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ROAD FREIGHT TRANSPORT DRIVER FATIQUE TEST: A PILOT STUDY

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Abstract

Road freight transport is one of the main modes of transporting goods in the European Union. This reality puts pressure on carriers to make every transport of goods fast, safe, cheap, and efficient. Based on these requirements, lorry drivers are often forced by their employers to break the current social legislation in the European Union and the rules of the road. Compared to the current social legislation in force in different parts of the world, the European Union rules on driving times, breaks and rest periods for drivers engaged in road haulage and passenger transport are the strictest. An important factor and reason of serious and fatal traffic accidents, extensive damage to goods or property in road freight transport is a driver. This article presents three different types of experiments that were carried out, and the results may help to improve the current situation. The main aim of this study was to verify whether the actual regulations are safe and suitable and compare the results of daily work of professional drivers in two different measurements. Last measurement was conducted with using Eye-tacking technology, which aimed to verify impact of experiences on the reaction times of drivers. The authors believe that the results of individual measurements can contribute to increasing safety in road freight transport with preparing future extended studies and proposing the possible changes of current regulation.

Keywords: vehicle technical inspection; traffic safety; vehicles; road transport

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1. Introduction

Driver fatigue is a critical aspect that must always be closely monitored by the drivers themselves. A sleepy driver can create a variety of mistakes and crashes on roads, resulting in financial loss, bodily damage, and, most importantly, human life loss [10]. Fatigue is a more common cause of accidents than driving under the influence of alcohol [10]. Drivers may feel tired due to lack of sleep, constant driving, drugs, and medication. If a driver falls asleep for just four seconds while travelling at a speed of 100 km/h the car will have gone 111 meters without a driver in control [28]. Further, increased reaction times of the drivers mean longer decision-making processes and can result in a collision or a traffic accident [25]. At high speed, a crash is likely with a high risk of death or severe injury. Around (16–20)% of fatal road accidents involve driver fatigue [15]. Fatigue is a major cause of crashes in the state of Victoria (Australia) resulting in some 50 deaths and approximately 300 serious injuries each year [29]. As we have successfully demonstrated that fatigue is a major cause of accidents, we also need to solve it [2]. This article describes in detail the research aimed at identifying driver fatigue in road freight transport. In the Slovak Republic and the European Union, the rules on driving times, breaks and rest periods for drivers engaged in road haulage and passenger transport are laid down in Regulation (EC) No 561/2006 of the European Parliament and of the Council. The aim of this Regulation is to improve working conditions and road safety, to promote better monitoring and enforcement by Member States and to improve working practices in the road transport sector [27]. Unfortunately, drivers are not familiar with the current version of Regulation which causes unpleasant mistakes in observing work rules [24]. We believe that we will be able to confirm or contribute to the improvement of current legislation, especially in the field of international road freight transport by planning measurement of the driver fatigue during real situations in traffic, but also measurements on a simulator. Therefore, the main aim of this study was to verify whether the current regulations in charge are safe and suitable of working condition for professional truck drivers and compare the daily work of professional drivers in two different measurements. The first part of the article discusses the methods and various types of fatigue detection and possible ways to record driver fatigue. The measurements are di-vided into two parts, where the first part of the measurements will be performed on the Simulator in the laboratories of the Science Park of the University of Žilina. The second part of the measurements will be carried out in real truck and in real road traffic. The second measurement will involve professional driver for better results of the experiment, compared to the first experiment on a simulator, which was conducted with a classic driver's license holder. As already mentioned, the planned research consists of two parts and several different measurements, which should provide us with different perspectives on the issues addressed. In the first part, measurements will be performed, the results of which will then be evaluated in the second part and specific outputs will be presented. The first part of the measurements will be performed on a simulator, where the face of the driver will be monitored by cameras for whole one day during eleven hours long driving performance. We may conclude from this measurement that the mandatory break time al-lowed the driver to get clear of fatigue and lack of concentration because the number of errors quickly dropped to the absolute minimum after the 45-minute break. In the second part of the measurement on the simulator, the eyes of the drivers will be monitored by Eye-tracking glasses. We observed that experiences influ-

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enced the drivers' response times. De-tailed data on the sleep were not captured because all drivers were prepared and informed about experiments. On the base of this information, we did not think to follow this information because every driver arrived well rested. The second part of the different measurements will be carried out in real traffic, where the faces of the selected driver will be monitored by cameras while driving. Significant signs of fatigue behavior were discovered in this measurement. Last part of paper is focused on evaluation and proposal for next future measurements. However, the primary goal of this pilot study and subsequent investigations is to gather valuable and verifiable materials to review the present policy structure and, in the case that weaknesses are recognized, to suggest potential adjustments.

2. Literature review and drowsiness detection

Most of the studies on driving mental fatigue has been conducted using driving simulators, mostly because they provide safe, affordable, well-controlled circumstances and make data gathering easy [26]. Driving simulation also makes it possible to assess a greater variety of driving circumstances, particularly risky or physically harmful ones [38]. These scenarios, which are obviously impossible to evaluate on the road or even on a test track, include evaluating the subject's capacity to avoid crashes and detecting the impact of drugs, alcohol, and exhaustion on driving [20]. According to Philip et al. (2005) [23], both real-world and computer-simulated driving scenarios are suitable for studying driver weariness. Drowsiness detection algorithm input sources can be differentiated by the raw measurement and the processing steps taken to convert measurements into features. Measures explored in the literature include heart rate [9], brain activity [5, 19, 30], eye closure and tracking [14, 32, 34], lane position [11, 28], and steering-wheel angle [6, 18]. Although most previous algorithms focus on a one type of measure, several employ a combination of measures [8, 39]. The most applied and theoretically rigorous measures are electroencephalogram (EEG), percent eye-closure over a fixed time window (PERCLOS), and steering-wheel angle [3]. EEG is advantageous because spectral patterns in the signal have a well-established link to the transition between wakefulness and sleep [13, 19]. EEG is limited by the amount of pre-processing required prior to classification, vulnerability to artifacts, and the feasibility of collecting EEG from drivers in real situations. PERCLOS, developed by Wierwille et al. (1994) [34], is the gold standard measure for drowsiness detection. PERCLOS predicts drowsiness based on the percentage of time an individual's eyes are more than 80% closed over a 2-min period. Dinges et al. (1998) [5] demonstrated that the PERCLOS algorithm had over 90% accuracy in detecting degraded performance during a vigilance task, which was more reliable across drivers than EEG, blinks, and head position in the study. PERCLOS has been incorporated into aftermarket devices such as the Co-pilot and has been used as a ground truth measure of drowsiness [33]. Despite its wide acceptance PERCLOS has several practical limitations. PERCLOS for real-time detection is limited because current camera technology required for its measurement is expensive, has not been extensively validated, and may be unreliable when the driver wears sunglasses or under weather conditions that produce high amounts of glare [3]. Despite these limitations, the substantial evidence showing the utility of PERCLOS suggests that it might be useful for benchmarking new algorithms [17, 22]. Nor can we forget

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to use Subjective Methods, which can help improve the level of experiments performed, as well. The Stanford sleepiness scale [12] and Karolinska sleepiness scale [1] are the two most used subjective methods. The Stanford scale is a 7-point measuring scale describing an individual's current state of drowsiness. The Karolinska Sleepiness Scale, on the other side, is a 9-point scale. This scale is more extensive, able to categorize driver drowsiness to several different levels [17, 25, 31]. The authors consider using the Stanford scale of drowsiness presented below in the Table 1, where the driver's state of drowsiness will be evaluated by means of a questionnaire and professional observation.

Tab. 1. The Stanford sleepiness scale [12]

Value	Description
1	Feeling active, vital, alert, or wide awake
2	Functioning at high levels, but not at peak; able to concentrate
3	Awake, but relaxed; responsive but not fully alert
4	Little foggy; not at peak
5	Foggy; losing interest in remaining awake; slowed down
6	Sleepy; woozy; fighting sleep; prefer to lie down
7	No longer fighting sleep; sleep onset soon; cannot stay awake

3. Materials and methods

The planned research aimed at identifying driver fatigue in road freight transport is divided into two phases, which are divided into several measurements, as already mentioned before. Firstly, we will introduce the driving simulator, the eye-tracking glasses, the characteristics of the camera used and various driving scenarios and procedures.

Materials

The cabin of this Simulator is created as a structural model of a real truck type (it is not made up of a real truck cabin). The interior equipment of the Simulator cabin copies the real cabin in terms of the layout of the controls and indicators. The steering wheel features are provided by the engine servo, gear lever, pedals, handbrake, and steering wheel position adjustment, which are equipped with compressed air power simulations corresponding to the actual vehicle. The image is projected in front of the driver on a system of three large-screen projection screens and at the same time into rear-view views placed in the space of the projection screen. The simulator is also equipped with a teacher's desk, which is used to control the system and a panel for starting the electrical and other circuits of the simulator, as you can see in the Figure 1. At the same time, it is possible to run individual training lessons from the teacher's desk. The computer image generator is located next to the driver's seat and generates images of both front and rear views of the monitors in relation to the landscape projected in front of the driver. The driver can watch the traffic behind the vehicle and perform, among other things, reversing training, as well.

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Fig. 1. Simulator [prepared by authors]

Based on the powerful processor, the dual lens simultaneously records the front camera and the interior camera of a part of the vehicle in 1080P 30P + 1080P 30P / 720P 30P + 720P 30P resolution. There is an option to only use the front camera only to record from the front at 4K 2160p 24P/1440p 30P/1080P 60P/1080P 30P/720P 60P/720P 30P. The exceptional low-profile design allows the on-board lens to be well hidden. Both cameras can be rotated 180 degrees forward and backward, 50 degrees left and right. The GPS module accurately records the position, speed, and route of vehicles. And it can be viewed using a GPS player on your computer. Super night vision, 1/2.9-inch light-sensitive im-age sensor, 4 infrared lights, f/1.8 aperture, and 6-lens lens, can produce clear videos and photos even in low light conditions. WDR technology automatically compensates for light/dark spots and balances exposure, allowing all details of a scene to be recorded live. LDWS: Lane Departure Warning System. FCWS: Frontal Collision Warning System. The built-in super capacitor prevents the battery from exploding during use. On-board is camera connected to a car charger, it is necessary.

In our study we used SMI Eye Tracking 2 Wireless, Eye-tracking glasses from SMI SensoMotoric Instruments. Eye-tracking is based on obtaining data on eye movement or eye pupils, respectively [21]. This data is obtained by the Eye tracker, which consists of two main components: a light source that emits infrared radiation and is aimed at the eye, and a camera that then captures infrared light reflections, including pupil movements. This device must be connected to a computer or other device that stores the scanned data [37]. Our study used Eye-tracking glasses. These glasses record a person's natural behaviour in real-time on a computer. The sampling frequency for eye movement is up to 120 Hz, and the viewing range is 80 degrees horizontally and 60 degrees vertically. In addition to recording images at a resolution of 1280x960 pixels at 24 fps or 960x780 pixels at 30 fps, the glasses also use an integrated microphone that picks up ambient sound. After using the Behavioural and Gaze Analysis software, the output data of the scan can be in the form of video or images.

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Methods

In this study, we worked with six different driving scenarios, which are presented and described below. Two different experiments were performed with the simulator, which are described above in the methodology section.

In the first measurement, we worked with five different driving scenarios, where drivers had total freedom to drive around scenarios and then in the second different experiment conducted on simulator with the use of eye-tracking glasses, we worked with one more different driving scenario, where each driver had to follow the same scenario. We gradually describe all the driving scenarios that were used in the first measurement, and at the end of this subsection, the last driving scenario used in the measurement with eye-tracking glasses will also be presented. The first and the longest driving scenario that the driver drove took place on a highway with regular traffic and it is shown in the Figure 2. This driving scenario lasted for four and half hours before driver took first obligatory pause lasted 45 minutes, according to the current regulation.

Fig. 2. Highway driving scenario [prepared by authors]

After the first obligatory pause of 45 minutes, what is necessary for every professional truck driver in European union to take for getting new four and half hours of more time to drive in that particular day, second driving scenario started. Driver drove in this driving scenario for two hours and it took place on a regular road with different type of obstacles on the road and around the road, also different speed limits and classic traffic with other cars but without hills. In this scenario road didn't go through any cities, it goes all the time out of the city or village like it is shown in the Figure 3.

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Fig. 3. Regular road scenario [prepared by authors]

After two hours of driving in previous driving scenario, fifteen minutes pause follow. Drivers can divide their 45-minute breaks to two separate parts of duration of minimum of fifteen minutes for the first pause and then the second pause cannot be shorter than 30 minutes and always together both breaks must be at least 45 minutes after every four and half hours of driving except the case when daily rest period or weekly rest period follow, then the break is not needed. During these fifteen minutes break, driving scenario was changed to the city mode, like it is shown in the Figure 4.

Fig. 4. City driving scenario [prepared by authors]

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In this third driving scenario, driver drove for two and half hours. After completing four and half hours in total with previous two hours driving in the regular road scenario and two and half hours in this city scenario, driver stopped the simulator truck and start-ed to rest for thirty minutes, what is the second part of the obligatory 45 minutes break be-fore drivers are allowed to drive more hours according to the regulation 561/2006. Regulation in the European Union allows truck drivers drive twice ten hours in one working week. Based on this information, we decided to extend the measurement and the driver's driving time by another hour to see number of mistakes and signs of tiredness behaviour at the end of driver work. We also changed the driving scenario to the similar one like second driving scenario was. In comparison with the second scenario, this fourth driving scenario contained hills and various ups and downs on the road with different obstacles around. This fourth driving scenario is shown in the Figure 5.

Fig. 5. Driving scenario with hills [prepared by authors]

After completing ten hours of driving time in one day, driver cannot continue to work and drive more hours according to the older regulation but according to the new adjustments in regulation from 15 July 2020, drivers may also exceed daily and weekly driving time by up to one hour in order to reach the employer's operational centre or the driver's place of residence to take a weekly rest period. Based on this new change, we prolong driving time of the driver for another one more hour. Before driver started to drive last eleventh hour in this day, driver took 30 minutes safety break. We also changed driving scenario during this break. Last driving scenario took place on a countryside road between different villages and farms like it is shown in the Figure 6.

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Fig. 6. Countryside road driving scenario [prepared by authors]

Evaluation of the process of this first measurement on the simulator, where one driver drove eleven hours in one day in five different driving scenarios, is presented in the results section. Driver was recorded with video camera while driving whole day and four different signs and mistakes were evaluated of this video records. One of the biggest reasons for 11 hours long experiment was to see driver behaviour and tiredness level after long hours driving performance.

In the second measurement, we only worked with one driving scenario. Four drivers participated in the second experiment with use of Eye-tracking glasses, and only drivers without glasses, drivers with good vision went in for this measurement. Drivers started always from the same beginning point and the same obstacles were presented to them. The risky driving scenario with a wild animal obstacle is shown below in the Figure 7.

Fig. 7. Risky driving scenario [prepared by authors]

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Evaluation of the reaction times of drivers in this first measurement on the simulator are presented in the results section.

Methodology

The first study is realized on the driving simulator in the laboratories of the Science Park of the University of Žilina. The first part of the measurements is based on the data collected while driving the Simulator. Data are collected continuously throughout the ride from the simulator and the video recording camera. The simulator collects records of vehicle condition and driver inputs (i.e. lane position, maximum and average speed, distance travelled, driving time, shifting without clutch, body collision with external object, clutch pedal position). The journey takes a minimum of 11 hours per one day and includes a realistic driving environment. Five slightly different driving scenarios are used, one for each ride, to eliminate the potential learning effect. Each scenario represents the same simulator events, but in a different order. Data from each measurement are collected and evaluated. The camera records various eye movements, including blinking and closing of the eyes, yawning, and head loss. The research consists of two separate visits to the simulator. The first visit is only a screening, introductory visit and the second visit will consist of a one-day drive from an early morning to evening condition. The second measurement on the simulator is performed using Eye-tracking glasses, which record the movements and reactions of the eyes to risky situations during a twenty-to-thirty-minute ride on the simulator [20]. The test phase of measuring and testing the equipment has currently taken place. Based on the results of this measurement, we can recognize when an obstacle appears on the road, when the driver notices it and then when the driver reacts and presses the brake pedal. Only drivers without glasses participated in this measurement, all drivers with glasses were excluded from this measurement. You can see the driver with the Eye-tracking glasses and at the same time you can see the driver's view with the help of the glasses in the Figure 8.

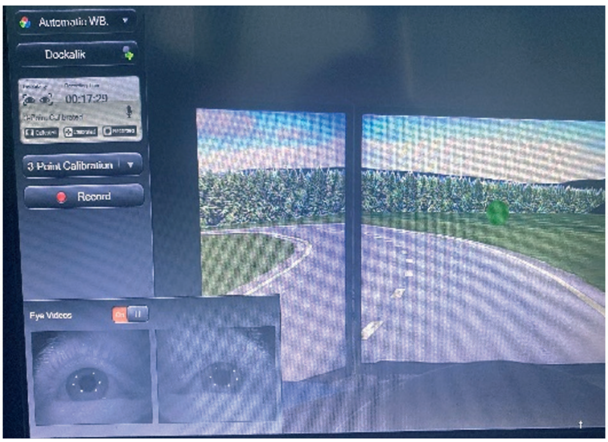

Fig. 8. Eye – tracking glasses and view of the driver [prepared by authors]

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The second part of the measurement is carried out in real vehicle with professional truck driver from Slovakia. The second measurement is based on the collection of GPS data, digital tachograph data and video data of driver monitored while driving. Data are collected over whole day and includes various journeys made by truck driver from Slovakia to different European countries. During different journeys, driver may behave differently in terms of driving safety. Numerous indicators represent various aspects of dangerous driving behaviour [39]. Extensive data are collected from driver and evaluated to see if the current legislation about driving time up to ten hours per day is safe and satisfactory.

At the end of the presented methodology, it is necessary to report that for the evaluation of the drivers' fatigue the subjective method is used. We expected to evaluate results with use of program imotions, but unfortunately program is not available yet. Authors are aware of possibility that this evaluation could lead to different results than program imotions, which was and is also planning to be used for future measurements. In the future evaluation of extensive data, Junaedi and Akbar drowsiness detection method is expected to be used [30]. To do this, the conventional confusion matrix will be used to generate the positive and negative prediction scores of each model and then deduct several performance measures from those scores [4]. On the other side, it should be noted that using a subjective method can be consider as accurate as imotions program due to the detailed and responsible evaluation of authors.

4. Results

The total driving time of the driver was 11 hours per one day, which was made possible by an amendment to Regulation 561/2006 adopted on 20 August 2020. During the whole time, driver was monitored by camera recording his face and upper part of the body, but also program of simulator recorded driver´s mistakes.

We found that symptoms of tiredness behaviour were more significant in the first part of measurement in the early morning than in the second part, not only yawning but also examples of head losing and supporting it with one hand or slower response reaction time. These signs of fatigue are higher at the beginning of the experiment, then the signs decreased, and driver started to focus on the road. We can observe that driver interest was slowly decreasing gradually with time of driving After taking 45-minute break, number of mistakes rapidly decreased to the minimum, we can review that obligatory break time helped driver to eliminate fatigue and lack of concentration. On the other side, we can observe that second short break with duration only 15 minutes after another two hours of driving did not help to decrease signs of fatigue behaviour, but it caused increasing of number of errors like not concentrating or jerking driving. The significant increase in jerking in 8 hour was due to the longer driving time between two breaks, more different driving scenarios and one only 15 minutes break, caused reduction in driver attention.

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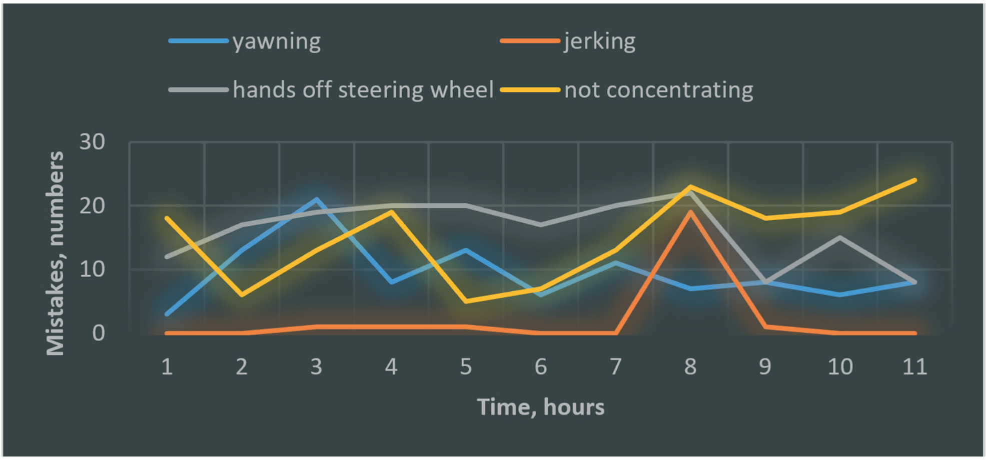

Fig. 9. Camera record of driver in simulator [prepared by authors]

After second break of 30 minutes before last driving part, we can see decreasing number of signs of fatigue behaviour, again. To sum up, on the other side, in the second part of measurement, we can see more mistakes, which could cause traffic accidents but most of mistakes were related to phone distraction either calling or texting and not symptoms of tiredness behaviour. Drivers in both experiments were not informed of recording errors in violation of the Road Traffic Act. Based on this big actual problem of using cell phone, driver was losing focus on the traffic situation, but we cannot evaluate, how much focus attention losing could lead to a traffic accident. To sum up, we can say that more dangerous situations were caused by lack of concentration than tired driver behaviour. We can confirm in this pi-lot study that current regulation about driving times and breaks is suitable. Evaluation of all driver mistakes and symptoms of tiredness behaviour are presented in the Figure 9.

Third study in total that we realized was to identify fatigue of driver while driving in the real traffic. Driver was following current social regulation with driving time maximum of 10 hours in one day. The driver worked as a regular day, except that during this one day the driver's performance was recorded by a face video camera. This analysis resulted in the same recognition as simulator study analysis. We evaluated signs of yawning, fatigue behaviour, not concentrating and getting hands off the steering wheel. First half and hour, driver was fresh and well rested driving on the regular road in Slovakia and then before crossing the border first part of 15 minutes break followed. Then the driver continued to drive almost 4 hours before he took second part of the break with minimum 30 minutes duration. After the break, 4.5 hours were performed in the highway. Before driver started last driving part, driver had to take a second 45-minute break. Last one hour of driving were out of the highway near to the unloading point where driver also stopped and performed a short daily rest pause of duration nine hours. The total driving time of the driver and performance that day was almost ten hours, and it was recorded during sunny day and early evening. During the whole time, driver was monitored by camera, which was recording his face and upper part of the

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body, but during driver breaks camera was off. We found the significant symptoms of tiredness behaviour in the first period of driving before taking second break with duration of 30 minutes and also the significant symptoms of not concentrating which could be caused by driver fatigue. We can observe that in the second part of measurement before last hour of driving there were starting symptoms of tiredness behaviour like yawning observed on the video record, slow head falling, head supporting with hand and rubbing eyes but after taking 45 minutes break, all symptoms disappeared. A high increase in lack of attention could have been caused by fatigue, and thus the distraction mostly with cell phone could have been used to reduce fatigue. On the other side, during whole measurement, we can see many mistakes more than in the simulator study which could endanger traffic safety. Most of the mistakes were related to phone distraction either calling or texting, as it was seen in simulator study, as well. Un-fortunately, we cannot estimate how much traffic accidents could have been compromised without front records. Evaluation of driver mistakes and symptoms of tiredness behaviour are presented in the Figure 10.

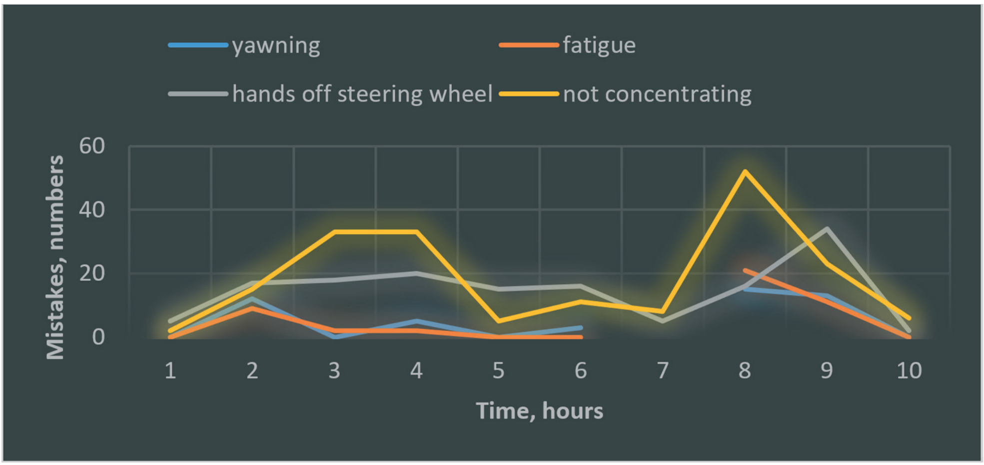

Fig. 10. Evaluation of driver in the real traffic [prepared by authors]

Second different study than first one that we realized on the simulator was to identify differences of driver reaction time using Eye-tracking glasses. This analysis resulted in recognition of the time, observing an obstacle and time of the decision to break. Two drivers with a driving license of group “C” and two drivers with a group “B” license took part in the measurement. All four candidates were 25 years old. The total driving time of one driver was 10 minutes to 15 minutes, depending on the driving speed in a risky environment. The risk environment and obstacles shown were randomly generated by the computer. Obstacles that appeared while driving were wild animals running across the road, falling trees on the road, or a tractor entering the road.

Using Eye-tracking glasses, we were not only able to determine the drivers’ reaction time in total, but we were able to divide this time into the obstacle observation time (yellow column)

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and the brake pedal time (blue column). Based on this data, we can say how long it takes the driver to react to a certain type of obstacle since he detects the obstacle, not since the obstacle appears on the screen. We decided to consider only the first 15 crisis responses for each driver because then the obstacles and the way they were displayed began to repeat. Figure 11 presents an average of the drivers' observation time (yellow colour) and brake pedal reaction time (blue colour). First and third driver were drivers with valid truck driving license compared to second and fourth driver where there were classic drivers with regular driving license. There is a fifth driver who is not considered because this driver knew obstacles and he was only a testing driver.

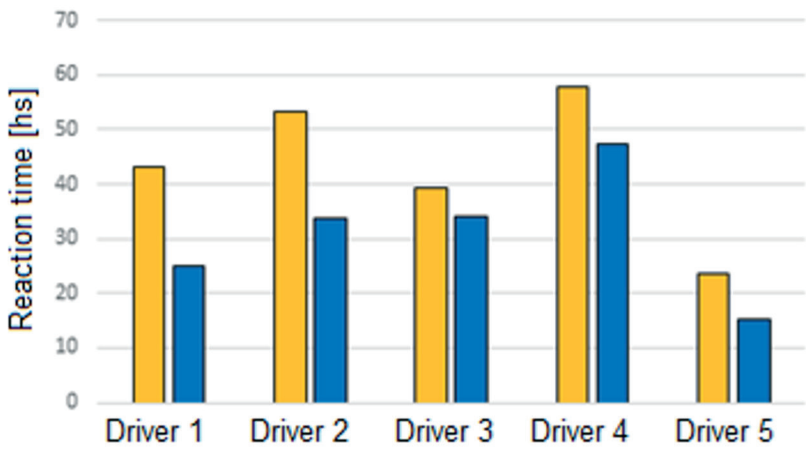

Fig. 11. Average of the drivers' observation time and brake pedal reaction time [prepared by authors]

5. Discussion

The World Health Organization (WHO) road safety report reveals approximately 1.2 million deaths due to driver fatigue each year from 2001 to 2013 [36]. Based on the analysis of accident statistics from the EU and the USA, it was found that the situation in the EU is better than in the USA, in terms of accident rates over a period of four years from 2009 to 2012. Even though the total number of fatal accidents in the EU and the USA is very similar [16]. By reason of the seriousness of this issue, there are several types of research to prevent sleepy drivers while driving a motor vehicle. One solution is to educate drivers about adverse conditions while driving at sleep. This approach means realizing the effects of lack of sleep, fatigue caused by long monotonous driving, but also other work, and hours of operation of delivery points [35]. Compared to the current social legislation in force in the United States of America, the European Union drivers can drive 4 hours to 10 hours less in one working week, and while in two weeks it can be a difference of up to 30 hours [7]. In our first study, two different experiments were conducted, which aimed to verify the driver's awareness condition when driving a lorry during a 10-hour working day. One of the studies was realized on the

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simulator, and the same type of the study took a part in the real traffic, as well. As already mentioned, there are differences in the results obtained between drivers' performances on the simulator and in the real vehicle. We did not find significant symptoms of tiredness behaviour during whole period of both drivers driving. As a result, drivers can drive safely 10 hours or 11 hours per day in accordance with applicable regulations as long as they comply with legal rest requirements. To summarize this part of the study, we need to conduct longer experiment, when more days in a row of one driver will be recorded and evaluated. On the other side, resulting from not concentrating, driver in the real traffic caused more dangerous situation which could lead to the traffic accident than driver on the simulator. Mostly, lack of concentration was related to using a mobile phone for either calling, or texting. Errors and violations of road traffic rules were recorded only when the driver had a phone in his hand, if he used a handsfree, this was not record-ed as an error. On the other side, it is necessary to consider that use of phone helps many drivers reduce passive fatigue. Based on the mentioned above, it is fair to conclude that the results coming from the simulator study are comparable with the results obtained from the study conducted in real traffic. Thanks to these studies, it is possible to carry out another similar measurement, where the driving time would be extended to 12 hours to 15 hours a day like it is in other countries. The task of this future measurement would be to verify that the driver is able to drive a motor vehicle safely in compliance with mandatory breaks at work for one 24-hour day. By such a measurement, we identify the potential maximum driving time for one day, a 24-hour period. This measurement will be supplemented by data recorded on the Simulator software, using a behavioural method such as lane departure, eye opening and closing time, etc. Behavioural methods will help to im-prove the resulting image of driver fatigue. We consider obtained results to be the starting point for comparison with other methods and future experiments. As already mentioned, the total driving time of the driver was increased up to 12 hours per one day, 24 hours period, by an amendment to Regulation 561/2006 adopted on 20 August 2020. As for the current regulation in the USA, it is possible to drive 11 hours for professional drivers every day between two weekly rest periods in road freight transport, unlike the EU, where this option for drivers is only once a week if other conditions are met. With increasing demand for goods, many vehicles are needed [33]. One possible solution could there-fore be to use existing vehicles with existing drivers, by extending their working, driving time to such several hours that it does not endanger road safety.

On the other side, in the second measurement, the reaction times of 2 experienced drivers and 2 unexperienced drivers were evaluated and compared. The main purpose of this study was to verify impact of experiences on the reaction times of drivers. Based on the results obtained, we can see that different experiences had an impact on the reaction time of drivers. According to calculations, at a speed of 50 km per hour and the difference between the reaction time around 20 hundred of seconds, the difference in braking distance is around 4 meters. At 80 km, the difference is more than 6 meters, and with increasing speed, the difference increases even more. Extending the braking distance will cause the vehicle not to stop in front of an obstacle in time but instead end up in an obstacle, thus, an accident will occur. To summarize our findings, apart from the effects of age, gender, fatigue, stress, medication, and other factors affecting driver reaction, driver experience affects drivers' response times, as well, but without obtaining more data, the results of this first study in this paper can

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be considered only indicative. The result of this study is very valuable for the preparation of future research programs for measuring drivers' reaction time, which will bring the desired effect. For a comprehensive approach to research, different measurements are planned to use subjective methods, physiological and behavioural methods, which should bring us a better final picture of the problem. Physiological methods, including EEG, ECG and electrooculogram (EOG), are considered the most accurate. Their high accuracy is ensured by the transmission of electrical signals of the driver inside the body, which can detect immediate changes in the vigilance of the driver. We believe that detailed research could bring useful basis for a possible change in current legislation that would not result in an increase in the number of traffic violations and accidents.

6. Conclusion

Performed experiments proved that there is a potential for future experiments, which could lead to changes of current regulation. To summarize, the finding resulting from the two full day experiments, we may conclude that driver's behaviour was similar both in the real traffic and on the simulator. This fact proves to us that it is possible to implement other more extensive measurements on the simulator, which will have a comparable explanatory value with the measurements made in the actual traffic. Based on the findings in eye-tracking glasses study, we may conclude that diverse experiences had an influence on drivers' reaction times during the Eye-tracking experiment. We plan to use the obtained data from future individual measurements to evaluate the current situation of drivers' behaviour in road freight transport. Information obtained from extensive data can serve as effective alternative measures on traffic exposure and enable more effective policy making. Although this study uses a highly faithful simulator, it does not accurately replicate the experience of actual management, so to improve the results we plan to compare two types of independent research from real traffic and a simulator. These future studies both in the real traffic and on the simulator will use data obtained from several different measurements with more participants. Many factors affect driver behaviour. Due to the small sample of drivers in individual measurements, right now we are not able to properly consider the personal characteristics of drivers (e.g., age, gender, education) and psychological conditions (e.g., agitation, depression). Despite these limitations, conducted research provided a systematic approach to identifying potential risks between different lorry drivers. One concern is which method and algorithm should be used to evaluate the results. There are several limitations to this study, including the use of a driving simulator, the de-sign of the study, the scope of the test data, and the scope of the basic truth of fatigue. These results and future results could be combined with safety interventions to address the causes of fatigue, such as incorrect working patterns and sleep disorders, to create comprehensive systems that will improve driving safety [20]. One of the possible benefits and changes that pilot study could bring and possible future studies is changing the driving time from 9 hours per day and maximum twice a week to 10 hours per day every day of the week. Of course, this pilot research needs to continue with extending this research more. However, the main aim of this study and future studies, is prepare valuable and verified documents to evaluate the current regulation, and in the case of findings of weaknesses, propose the possible changes.

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8. References

[1] Åkerstedt T., Gillberg M.: Subjective and objective sleepiness in the active individual. International Journal of Neuroscience. 1990, 29–37, DOI: 10.3109/00207459008994241.

[2] Apoorva A., Vali D., Rakesh K.R.: Review on Drowsiness Detection. EAI Endorsed Transactions on Smart Cities. 2020, 4(12), 165517, DOI: 10.4108/eai.13-7-2018.165517.

[3] Balkin T.J., Horrey W.J., Graeber R.C., Czeisler C.A., Dinges D.F.: The challenges and opportunities of technological approaches to fatigue management. Accident Analysis & Prevention, 2011, 43(2), 565–572, DOI: 10.1016/j.aap.2009.12.006.

[4] Bamidele A., Kamardin K., Syazarin N., Mohd S., Shafi I., Azizan A., et al.: Non-intrusive driver drowsiness detection based on face and eye tracking. (IJACSA) International Journal of Advanced Computer Science and Applications. 2019, 10(7), 549–569, DOI: 10.14569/IJACSA.2019.0100775.

[5] Dinges D.F., Mallis M.M., Maislin G., Powell J.W.: Evaluation of techniques for ocular measurement as an index of fatigue and as the basis for alertness management. National Highway Traffic Safety Administration. 1998 (DOT-HS-808-762). United States. https://rosap.ntl.bts.gov/view/dot/2518 (accessed on 19.05.2023).

[6] Eskandarian A., Mortazavi A.: Evaluation of a smart algorithm for commercial vehicle driver drowsiness detection. IEEE Intelligent Vehicles Symposium Proceedings. 2007, 4290173, 553–559, DOI: 10.1109/IVS.2007.4290173.

[7] Federal Motor Carrier Safety Administration (FMCSA), 2020. https://www.fmcsa.dot.gov/regulations/hours-service/summary-hours-service-regulations. (accessed on 11.03.2023).

[8] Forsman P.M., Vila B.J., Short R.A., Mott C.G., Van Dongen H.P.: Efficient driver drowsiness detection at moderate levels of drowsiness. Accident Analysis & Prevention. 2013, 50, 341–350, DOI: 10.1016/j.aap.2012.05.005.

[9] Furman G.D., Baharav A., Cahan C., Akselrod S.: Early detection of falling asleep at the wheel: A heart rate variability approach. 2008 Computers in Cardiology. 2008, 35, 1109–1112, DOI: 10.1109/CIC.2008.4749240.

[10] Ghole U., Chavan P., Gandhi S., Gawde R., Fakir K.: Drowsiness detection and monitoring system. ITM Web of Conferences. 2020, 32, 03045, DOI: 10.1051/itmconf/20203203045.

[11] Hanowski R.J., Bowman D., Alden A., Wierwille W.W., Carroll R.: PERCLOS+: Development of a robust field measure of driver drowsiness. 15th World Congress on Intelligent Transport Systems and ITS America's 2008 Annual Meeting. 2008, 7, 4783–4794.

[12] Hoddes E., Zarcone V., Smythe H., Phillips R., Dement W.C.: Quantification of Sleepiness: A New Approach. Psychophysiology. 1973, 10(4), 431–436, DOI: 10.1111/j.1469-8986.1973.tb00801.x.

[13] Hudec J., Šarkan B., Caban J., Stopka O.: The impact of driving schools' training on fatal traffic accidents in the Slovak Republic. Scientific Journal of Silesian University of Technology. Series Transport. 2021, 110, 45–57, DOI: 10.20858/sjsutst.2021.110.4.

[14] Ji Q., Zhu Z., Lan P.: Real-time nonintrusive monitoring and prediction of driver fatigue. IEEE transactions on vehicular technology. 2004, 53(4), 1052–1068, DOI: 10.1109/TVT.2004.830974.

[15] Junaedi S., Akbar H.: Driver drowsiness detection based on face feature and PERCLOS. In Journal of Physics: Conference Series. 2018, 1090(1), 012037, DOI: 10.1088/1742-6596/1090/1/012037.

https://doi.org/10.14669/AM/172910

[16] Kapusta J., Kalašová A.: A comparison of truck driver safety between the EU and the USA. Scientific Journal of Silesian University of Technology. Series Transport. 2016, 93, 49–58, DOI: 10.20858/sjsutst.2016.93.6.

[17] Kim S., Miyamoto T., Kuboyama T., Moriyoshi Y.: Characterizing human driver characteristics using an artificial neural network and a theoretical model. Control Theory Technology. 2020, 20(2), 263–278, DOI: 10.1007/s11768-022-00099-7.

[18] Krajewski J., Golz M., Sommer D.: Detecting sleepy drivers by pattern recognition based analysis of steering wheel behaviour. Der Mensch im Mittelpunkt technischer Systeme (People are at the center of technical systems). 2009, 288–291.

[19] Lal S.K., Craig A., Boord P., Kirkup L., Nguyen H.: Development of an algorithm for an EEG-based driver fatigue countermeasure. Journal of safety Research. 2003, 34(3), 321–328, DOI: 10.1016/S0022-4375(03)00027-6.

[20] Lew H.L., Poole J.H., Lee E.H., Jaffe D.L., Huang H.C., Brodd E.: Predictive validity of driving-simulator assessments following traumatic brain injury: a preliminary study. Brain injury. 2005, 19(3), 177–188, DOI: 10.1080/02699050400017171.

[21] Madleňák R., Madleňáková L.: Multi-criteria evaluation of e-shop methods of delivery from the customer's perspective. Transport Problems. 2020, 15(1), 5–14, DOI: 10.21307/tp-2020-001.

[22] McDonald A.D., Lee J.D., Schwarz C., Brown T.L.: A contextual and temporal algorithm for driver drowsiness detection. Accident Analysis & Prevention. 2018, 113, 25–37, DOI: 10.1016/j.aap.2018.01.005.

[23] Philip P., Sagaspe P., Taillard J., Valtat C., Moore N., Åkerstedt T., et al.: Fatigue, sleepiness, and performance in simulated versus real driving conditions. Sleep. 2005, 28(12), 1511–1516, DOI: 10.1093/sleep/28.12.1511.

[24] Poliak M., Beňuš J., Lazaroiu G.: Violations of social regulation and traffic accidents in road freight transport. The Archives of Automotive Engineering – Archiwum Motoryzacji. 2022, 97(3), 51–59, DOI: 10.14669/AM/155050.

[25] Putilov A.A., Donskaya O.G.: Construction and validation of the EEG analogues of the Karolinska sleepiness scale based on the Karolinska drowsiness test. Clinical Neurophysiology. 2013, 124(7), 1346–1352, DOI: 10.1016/j.clinph.2013.01.018.

[26] Reed M.P., Green P.A.: Comparison of driving performance on-road and in a low-cost simulator using a concurrent telephone dialling task. Ergonomics. 1999, 42(8), 1015–1037, DOI: 10.1080/001401399185117.

[27] Regulation (EC) No 561/2006 of the European Parliament and of the Council of 15 March 2006 on the harmonization of certain social legislation relating to road transport and amending Council Regulations (EEC) No 3821/85 and (EC) No 2135/98 and repealing Council Regulation (EEC) No 3820/85. https://eur-lex.europa.eu/legal-content/SK/TXT/?uri=CELEX%3A02006R0561-20200820&qid=1694545751457 (accessed on: on: 10.06.2023).

[28] Safe driving tips FATIGUE: https://www.mylicence.sa.gov.au/safe-driving-tips/fatigue. (accessed on: 12.05.2023).

[29] Stoma M., Caban J., Dudziak A., Kuranc A.: Selected Aspects of the Road Traffic Safety Management System. Communications - Scientific Letters of the University of Zilina. 2021, 23(2), F33–F42, DOI: 10.26552/com.C.2021.2.F33-F42.

[30] Tarkowski S., Caban J., Dzieńkowski M., Nieoczym A. Zarajczyk J.: Driver's distraction and its potential influence on the extension of reaction time. The Archives of Automotive Engineering – Archiwum Motoryzacji. 2022, 98(4), 65–78, DOI: 10.14669/AM/157645.

[31] Tarkowski S., Nieoczym A., Caban J., Madleňák R.: The Possibility of Noticing the Cyclists Based on Reflective Effect of the Elements on the Bicycle Pedals. Periodica Polytechnica Transportation Engineering. 2021, 49(2), 132–138, DOI: 10.3311/PPtr.14669.

[32] Vichova K., Veselik P., Heinzova R., Dvoracek R.: Road Transport and Its Impact on Air Pollution during the COVID-19 Pandemic. Sustainability. 2021, 13(21), 11803, DOI: 10.3390/su132111803.

https://doi.org/10.14669/AM/172910

[33] Wierwille W.W., Wreggit S.S., Kirn C.L., Ellsworth L.A., Fairbanks R.J.: Research on vehicle-based driver status/performance monitoring; development, validation, and refinement of algorithms for detection of driver drowsiness. National Technical Information Service, Springfield, Virginia final report (No. HS-808 247). 1994. https://rosap.ntl.bts.gov/view/dot/2578 (accessed on: 18.06.2023).

[34] Williamson A., Friswell R., Olivier J., Grzebieta R.: Are drivers aware of sleepiness and increasing crash risk while driving? Accident Analysis and Prevention. 2014, 70, 225–234, DOI: 10.1016/j.aap.2014.04.007.

[35] World Health Organization: Global status report on road safety 2015. 2015, 1–16. https://www.afro.who.int/sites/default/files/2017-06/9789241565066_eng.pdf (accessed on: 10.06.2023).

[36] Zehnder E.C., Schmölzer G.M., van Manen M., Law B.H.: Using eye-tracking augmented cognitive task analysis to explore healthcare professionals' cognition during neonatal resuscitation. Resuscitation Plus. 2021, 6, 100119, DOI: 10.1016/j.resplu.2021.100119.

[37] Zhao C., Zhao M., Liu J., Zheng C.: Electroencephalogram and electrocardiograph assessment of mental fa-tigue in a driving simulator. Accident Analysis & Prevention. 2012, 45, 83–90, DOI: 10.1016/j.aap.2011.11.019.

[38] Zhou T., Zhang J.: Analysis of commercial truck drivers' potentially dangerous driving behaviors based on 11-month digital tachograph data and multilevel modeling approach. Accident Analysis & Prevention. 2019, 132, 105256, DOI: 10.1016/j.aap.2019.105256.

[39] Zilberg E., Burton D., Zheng M.X., Karrar M., Lal S.: Methodology and initial analysis results for development of non-invasive and hybrid driver drowsiness detection systems. The 2nd International Conference on Wireless Broadband and Ultra-Wideband Communications. 2008, 4299665, 16–36, DOI: 10.1109/AUSWIRELESS.2007.44.