OCULOGRAPHIC RESEARCH ON CHOSEN ASPECTS OF ROAD TRAFFIC SAFETY

Mikołaj Kruszewski, Michał Niezgoda, Ewa Łazowska, Tomasz Kamiński

Motor Transport Institute, Transport Management and Telematics Center
Jagiellońska Street 80, 03-301 Warsaw, Poland
tel.: +48 22 4385405, fax: +48 22 4385401
e-mail: mikolaj.kruszewski@its.waw.pl

Abstract

Driving is an extremely complex behaviour that is also very difficult to measure. Recently, were conducted research which main purpose was quantification of chosen driving parameters to identify dangerous behaviours. For these research modern apparatus for psychophysiology reactions were commonly used, and experiments were made with the use of the driving simulator. Despite such possibilities, most of the researches over road traffic safety are still conducted with the use of self-reported questionnaires or with subjective evaluation of specialists.

During driving process one of the most important aspect is a proper observation of road and its environment. Correct perception is necessary for proper reaction of driver for occurring events. Drivers attention is absorbed not only by the road, other road users and traffic infrastructure, but also by road environment elements like buildings, billboards and advertisements could attract his attention. A key to understand drivers' behaviour seems to be measurement of his visual activity. To measure it, eye tracking instruments could be used, which allows to track drivers eyeball movements during driving. In Motor Transport Institute were recently conducted studies on drivers' visual behaviour and indication of some which could be potentially dangerous. There were also indicated some differences over population in visual search strategies. These studies led to identification of some undesirable behaviours which could led to accidents.

Following paper presents briefly process and results of chosen Motor Transport Institute research with use of a high-class driving simulator and mobile eye-tracker. Also apparatus parameters and used simulation scenarios were described.

Keywords: *eye-tracking, high-class simulator, driver behaviour, road traffic safety*

1. Introduction

Road traffic system is very dynamic and depends strictly on the relationship between its users (drivers, pedestrians etc), vehicles and environment (including road infrastructure). This system consists of unlimited number of variables which could affect traffic safety. Traffic safety seems to be one of major challenges for transportation research. Especially due to World Health Organization (WHO) report over traffic safety which indicates that presently fatal accidents are the 9^{th} major causes of death, and till 2030 will become 5^{th}.

There is still a growing need for interdisciplinary standards, which could be used in drivers' behaviour measurement. Svansson [8] indicates, that cooperation between different approaches is possible. Broad scientific consensus indicates driver (or more generally user) behaviour as a main cause of risk in road traffic. However, still a complex system for diagnosis dangerous behaviours by quantitative measurements has not been developed.

Vision is considered as the most valuable source of information during driving [3]. Driving is a process seek of information that is next selected and processed [1]. Our eyes could move even three times per second, and aspects of vision selectivity and eye movements seems to be most urgent to recognize. Research carried out by Sivak [7] indicates that visual stimuli affects driver behaviour in 83%. Additionally should be mentioned that Fits and Posner [2] claim also that drivers reacts not only on occurring stimulus but also our reactions are consistent with specific individual model.

At the same time, it is easy to observe that there is a significant distinction between risk caused by novice and experienced drivers. Due to newest Polish Police Headquarters annual report on traffic safety [4] novice and young drivers causes more than 20% of all accidents. It seems that this two facts could lead us to thesis, that one of reasons that accidents occur is formation of invalid model of visual attention or not formation of such model at all (in case of novice drivers).

Our pilot research is focused on indication if there are any differences between novice and experienced drivers visual attention models, and on which aspects we should put the emphasis in further research on traffic safety in terms of human behaviour. In psychology it is indicated that human have limited resources for cognitive processes, which we had used in our work to regulation of cognitive loading of the driver by complexity of the task expressed in traffic density on the road.

Due to general theorem of the cognitive science, fixation of vision is strictly related to mental processes. Taking this into account, we have proposed the use of eye tracking device for measurement of visual processes of the driver. The fact that driver's visual attention is attracted not only by road, other users and road infrastructure (signs etc.), but also by all of the other elements of view like roadside advertisements, buildings etc. prompted us to project also scenarios which have such elements. Following this we have developed scenario in which there are some advertisement billboards on the roadside which should attract drivers' attention.

To obtain possibly high repetitiveness of the traffic conditions, our work based on research using high-class car simulator, which have been further described in the following chapters.

2. Participants

Our research was performed as a pilot study in which took part several drivers. Due to occurrence of simulation sickness symptoms we have excluded few of them, so finally in study have been taken measurements of 10 subjects. Five of them were qualified as novice drivers – have had driving license shorter than 3 years and have driven less than 5 000 km. The other five were qualified as experienced drivers who have their driving license for more than 6 years, and have driven more than 50 000 km. Subjects were male and female drivers recruited through the personal contacts. Mean age was 30.4 years (SD=11.65, maximum=51). 40% of the participants were female. All participants were in good health condition.

3. Apparatus

Eye tracking is a technique with more than 100-year history used in various scientific fields including issues which require analysis of the human eye movement. Eye tracking study is performed by recording the human visual activity during specific activities. Firstly oculographs were static devices, mounted to the table and needed to have strictly fixed subject's head for proper use. Recently, technological advances made it possible to perform studies using the device mounted on the subject's head, making a completely non-invasive measurements by non-contact video observation of pupil movement.

In non-contact video a beam of infrared light is sent to the eye and gets back to the device, thanks to the reflection made on the surface of the eye. Afterwards it is detected by the optical sensor. Information is analysed in terms of certain parameters related to its reflection, which allows to determine the movements of the eye. Eye trackers which uses non-contact optical method base on the detection of the centre of the eye pupil and the light reflection from cornea, so called first Purkinje image.

The most popular parameters measured in eye tracking studies are fixations and saccades. Fixation is a case, in which the eye focuses on a specific area. The subject perceives in a precise way only a small part of its field of view (about 1.5 degree). As it was mentioned earlier, there is assumed that measurement of fixation includes also the measurement of prioritizing object in the field of vision and its cognitive processing. So generally it is assumed that fixation on specific object means a transfer of attention to this object.

Rapid displacement of the eye from one fixation point to another is called saccade. This is one of the fastest movements performed by the human body, lasting 30 to 80 ms. We can say that during the saccade a lack of focus on any environment point makes that a human sees only the location of the initial and final points designated by saccade. Eye movement during a saccade rarely takes the shortest way - it can take several different shapes and curves.

There are also other eye movements which could be measured by modern oculograph devices such as glissades, microsaccades or tremors, but for measurements of drivers' attention fixations and saccades seems to be the most important.

In our studies the SMI Eye Tracking Glasses were used (see Fig. 1), which make it possible to gather information about subject's visual activity in normal car driving real-life traffic conditions, as well as in advanced driving simulator during simulation session. In the following table main technical features of SMI ETG were summarized.

Tab. 1. SMI Eye Tracking Glasses parameters

Human interface design	Non-invasive video based glasses-type eye tracker
Glasses	Weight: 75 g, Size: 173 x 58 x 168 mm, Head width (ear-to-ear): 138-180 mm, Estimated age: 7+
Calibration	Instant calibration cursor with 0-point calibration, 1-point calibration and 3-point calibration modes (pre-recording) and offline calibration
Eye tracking principle	Binocular eye tracking with automatic parallax compensation; Pupil/CR, dark pupil tracking
Temporal resolution	30 Hz binocular
Spatial resolution	0.1°
Gaze position accuracy	0.5° over all distances
Tracking distance	40 cm - +∞
Gaze tracking range	80° horizontal, 60° vertical
HD scene camera	Resolution: 1280 x 960 progressive at 24 fps; Video format: H.264; Field of view: 60° horizontal, 46° vertical
Eyewear compatibility	Works with contact lenses
Audio	Integrated microphone
Online communication	Online scene video with gaze position, pupil diameter/position, tracking status, eye image Online interfacing via SDK (Ethernet & WLAN)* Remote wireless access and monitoring
Digital data access	Network connection (Ethernet/UPD)
Norm compliance	CE Declaration of Conformity; EN61010-1:2001; Eye Safety EN60601-1-2 + EN55011, class B; IP Class: 20

Main advantage resulting from the use of mobile oculograph is the possibility to perform studies in real life conditions. In our studies SMI ETG is mainly used in advenced high-class driving simulator AS1200-6 (see Fig. 2) of the Norwegian AutoSim production.

Simulator consists of full sized and fully functional Opel Astra IV cabin, visualization system, and motion platform with six degrees of freedom. Inside the cabin were generated mechanical stimuli (vibrations of the cabin and vibrations of the driver seat) and sound effects additionally. All these raise the reality of simulation and allows to simulate the process of driving a vehicle as realistically as possible.

Fig. 1. SMI Eye Tracking Glasses

Fig. 2. AutoSim AS 1200-6 advanced high-class car simulator

Visualization system based on set of four projectors and cylindrical screen with 200 degrees of vision range, which allows to completely cover the range of sight of the driver. Three LCD screens are used to simulate car mirrors view additionally.

Motion platform is built in a structure called "hexapod" which is based on six actuators, giving the possibility to simulate all 6 degrees of freedom. The platform allows to simulate cabin movements in respect of simulated speeds, linear accelerations and angular accelerations, which measured from driver's seat are:

- for angular movements:
  - displacement ± 22 (21) degree,
  - maximum velocity of displacement ±30 (40) degree/second,
  - maximum acceleration of displacement ± 500 (400) degree/second^2,
- for linear movements:
  - displacement ± 0.25 (0.18) meter,
  - maximum velocity of displacement ± 0.5 (0.3) meter/second,
  - maximum acceleration of displacement ± 0.6 (0.5) G.

Simulator allows to perform experiments in different traffic conditions and with full control of all environment conditions: weather, lighting conditions (day, night, twilight etc.), rain and snow, as well as control of other users of the roads and ongoing events.

4. Procedure and driving scenarios

The whole task consisted of four test scenarios in which occurred different traffic and environmental conditions. In all scenarios the same test track have been used, containing about 6.5 km of motorway with few buildings on both sides of the road. In the scenario we included 6 sections of speed limits, which were determined by signs and varied from 90 to 130 km/h. The whole procedure took approximately one hour for each participant. Participants started with signing consent form to take part in driving simulators study. Later, but before test scenarios drivers were given a short 10-20-minutes adaption scenario in which they could acquaint vehicle and check their sensitivity for simulation sickness symptoms.

In each scenario one aspect of environment or traffic conditions was changed. First of it was linked with the complexity of traffic conditions. In two scenarios traffic was quite small (low-complexity situation), and only 5 other vehicles were swarming throughout the whole route. In the other two scenarios there was 25 vehicles moving through the road.

Second changing condition concerns existence of roadside advertisements. In two scenarios were implemented 8, actually occurring near real world roadsides, billboards located on the roadside in the pre-determined locations. The distance between billboards were about 250 meters. During the drive, the accumulation of roadside advertisements helped to measure the degree of drawing attention to the visual signals. The other two didn't include any roadside advertisements at all. Configuration of conditions in research scenarios were gathered in the table below.

Tab. 2. Conditions in research test scenarios

		Roadside advertisements	
		none	24 billboards
Traffic conditions	Low traffic	Scenario 1	Scenario 3
	High traffic	Scenario 2	Scenario 4

Fig. 3. Left: Screen from the simulation scenario – operator view Right: Selected advertisements used in scenarios

During scenarios participants had SMI ETG eye tracker mounted, which gathered information about their visual activity. At the start of every scenario there a calibration was made, and in the end there was additionally displayed calibration screen for verification.

Between scenarios short breaks were conducted in order to mitigate the effects of potential simulator sickness. At the end drivers received a small gift for participating in the study.

5. Results

During analysis were used mainly data about participants fixations in predefined areas of interests (AOI), as well as overall visual activity parameters. For scenarios containing billboards, AOI`s were manually applied on the context video of the eye tracker and analyzed with the use of dedicated SMI softwere - BeGaze 2.0. For statistical analysis was used

First studied aspect concerns mean time of fixations in low and high traffic density situations (without advertisments). In low-complexity scenario novice drivers (ND) had 240 ms mean time of fixation (MTF) (SD=92ms) while they had 215 ms MTF (SD=70ms) in high density traffic scenario. Experienced drivers (ED) had much lower differences in both scenarios – 298 ms MTF (SD=64ms) for low, and 302 ms MTF (SD=56ms) for high density traffic (see Fig. 4).

Another studied aspect concerns comparison between ND and ED for fixation's localization deviation in the field of view along vertical and horizontal axis. Results were measured in pixels (px) of eye tracker scene camera view. For vertical axis results for ND and ED were very similar oscillating between 98 px to 119 px providing no significant differences. For horizontal axis occurred more significant differences between ND and ED. ND in low traffic scenario had mean fixation`s SD 93px while ED had 123px, and in high traffic scenario fixation`s SD 137px (see Fig. 4).

For both these aspects due to low participants population the statistically significance of differences was not indicated.

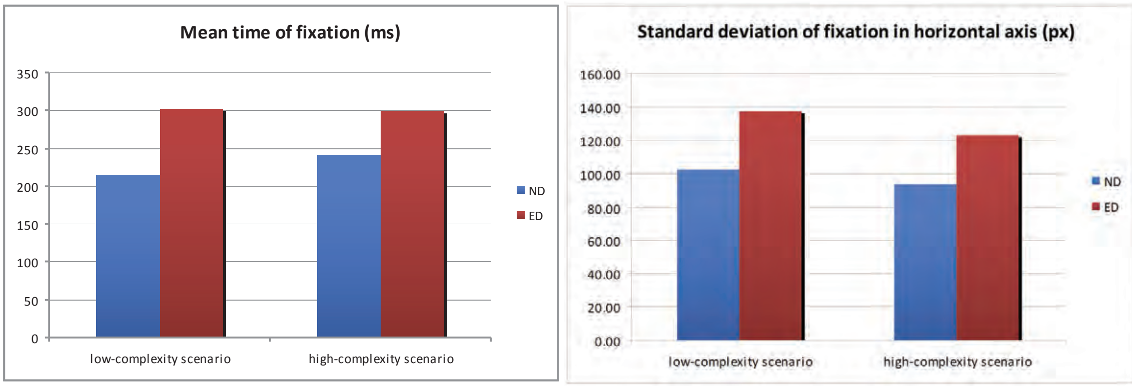


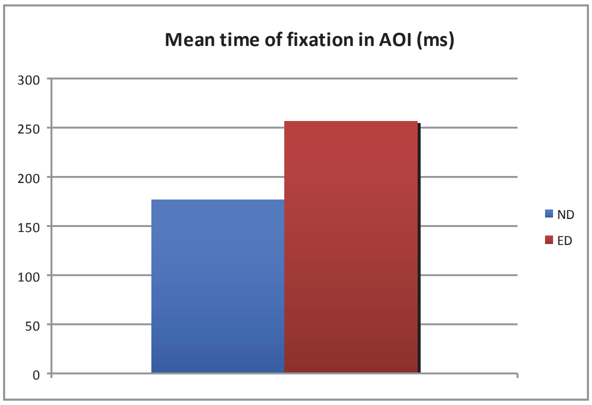
Fig. 4. Comparison of novice and experienced drivers in low and high density traffic scenarios. Left: Comparison of mean time of fixation (MTF). Right: Comparison of standard deviation of fixation (SDF)

Besides the statistical insignificance, measures clearly indicate, that differences in these two aspects of drivers visual attention model are quite significant. ND are definitely more susceptible for changing traffic conditions and while driving task difficulty is higher their visual activity is changing to more frequent and much shorter fixations. ED have established model of the road scene observation and mean their mean time of fixation does not changed while traffic situation becomes more demanding. There could be observed, that their fixation's deviation is much higher in both demanding and undemanding traffic conditions, and distinctly changes due to traffic conditions. It could be explained by their habit to observe not only the road in front of them, but also control situation behind by looking at the mirrors. ND have not formed this habit, so their visual activity concentrate over the road ahead.

Still this thesis have to be confirmed on bigger population.

The other measured aspect was concerned over influence of roadside advertisement on novice and experienced drivers. In this matter results were statistically significant.

In experiment were measured times in which drivers focused their fixation on billboards. First comparison was made over participants' mean time of fixation in the billboard AOI. For ND mean time of fixation was 176ms (SD=47ms) while for ED was 256ms (SD=62ms). Also summarized time of fixations in billboard AOI's in relation to travel time (expressed in % of travel time) was much higher for ED and was 2.79% (SD=0.43) while for ND it was only 0.94% (SD=0.43) (see Fig. 5).



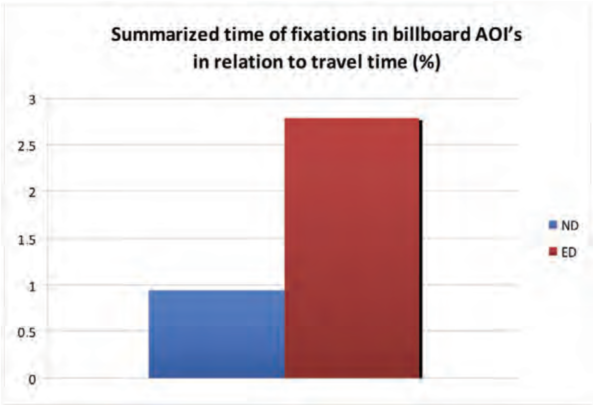


Fig. 5. Comparison of novice and experienced drivers observation of roadside advertisements. Left: Comparison of mean time of fixation in billboard AOI's. Right: Comparison of summarized time of fixations in billboard AOI's in relation to travel time

One could say that it indicates, that ED could have more resources for other activity than process of driving and could spend it on other tasks. On the other hand ED could have better models for observation not only the road ahead, but also the situation all around and due to that more frequently look at advertisements. They also could have better control over the road situation and more freely could move their attention to advertisements. Confirmation of this thesis needs modification of experiment and creation of more AOI's than only on billboards, but additionally on other elements of road, on other users and on control devices and mirrors.

6. Summary

At this stage, there is no basis to reach reliable conclusions about link between different drivers models of visual attention and its influence on traffic safety (none of the participants have caused an accident during driving). Still experiment shows that there are some distinct differences between novice and experienced drivers visual attention strategies. To gain reliable data in these matter it seems necessary to constrain some dangerous situations in the scenario, or to measure some behaviours which could result causing dangerous situations. For such may be used Generic Error Model System (GEMS) and some of the dangerous situations indicated in Driver Behaviour Questionnaire [6] in which drivers behaviour was described in terms of errors that he commits and divided into category of skill, knowledge, rule errors. Operationalization of such behaviours seems to have solid bases for research over road safety in terms of human behaviour, and that will be performed next in our research work.

Besides small success of our work in describing traffic safety, the experiment provided us with some meaningful practical conclusions over preparing experiments with the use of high-class simulator. First of all, experiment shows that its procedure could not be strictly fixed due to occurrence of simulator sickness symptoms (SSS). Some of the participants have had no problems with driving two sessions (two scenarios each). Some had to have a small break every scenario. Unfortunately there is no possibility to exclude people who had significant problems with SSS on the adaptation stage and one could drop out of even on the end of experiment.

The second conclusion concerns analysis of eye tracking data and proper selection of AOI's in eye tracker scene view. Unfortunately for mobile eye trackers there is a need to manually select AOI's for every person separately. In available software are only the simplest algorithms for automation of these process and repeatedly happens that operator need to select areas manually frame by frame. Such need causes that the process is quite large time-consuming and for 5 minutes video operator needs even about 2.5 h (in case in which only 2-3 areas appeared at the same moment in the scenario).

Experiment was very useful for further development of research in the laboratory, providing meaningful practical experience, especially in terms of use of mobile eye tracking device.

Acknowledgement

Authors would like to thank Ms. Ewa Smoczynska for her engagement during development and improvement of simulation scenarios, prof. Adam Tarnowski for his useful comments concerning traffic psychology and Mr. Marek Marczak for his tireless work on the analysis of eye tracking data.

Research has been performed as a pilot study for preparation to perform experiments under EYEVID project funded by the National Centre for Research and Development (grant agreement no PBS1/B6/9/2012).

References

[1] Castro, C., *Visual Demands and Driving*, w Castro C. (red.) *Visual and Cognitive Performance in Driving*, Taylor & Francis Group CRC Press, pp. 1-31, 2009.
[2] Fits, P. M., Posner, M. I., *Human performance*, CA: Brooks/Cole, Belmont 1967.
[3] Ho, C., Spence, C., *Multisensory Driver, Human Factors in Road and Rail Transport*, pp. 1-35, Ashgate 2008.
[4] Komenda Główna Policji, strona internetowa www.policja.pl.
[5] Rasmussen, J., *The Definition of Human Error and a Taxonomy for Technical System Design*. In: New Technology and Human Error. Rasmussen, J., Duncan, K., and Leplat, J. (Eds.) 1987.
[6] Reason, J. *Human error*. Cambridge University Press, 1990.
[7] Sivak, M., *The information that drivers use: Is it indeed 90% visual*? Perception, 25, 1081-1089, 1996.
[8] Svensson, A., *A Method for Analysing the Traffic Process*, Safety Perspective, Bulletin 166, Lund University, Lund, Sweden 1998.
[9] World Health Organization, *Global Status Report on Road Safety – Time for Action*, Geneva, Switzerland 2009.