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ANALYSIS OF TRAIN DRIVER BEHAVIOR USING EYE-TRACKING GLASSES

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ABSTRACT

According to statistics, rail transport is one of the safest means of transport. This work primary goal is to improve safety in rail transport, while in the master's thesis the goal and research methods were extended, supplementing them with a study of the driver's behavior in both training and active service using the eye-tracking method. It should be mentioned that human life is a superior good, despite everything, thanks to having the best safety indicators, work is still underway to minimize unfavorable events and incidents in rail transport. In the daily functioning of rail transport, the passenger is interested in traveling from point A to point B in the shortest possible time and while maintaining a high standard of comfort, often not paying attention to safety aspects. Incidents, accidents and serious accidents at rail-road crossings involving drivers of passenger cars, trucks and train sets are still a big problem. Unfortunately, this results from a lack of awareness of the hazard occurring when not following the indications of safety devices at rail-road crossings and a lack of awareness of the correct procedure in the event of a dangerous situation. One of the methods of increasing safety and preventing and predicting dangerous events is annual three-hour training on a railway vehicle simulator. In the Railway Company in the Silesian Voivodeship, drivers who have been employed for less than two years undergo simulator training twice a year to check their level of knowledge and how to act in typical and atypical situations. This paper presents an analysis of the driver's work during a training session on a railway vehicle simulator and during the driver's active service using eye-tracking glasses. This allowed for checking the driver's behavior during the training session and during active service where the driver is responsible for the correct course of the transport process, maintaining all safety aspects, conducting the train set in accordance with applicable regulations on lines managed by PKP PLK and in private areas.

Keywords

Train Driver Behavior, Eye-Tracking Glasses, Rail Transport Safety, Simulator Training, Human Factors, Transport Process, Cognitive Distraction, Visual Attention, Railway Infrastructure, Passenger Transport, Safety Regulations, Driver Performance, Technological Innovation, Behavioral Analysis, Active Service, Digital Simulation, Heat Maps, Fixation Maps, Professional Experience, Stress Factors

1. INTRODUCTION

In the last years of the 21st century, scientists point to the great development and popularization of research using eye-tracking methods, which is conditioned by the development of technology with a simultaneous in the cos of its production. Previous researches have been very often defined as troublesome, costly and time-consuming. Due to more and more advanced technological progress, this situation has changed. [1] On the basis of scientific research, in this case on a group of passenger car drivers, it was found that the main factor in the occurrence of dangerous situations is the distraction of their attention resulting from the surrounding environment, for example: other road users, buildings, vegetation. Excessive strain on the cognitive system causes a deterioration in perceptual abilities, affecting reaction time and the correctness of decision-making. [2] In the case of rail transport, it is also very important for the train driver to focus on duties and it is also accompanied by factors that may affect his focus. The aim of this work was to conduct research involving the analysis of the work and behavior of a train driver in passenger transport during a training session on a train simulator and during the driver's active service. Eye-tracking glasses were used for this purpose. The obtained research results can be used as recommendations for improving the actions of the carrier, the train driver or, at a later stage, the rolling stock designer. The primary goal of the work is to present the difference in behavior during a training session on a simulator compared to active service, reactions and observation of individual elements of infrastructure, environment or elements in the driver's cabin responsible for facilitating the transport process in passenger traffic. In the case of cyclical tests using eye-tracking glasses, it is possible to check habits, improve competences depending on experience or stress factors.

The scope of the work includes tests on the Katowice – Gliwice and Gliwice – Katowice route sections. In the case of the driver's active service, a visit to the Technical Inspection Post in Gliwice was also presented. In the case of the collected materials from the railway vehicle simulator, variable weather conditions and random situations related to the interference of wild animals or third parties were used. In order to check the comfort and safety of performing the tests, tests on the railway vehicle simulator were performed first. A positive opinion of the driver-instructor after completing a training session on the railway vehicle simulator allowed us to proceed to performing tests using eye-tracking glasses during the driver's active service. Fig. 1 and Fig. 2 below show photos of the railway vehicle simulator used to conduct the tests. The railway vehicle simulator is located at the headquarters of the Koleje Śląskie Company in Katowice, at Raciborska Street. In the field of transport and public transport, eye-tracking research is constantly carried out, with a strong focus on rail transport. The publications present for example a description of the research carried out on a group of tram drivers depending on age, gender and professional experience. From a scientific point of view, it has been found that employees with more seniority focus more on factors that are important from the point of view of safety rules. [3]

Fig. 1 and Fig. 2 shows the interior of the driver's cabin of a railway vehicle simulator, which is a reflection of the ELF II vehicle from PESA. ELF II vehicles are used to perform transport processes.

Fig 1: Photo of the driver's cabin of the SIMFactor railway vehicle simulator located at the headquarters of Koleje Śląskie

Fig 2: Photo of a fragment of the driver's desk of the SimFactor railway vehicle simulator located at the headquarters of Koleje Śląskie Company, together with a touch screen

2. INVESTIGATION RESULTS

2.1 Research using eye tracking glasses

Eye-tracking is nothing more than tracking the eyesight by checking and marking the path it takes. A research technique and method designed to measure, record and, in the final stage, analyze data on the position and movements of the eyeballs in a given time period. This method has often been characterized as a gateway to a wide spectrum of human cognitive aspects. Eye-tracking plays an important role in creating heat maps, or heat maps, aimed at presenting the points on which the recipient's eyesight is focused the most. The basic application of eye-tracking is the creation of websites, which, through appropriate graphic layout, are able to attract or encourage the customer to use the services or purchase the services offered. In the case of the master's thesis, the scientific side of the problem will be presented, which is based on the reaction of the human body to stimuli occurring during the profession of a train driver. [1]

Eye-tracking research began in the 19th century, and was based on the observation of the human eyeball. The names associated with the research include Louis Emile Javal and Guy Thomas Buswell. The operation of eye-trackers in modern models is based on a method called corneal reflection, which involves detecting and tracking the position and movements of the eyeballs. The high resolution of the camera allows for the detection of the position of the pupils, which are illuminated using infrared. Infrared is reflected from the pupils, which allows for the performance of reflections that allow for the identification of the place observed by the subject. It is worth emphasizing, however, that the points recorded by eye-tracking glasses do not necessarily confirm the places that were noticed by the subjects. These are places that were noticed and saved in the memory of the subject's brain. The best example is filling in documentation, when, while thinking, the eyesight escapes to places that the subject did not think about and did not need to see. In the case of a train driver's work, one may encounter writing out a railway vehicle's on-board book, a written order, or a monthly work time card. These are activities performed automatically or often requiring greater concentration.

Eye movement can be examined using:

- Eyeglasses with eye pads – a method that provides accurate results (Fig. 3);
- Non-contact glasses, which are based on the optical examination of eye movement;
- Eyeglasses based on the use of electrical potential, using electrodes mounted around the eyes.

The data collected during the study provide extensive knowledge on the discussed issue. Appropriate presentation of data allows for efficient and easy reading of the collected results, the most popular and reliable methods of analysis include:

- Heat maps – presentation of places that were most often observed by the examined person using colored spots. Longer focus on one point is marked with an intense warm color, while shorter time of focusing the eyes is marked with cooler colors. Empty places, i.e. those that do not have a marker of any color, indicate that these places were not noticed by the examined person or the eye-tracker skipped them due to the short time of focusing the eyes. There is also a method of displaying a heat map in the darkroom, where only the areas on which the examined person focused their gaze and which were registered by the eye tracker will be illuminated.
- Fixation map – is based on the heat map mechanism, but also shows the path of the eyeball movement using a straight line. This is the stabilization of the retina over a stationary object (this process takes from 100 to 600 milliseconds). The circles mark the subsequent places where the examined person focused their gaze (fixations). The larger the diameter of the circle, the longer the examined person focused their gaze in a given place. The numbering inside the circle indicates the order of looking.
- Film material with the marked point that is observed at a given moment;
- Grid – allows the examined image to be divided into a grid of a specified density;
- Saccade – a sudden transfer of gaze from one focus point to another (duration from 20 to 40 milliseconds);
- Presenting data in the form of an Excel spreadsheet.

Designing and preparing for an eye-tracking study should begin with establishing research assumptions. Hypotheses should be prepared very precisely due to the desire and need to obtain exemplary behavior or exemplary reaction of the person being examined to individual stimuli. Properly formulated hypotheses will allow for an efficient and transparent presentation of the problem being studied and deviations from the assumed reference model. It is worth noting that these are studies conducted using a computer method and allowance should be made for the computational and performance capabilities of the systems. [1-3]

After each training session, the driver who participated in the study (Fig. 4) will receive a report with a description of the course of the study, tips and comments regarding their behavior during the training session. The report will be used in the future to analyze the acquired skills and changes in the driver's behavior. Due to the initial process of conducting the tests, the drivers participating in the study will participate in it voluntarily. Drivers wishing to participate in the training will contact the representative of the Vocational Training Center by e-mail to arrange a training date and to appoint a driver-instructor for the given day of the study. The time allocated for the study will be included in the drivers' time sheet and they will receive remuneration resulting from the hours worked and courtesy in contributing to the development of scientific research. During the study for the master's thesis, eye-tracking glasses were used together with ETG software from the German company SensoMotoricInstruments. The device consists of eye-tracking glasses connected to a workstation, while the workstation is connected directly to a smartphone. The smartphone is equipped with software that is activated when the device is started. In the software menu, the project being performed is named and the data of the person being examined is entered. Then, after putting on the glasses and adjusting them precisely using the nose pads, the device calibration begins. The device panel allows you to select the type of calibration from single-point to three-point. In the case of performing the test, single-point calibration was selected. The next step is to focus the person's eyesight on a distant point, the preview on the smartphone shows the focus of the person's eyesight using a green dot. After the person being examined focuses properly on the observed object, the calibration is confirmed by clicking on the screen. After performing the above-described activities, eye-tracking tests can be started. The duration of the test should be mapped in accordance with the characteristics of performing a given activity and carried out in conditions characteristic of the given activity in order to best present the reaction to the transmitted content and stimuli.

Fig 3: Eye-tracking glasses used during research

Fig 4: Active duty train driver wearing eye-tracking glasses

2.2 Analysis of tests performed using a railway vehicle simulator

Traction vehicle drivers in Poland are required to complete three hours of training on a rail vehicle simulator per year. Depending on the internal regulations in rail companies, the training time may be extended or divided into more shorter training sessions, which will total three hours. Rail vehicle simulators must be mapped 1 to 1 with vehicles operated by Polish rail companies and with vehicles on the infrastructure of the Polish Railway Lines, including internal lines (Fig. 5). Training sessions must be conducted in accordance with scenarios created by the Office of Rail Transport. Simulator training must be carried out under the supervision of a driver-instructor, who influences the course of training using the instructor panel. In the Koleje Śląskie company, the rail vehicle simulator has a mapped driver's cabin of an ELF II series vehicle, along with the railway routes operated by Koleje Śląskie drivers. SIMFactor is responsible for the design of the simulator, the software and the routes operated by the traction vehicle simulator.

Fig 5: A driver in the driver's cabin of a railway vehicle simulator while conducting a test using eye-tracking glasses

The training on a railway vehicle simulator using eye-tracking glasses allowed to present the behaviour of a traction vehicle driver during a training session. In the case of the conducted study, the trainee was a driver with many years of experience in driving traction vehicles in freight and passenger traffic, for many years acting as a driver-instructor in the Koleje Śląskie Company. In order to increase the safety aspect, the training on a railway vehicle simulator was held first, which allowed to dispel any doubts regarding driving vehicles using eye-tracking glasses. During the training, the driver's behaviour was influenced by changing weather conditions, the occurrence of an unusual traffic incident related to the presence of wild forest animals on the track.

The training session on the rail vehicle simulator took place on the Gliwice Technical Inspection Station (PRT) – Katowice route in variable weather conditions and with accompanying unusual situations, which have a direct impact on the safety of the transport process. Below is an example report from the course of the training session as well as the results of tests conducted using eye-tracking glasses. The report, which is automatically generated by the simulator software based on the training conducted, contains information consisting of the following content:

a) Name and surname of the trainee;

b) Name and surname of the instructor conducting the training;

c) Type of training with the name of the scenario;

d) Date of training with the start time;

e) Starting point in the form of coordinates;

f) Type of vehicle;

g) Description of the course of the training session by the driver-instructor, description of the driver's conduct and reactions to individual tasks occurring during the training session. The driver assesses the driver's conduct as correct or incorrect. h) Final commentary containing comments along with determining the training result as positive or negative.

i) Speed graph, pressure graph in the main pipe (fig. 6);

j) Current draw graph;

k) Pressure graph in the brake cylinders;

l) Description of the session along with errors and information about the training course.

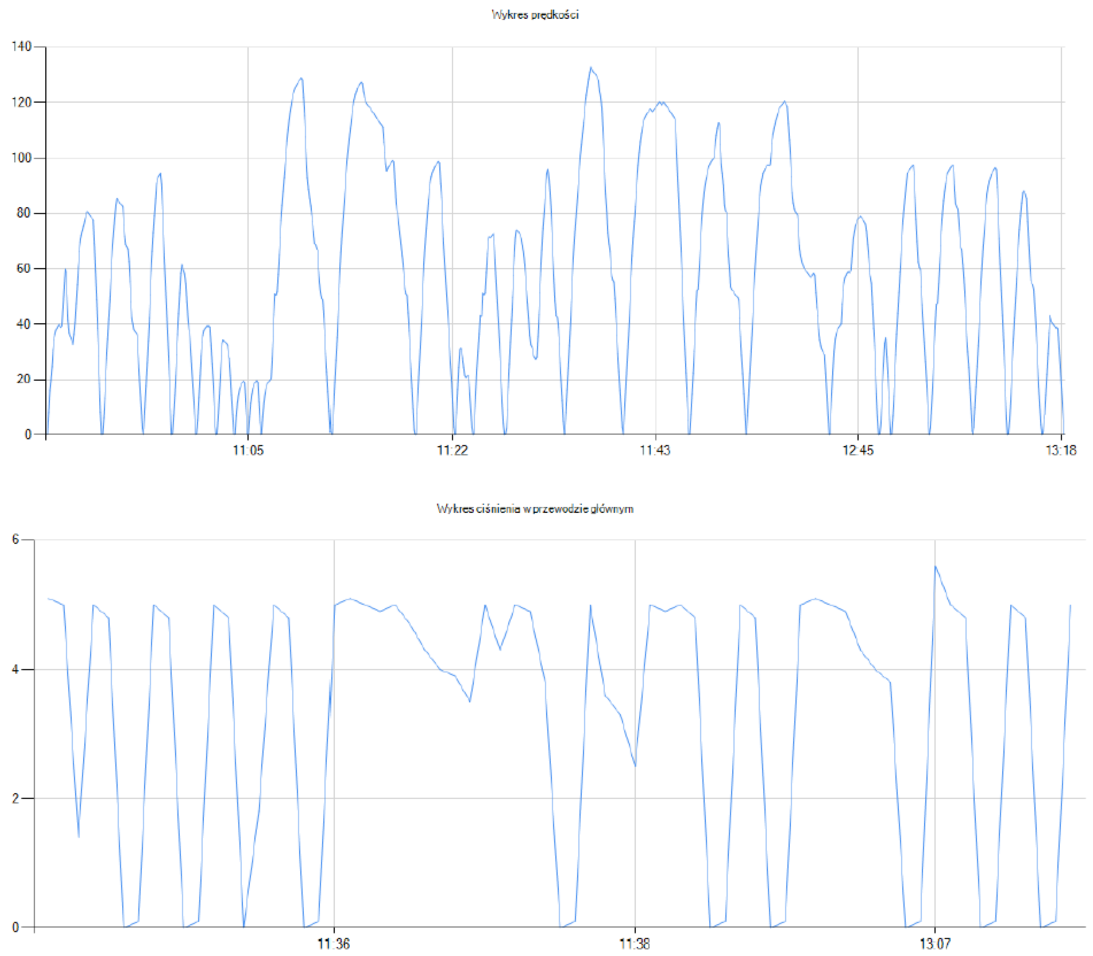

Fig 6: Graph from the report of the training session on the railway vehicle simulator, data included in point i)

Based on the analysis of the data collected from the training session, the following data were extracted, which are presented in Table 1 and Fig 5.

a) Time of observation of the trail and semaphore indications;

b) Time of observation of the driver's desk;

c) Time of observation of factors of an unusual event - forest wild animals;

d) Time of observation of the speedometer;

e) Time allocated for other activities.

Table 1. Time spent by the driver on performing activities related to driving the vehicle

No.	Activity	Time	Notes
I	Observation of the route and semaphore indications	1329	Observation of semaphores, indicators, platform edges, and traction network lines.
II	Observation of the driver's desk	125	Air in brake cylinders, cruise control, warning lights.
III	Observation of factors of an unusual event – wild forest animals	20	Simultaneously with the continuous alert signal and implementation of emergency braking.

IV	Observing the speedometer	116	lack
V	Other activities	27	Radiotelephone including changing radio channels.

2.3 Comparison of tests during a simulator training session and during a driver's active service

Due to the nature of the research, it is worth considering the method of conducting the research and the person being examined. In the case of a driver-instructor, this is a person with many years of experience who performs activities intuitively and according to practiced patterns that significantly facilitate the performance of their profession. In the case of drivers with less experience, there will be visible deviations from the model procedure due to their experience, familiarity, and the process of conducting the research will be an additional stressful factor. It is worth bearing in mind that over time, the research conducted will be precise and irregularities obtained during the previous course of scientific research will be eliminated. Based on the research conducted and the analysis conducted, a summary table was prepared along with graphs describing the difference in the driver's behavior depending on the activity performed. The activities concern the training session on the simulator and the driver's active service. The results of the analysis are presented as follows – Fig. 7:

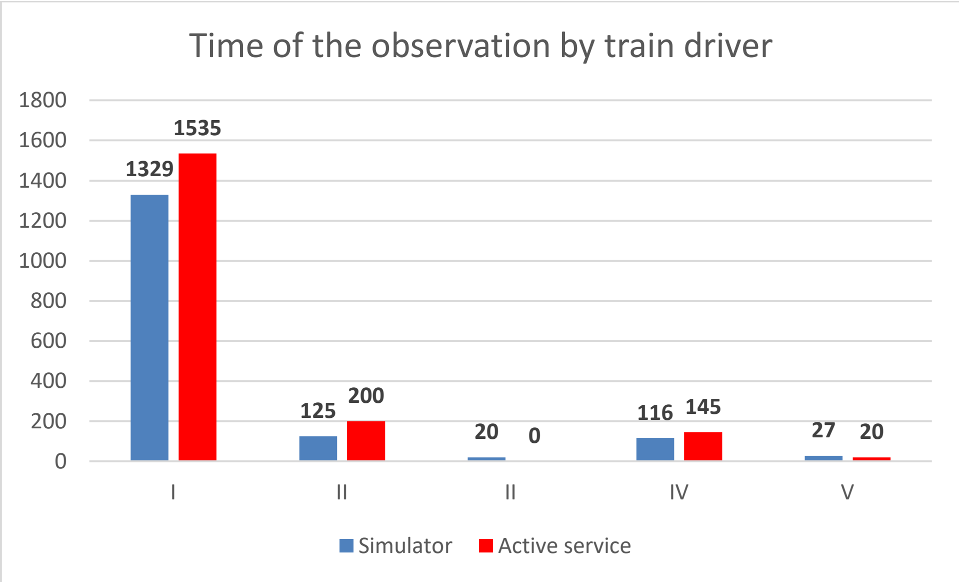

Fig 7: Comparison of the driver's observation time of the surroundings depending on the activity performed.

3. RESULTS AND DISCUSSION

Simulator training is a very good way to check the reaction and behavior of the employee being trained to typical or unusual traffic situations that accompany them during their work as a train driver. In order to improve the training process and increase the effectiveness of training drivers, the driver should solve a test on railway traffic and signaling issues before starting the training session and obtain 100% correct answers in order to obtain a positive assessment. The driver should also solve a test on the construction and operation of railway vehicles, in order to obtain a positive assessment the driver should obtain 75% correct answers. Of course, a negative result would oblige the driver to take the test again and obtain a positive result in order to be admitted to the training session on the railway simulator.

Another proposal to increase the effectiveness of training on a rail vehicle simulator involves providing the trainee with video material of the training session after the training session has been completed. Based on the video materials available, the trainee will be required to analyze the training session and their own behavior in order to draw conclusions and point out irregularities in their behavior. In order to increase awareness and responsibility in positions directly related to the management and safety of rail traffic, the trainee would take on the role of a traffic controller at least once every three years and have a direct influence on the course of the training session on the rail vehicle simulator.

This work presents a scenario of a training session on a railway vehicle simulator using eye-tracking glasses. Proper and regular testing using the glasses will allow for presenting the influence of external stimuli on the driver's behavior and will allow for illustrating the influence of acquired experience on solving typical and atypical traffic situations in rail traffic..

4. CONCLUSIONS

In summary, it can be stated that each training process and checking the level of knowledge of employees has its advantages and disadvantages. It should be remembered that, in particular, it is up to employees performing their duties correctly whether the course of the transport process will be safe and complete. The behavior of a railway vehicle driver during a training session on a railway vehicle simulator and during the driver's active service does not differ significantly from each other. Simulator training is carried out in order to perform a simulation as close as possible to real conditions, which significantly facilitates the reproduction of the driver's cabin in a 1 to 1 ratio with the applicable and available vehicles in a given railway company. The course of the simulation allows for the adaptation of the traffic situation to the conditions encountered on railway lines in reality. Based on the conducted research and analysis, the differences that are encountered during the work of a driver were presented. The active service of a driver requires the railway vehicle driver to be more focused and precise when performing his duties, while simultaneously controlling the correct performance of duties by other employees responsible for rail traffic safety.

Based on the presented work, it can therefore be concluded that it is important to increase people's awareness of the proper performance of their duties, to put priority on compliance with applicable regulations and to use the valuable comments of employees with greater seniority. The work indicates that, contrary to prevailing stereotypes, sources of threats during the transport process are random situations and those consisting of rare factors. These include, for example, the intrusion of wild animals or the presence of an intoxicated person at the platform gauge. It is worth noting that in the case of proper conduct, the driver does not contribute in any way to the occurrence of a railway incident and all his efforts are aimed at preventing or minimizing the occurrence of a dangerous situation.

Based on the preliminary studies conducted, it can be stated that the presented research technique indicates a very large potential for its use to improve safety in Rail Transport and the justification for the development of research focused on detailed analysis of measurement results and their correlation, e.g. with the psychophysical state of the driver or work experience. The author hopes that the topic presented in the paper will contribute, at least to a minimal extent, to the growth of the development of scientific research using eye-tracking glasses.

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