) the phone call. There is no difference in spindle rate between morning and afternoon session (figure 3).

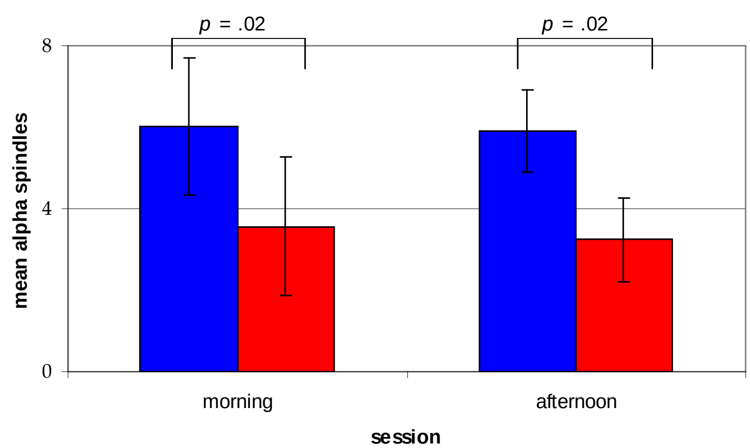

Figure 3: Alpha spindle rate in spindles per minute depending on the interval (before the phone call (blue) - during the call (red)) and time of day (morning - afternoon). Error bars illustrate the standard error of the mean.

In the next step, the duration of the effect is studied. The 20 minute interval before the phone call (blue) is compared to the 20 minutes after the phone call (red). The ANOVA shows a main effect of the interval (F(1,16) = 4.47, p=0.05), a tendency for time of day (F(1,16) = 4.20, p=0.06) and a significant interaction (F(1,16)=4.57, p=0.05) (figure 4). T-tests comparing before and after the phone call separately for morning and afternoon session show a significant reduction of spindle rate in the 20 minutes after the call for the afternoon session (t(1,16)=2.49, p=0.02), but not for the morning session (t(16)=0.43, p=0.67)

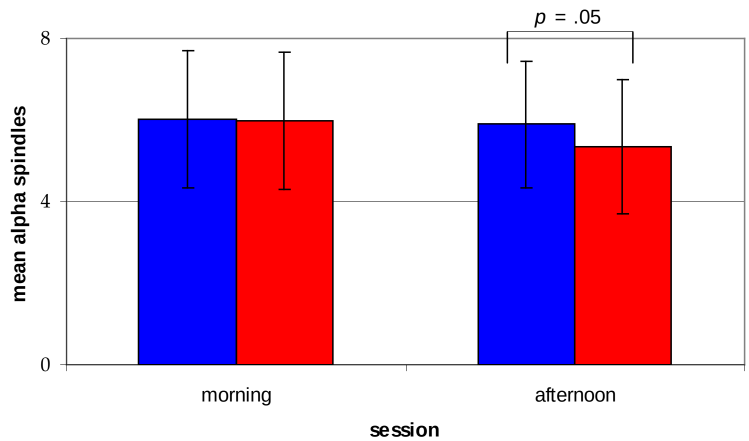

Figure 4: Alpha spindle rate in spindles per minute depending on interval (before the phone call (blue) - after the call (red)) and time of day (morning - afternoon). Error bars illustrate the standard error of the mean.

Eye-lid opening level

The following statistical analysis evaluates again 20 minutes before and after the phone calls. Now, the 20 minutes are divided into intervals with 5 minutes of duration. The change in the relative blink duration is evaluated separately for morning and afternoon session and separately for each phone call. This is necessary because due to problems with measurement stability some drivers could not be included into the analysis for all phone calls.

There is a significant decrease in the relative blink duration in the morning and afternoon session due to the first phone call (morning: N = 14, F(8,104) = 7.50, p < .001; afternoon: N = 11, F(8,80) = 5.74, p < .001). Contrast analysis shows that in the morning session the relative blink duration differs significantly between the phone call (t = 4.40, p < .001) and the two 5-minutes-intervals after the phone call (t = 2.51, p < .05) compared to the twenty minutes before the phone call. The same duration of the effect can be found for the afternoon session (during phone call: t = 4.39, p < .01; two 5-minutes-intervals after: t = 3.64, p < .05). The second call in the morning session is also related to a significant decrease in the relative blink duration (N = 14, F(8,96) = 2.69, p < .05). During the call (t = 2.67, p < .05) and five minutes afterwards (t = 2.26, p < .05) the duration is significantly lower than during the 20 minutes before the call.

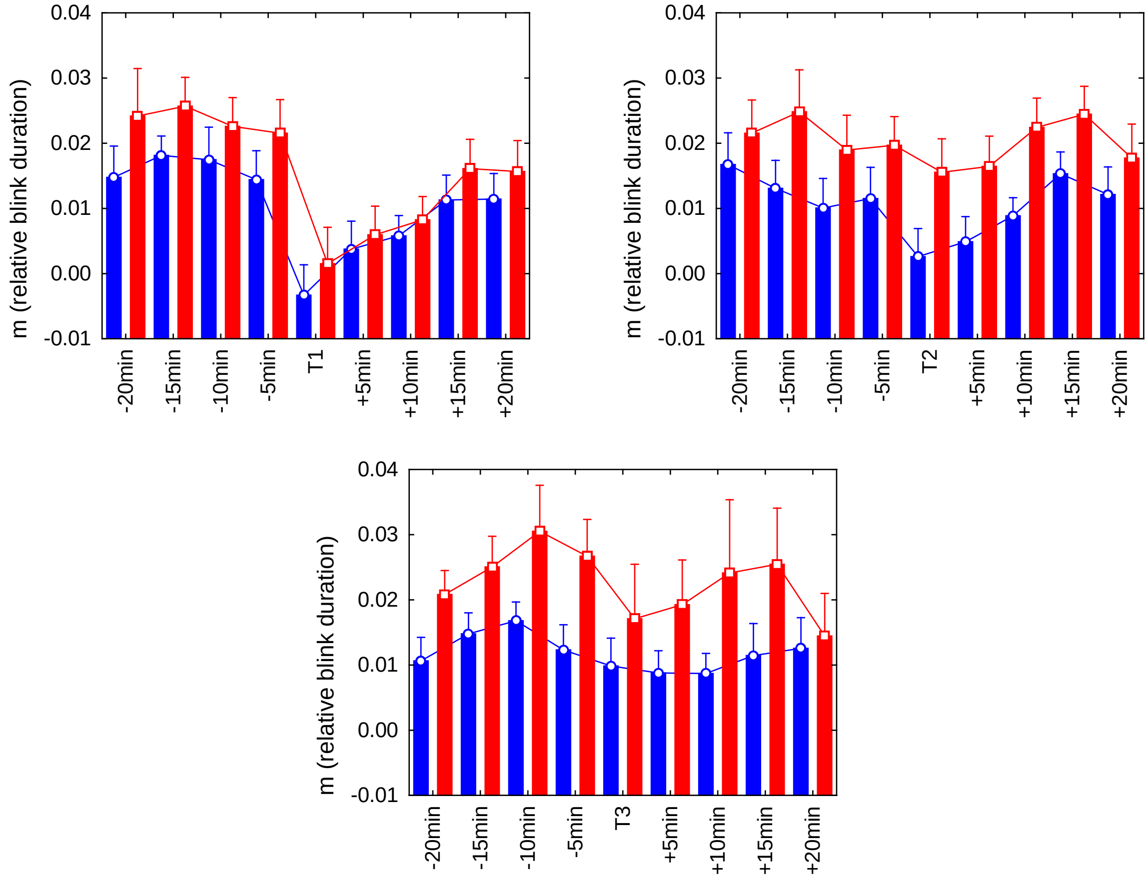

Figure 5: Influence of phone calls T1 (upper left), T2 (upper right) and T3 (lower) on relative blink duration in morning (blue) and afternoon (red) sessions.

For the second call in the afternoon session, the decrease in relative blink duration is not significant. For the third phone call in both the morning and afternoon session, the decrease in relative blink duration is again not significant. The basic level of the relative blink duration is higher in the afternoon than in the morning which indicates an increase in fatigue over the day.

DISCUSSION

Results for two different psychophysiological indicators were presented which both reflect drivers' state. With both indicators, a reduction of fatigue can be found during and after the phone calls. In the EEG, the alpha spindle rate showed a significant reduction during the phone call. This effect is independent of the time of day. A comparison of the time intervals before and after the phone calls shows that in the afternoon the reduction of spindle rate endured for 20 minutes after the phone call. In the morning, the effect seems to be restricted to the call itself. Because the analysis of the time period after the phone call has been conducted only for a time interval of 20 minutes, the exact length of the effect cannot be determined.

For the parameter based on eye-lid opening level, results look a bit different. Again, results indicate a reduction of fatigue during and after the phone calls. The duration of blinks was reduced up to ten minutes after the first phone call in the morning and afternoon session. For the second phone call in the morning, the duration was reduced until five minutes after the call. For the second phone call in the afternoon session and the third phone call in the morning and afternoon session the duration of blinks was not affected by the phone calls. In summary the results support the assumption that the phone calls help drivers to become more alert and awake.

The differences between the two parameters might be due to the fact that they measure and differentiate different levels of driver state. If we consider driver state as a continuum ranging between alert and asleep with states of diminished vigilance and drowsiness in between, different measures are able to reflect changes in state in different sections of the continuum. For instance, it is known that drivers are able to differentiate different levels of fatigue as long as they are not too tired. But as soon as their state gets closer to falling asleep, it becomes more difficult for them to reliably judge their state. Parameters based on eye-lid opening level are less sensitive to changes of driver state at lower levels of fatigue but they are suited to differentiate changes as soon as the driver gets more fatigued (Hargutt, 2003). Similar to the differences known between subjective ratings and parameters of eye-lid opening level, it seems likely that parameters based on the EEG and parameter of eye-lid opening level differentiate along different sections of the assumed continuum. The level of the relative blink duration was generally increased in the afternoon, suggesting that drivers were more tired in the afternoon due to the circadian rhythm, the warm meal and the long travel time than in the morning session. Combining that result with the effects found in the EEG, it can be concluded that alpha spindles are better suited to differentiate changes in state if the drivers is already getting drowsy. Therefore, the effect of the phone calls is more pronounced in the EEG for the afternoon session. This interpretation is supported by the fact that the level of relative blink duration is higher in the afternoon than in the morning and there is a tendency for a higher alpha spindle rate in the afternoon. Therefore, both parameters hint at an increase of fatigue during the afternoon session. In summary, it can be concluded from the results presented above that the drivers became more alert and active due to the phone calls. How long this effected lasted is not clear. Both measures hint at a reduction of fatigue during the call itself and up to ten till twenty minutes afterwards. Furthermore, the duration of the effects seems to be influenced by drivers' state. In the afternoon and during later calls the effect lasts for a shorter time than earlier in the experiment.

We believe that talking on the phone improves drivers' state because the monotonous driving task gets interrupted and the driver gets involved in a conversation that puts some cognitive demands on him. The fact that the duration of the effect differs for the different phone calls can be due to at least two reasons. First, it is possible that talking on the phone only improves drivers' state as long as the driver is in a state of diminished vigilance. But as soon as the driver starts being drowsy, only a rest can improve driver's state for a longer time. Now, talking on the phone is no effective countermeasure any more. The other possibility is that drivers got used to the phone calls during the experiment. During the first calls, the conversation was still something new that engaged drivers' attention up to ten minutes after the call itself. After some calls, drivers got used to the calls and therefore the conversation stopped to improve drivers' condition for longer than the call itself lasted.

CONCLUSION

Previous research developed methods that allow inferring driver's state e.g. from steering behavior or eyelid opening in the vehicle. What is still unclear is what to do with the knowledge that a driver is for instance getting drowsy. An in-vehicle system which tries to influence driver's condition was developed by Dobler et al. (2008). The system identifies driver's state based on different parameters and tries to influence it. In case the assessed level of drivers' activation is lower than the optimal level, the algorithm interprets the driver's state as underloaded which may lead to a decrease in performance. In that situation, the system offers countermeasures to the driver (Dobler et al., 2008). The presented research can help to identify appropriate countermeasures to prevent negative consequences of driving in underload situations. Not only phone calls but a wide range of other, possibly vitalizing countermeasures like music, documentations, audio books, and quiz to train general or job-related knowledge as well as a vocabulary trainer for foreign languages could be offered by such a system in potential underload situations.

The presented study shows the positive effects of telephoning as a special form of communication in monotonous driving situations. In cases of real fatigue, talking on the phone might not be effective as a countermeasure and must not be applied. In case the described assistant system evaluates the state of the driver as real fatigue, the system prevents that the driver starts engaging in potential countermeasures in order not to prevent misuse of the system. In such situations, the assistant-system suggests having a rest at the next parking lot and with the help of a navigation system might guide the driver to a place where he can have a short sleep driver (Dobler et al., 2008).

REFERENCES

Abdel-Aty, M. (2003). Investigating the relationship between cellular phone use and traffic safety. *TE Journal*, Vol. 73, pp. 38-42.

Akerstedt, T. (1990). Subjective and objective sleepiness in the active individual. *International Journal of Neuroscience*, Vol. 52, pp. 29-37.

Alm, H. & Nilsson, L. (1994). Changes in driver behaviour as a function of hands-free mobile phones – A simulator study. *Accident Analysis and Prevention*, Vol. 26, No. 4, pp. 441-451.

Anselm, D. & Hell, W. (2002). Einschlafen am Steuer. Eine häufig unterschätzte Unfallursache. *Verkehrsunfall und Fahrzeugtechnik*, Vol. 40, pp. 62-66.

Burns, P. C., Parkes, A., Burton, S., Smith, R. K., & Burch, D. (2002). How dangerous is driving with a mobile phone? Benchmarking the impairment to alcohol. TRL Report TRL547. TRL Limited, Berkshire, United Kingdom.

Consiglio, W., Driscoll, P., Witte, M. & Berg, W.P. (2003). Effect of cellular telephone conversations and other potential interference on reaction time in a braking response. *Accident Analysis and Prevention*, Vol. 35, pp. 495-500.

Dobler, G., Elitok, E., Entenmann, V., Gottlieb, W., Kuhn, K.-P., Ludwig, M., Proettel, A., Rothe, S. & Theofanou, D. (2008). Patent EP 1 625 040 B1. Verfahren und Vorrichtung zur Beeinflussung der Beanspruchung eines Fahrers in einem Kraftfahrzeug. Daimler AG. Patent from 13.02.2008.

Evers, C., Auerbach, K. (2003). *Verhaltensbezogene Ursachen schwerer Lkw-Unfälle*. Berichte der Bundesanstalt für Straßenwesen, Mensch und Sicherheit, Heft M 174.

Garbarino, S., Nobili, L., Beelke, M., De Carli, F. & Ferrillo, F. (2001). The Contributing Role of Sleepiness in Highway Vehicle Accidents. *Sleep*, Vol. 24, No. 2, 203-206.

Gradenegger, B., Kenntner-Mabiala, R., Hargutt, V. & Krüger, H.-P. (2008). *Interner Auswertungsbericht der Lidschlussdaten*. Internal report for the Daimler AG. Würzburg: Universität Würzburg.

Hargutt, V. (2003). *Das Lidschlussverhalten als Indikator für Aufmerksamkeits- und Müdigkeitsprozesse bei Arbeitshandlungen.* In VDI-Gesellschaft Fahrzeug- und Verkehrstechnik (Hrsg.), Reihe 17: Biotechnik/Medizintechnik (VDI-Fortschritt-Bericht, Nr. 233). Düsseldorf: VDI-Verlag.

Hickman, J. S., Hanowski, R. J., & Bocanegra, J. (2010). *Distraction in commercial trucks and buses: Assessing prevalence and risk in conjunction with crashes and near-crashes* (No. Report FMCSA-RRR-10-049). Washington D.C.: Federal Motor Carrier Safety Administration.

Horne, J. A. & Reyner, L. A. (1995). Sleep related vehicle accidents. *British Medical Journal*, Vol. 310, pp. 565-567.

Horrey, W.J. & Wickens, C.D. (2004). *Cell phones and driving performance: A meta analysis*. Proceedings of the Human Factors and Ergonomics Society 48th Annual Meeting (pp. 2304-2308). Santa Monica, CA: Human Factors and Ergonomics Society.

Ji, Q., Zhu, Z. & Lan, P. (2004). Real-Time Nonintrusive Monitoring and Prediction of Driver Fatigue. *IEEE Transactions on Vehicular Technology,* Vol. 53, No. 4, pp. 1052-1068.

Kircher, A., Vogel, K., Tornros J., Bolling, A., Nilsson, L., Patten, C., Malmstrom, T. & Ceci, R. (2003). *Mobile Telephone Simulator Study*. Swedish National Road and Transport Research Institute (VTI), Linkoping, Sweden.

Krüger, H.-P. (2005). *Fahrerassistenz von morgen Anforderungen und Ausblick.* Presentation given at: Bayern innovativ. Kooperationsforum „Fahrerassistenzsysteme“, 14th April 2005 in Aschaffenburg. Center for traffic sciences at the University of Würzburg.

Markand, O. (1990). Alpha rhythms. *Journal of Clinical Neurophysiology*, Vol. 7, No. 2, pp. 163-189.

Maycock, G. (1997). Sleepiness and Driving: The Experience of U.K. Car Drivers. *Accident Analysis & Prevention*, Vol. 29, No. 4, pp. 453-462.

McCartt, A.T., Hellinga, L.A. & Braitman, K.A. (2006). Cell Phones and Driving: Review of Research. *Traffic Injury Prevention*, Vol. 7, No. 2, pp. 89-106.

McEvoy, S.P., Stevenson, M.R., McCartt, A.T., Woodward, M., Haworth, C., Palamara, P. & Cercarelli, R. (2005). Role of mobile phones in motor vehicle crashes resulting in hospital attendance: A case-crossover study. *British Medical Journal*, Vol. 331, pp. 428-430.

McKnight, A.J. & McKnight, A.S. (1993). The effect of cellular phone use upon driver attention. *Accident Analysis and Prevention*, Vol. 25, No. 3, pp. 259-265.

Olson, R. L., Hanowski, R. J., Hickman, J. S., & Bocanegra, J. (2009). *Driver distraction in commercial vehicle operations, final report* (Report No. FMCSA-RRR-09-042). Washington, D.C.: Federal Motor Carrier Safety Administration.

Popp, R. (2005). *Gegenmaßnahmen bei Schläfrigkeit. Der Effekt von kurzwelligem Licht und olfaktorischer Stimulation*. Dissertation. Regensburg: Universität Regensburg.

Rakauskas, M., Ward, N., Bernat, E., Cadwallader, M. & De Waard, D. (2004). *Driving Performance During Cell Phone Conversations and Common IN-Vehicle Tasks While Sober and Drunk*. (Tech Report MN/RC-2005-41). Minnesota: University of Minnesota.

Rothe, S. (1995). *Fahrerwarnsystem – Einschlafwarner*. VDI Berichte, 1188, S. 341-351.

Sagberg, F., Jackson, P., Krüger, H.-P., Muzet, A. & Williams, A.J. (2004). *Fatigue, sleepiness and reduced alertness as risk factors in driving*. TOI Report 739. Oslo, Norwegen.

Schmidt, E.A. (2010). *Die objektive Erfassung von Müdigkeit während monotoner Tagfahrten und deren verbale Selbsteinschätzung durch den Fahrer.* Dissertation. Düsseldorf: Heinrich Heine Universität Düsseldorf.

Shinar, D., Tractinsky, N. & Compton, R. (2002). *Effects of Practice with Auditory Distraction in Simulated Driving*. Transportation Research Board 81st Annual Meeting Compendium of Papers. Transportation Research Board, Washington DC.

Strayer, D.L. & Johnston, W.A. (2001). Driven to distraction: dual-task studies of simulated driving and conversing on a cellular telephone. *Psychological Science*, Vol. 12, pp. 462-466.

Strayer, D.L., Drews, F.A. & Crouch, O.J. (2003). *Fatal distraction? A Comparison of the Cell Phone Driver and the Drunk Drive*. The Second International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, 25-29. University of Iowa Public Policy Center. Iowa City, IA.

Strayer, D.L., Drews, F.A., Crouch, O.J. & Johnston, W.A. (2005). Why Do Cell Phone Conversations Interfere with Driving? In: Walker W.R., Herrmann D. (Eds.). *Cognitive Technology: Transforming Thought and Society*. McFarland & Company Inc., Jefferson, NC.

Torsvall, L. & Akerstedt, T. (1987). Sleepiness in the job: continuously measured EEG changes in train drivers. *Electroencephalographic Clinical Neurophysiology*, Vol. 66, pp. 502-511.

Zulley, J., Crönlein, T.O., Hell, W. & Langwieder, K. (1995). Falling asleep at the wheel: the chief cause of severe traffic accidents. *Wiener Medizinische Wochenschrift*, Vol. 145, p. 473.