Pilot Study over Secondary Task Cognitive Workload Induced on Drivers in AS 1200-6 Simulator

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Modern cars are more and more frequently equipped not only with the driver assisting systems, but also with multimedia devices allowing to track the information, use the Internet or send and receive e-mails. This type of activity can cause dangerous situations by inducing various forms of distraction to the driver. In order to identify the effects caused by performing additional tasks while driving, two types of secondary tasks were proposed.
The following article presents the results of a pilot study that uses two additional tasks to induce the driver with cognitive load not related to driving. At the same time, in the course of the experiment, both the driving performance and the quality of performing additional tasks were observed. The article describes selected results of the conducted study.

Keywords: driving simulators, cognitive load, secondary task.

1. INTRODUCTION

In the recent times the equipment of vehicles has undergone significant changes in the area of allowing drivers to use, while driving, multimedia devices providing information on road conditions, routing, or current and future weather conditions, but also allowing to make telephone calls, check e-mails or search for the information via the Internet. It has also become popular to install additional, so-called, nomadic equipment in vehicles, supplementing the vehicle's equipment with the services drivers might need. A driver interacting with these devices while driving is often forced to move his/her attention to operate the device, which may reduce the quality of driving. The driver's distraction is considered one of the most common causes for the occurrence of road traffic accidents [9].

The article describes research experiment designed to determine the effect of performing secondary tasks on the quality of driving vehicles. The article summarizes also the results of a pilot study conducted in order to verify the accuracy of the test procedure and identify possible problems. The experiment was based on the research plan described in [10].

2. RESEARCH EXPERIMENT

The research experiment was conducted to identify the main effects of driving in a state of distraction caused by performing additional tasks. An additional aim of the pilot study was to verify the procedures that are used.

2.1. RESEARCH PROGRAM

Investigations of the effect of cognitive load on the driver were carried out according to the diagram shown in Fig. 1. In the course of the preparation for the study, drivers had to fill in a questionnaire, sign a consent to participate in the study, and a declaration of being familiar with the possible consequences of taking part in research using driving simulators.

Afterwards, participants completed first SSQ (SSQ1) survey and began the adaptive driving session on the driving simulator. For the purposes of adaptation, it was decided to use a scenario in which participants had to drive about 8 km of the route, which initially led through the motorway, then along the suburban road, and on a small section also on the local built-up area roads. In the last part of the adaptive scenario, participants were asked to stay, at the distance of approx. 35 m behind the vehicle. Their actual distance from the vehicle was displayed on the simulator screen.

The adaptive driving was followed by an approx. 15-minute break.

In the next stages of the study participants had to drive two research scenarios with an approx. 15-minute break between them. After driving each scenario, participants filled out other SSQ (SSQ2, SSQ3 and SSQ4) questionnaires.

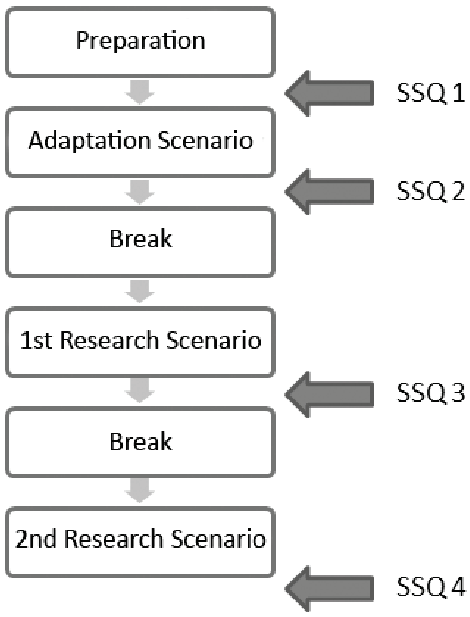


Fig. 1. The research procedure applied.
Source: Motor Transport Institute's materials.

Driving tests adapted according to the 3VPT task were carried out as research scenarios (see chapter 2.3.1), during which one of the secondary tasks was presented: either an "n-back" task (see chapter 2.3.2) or an "arrow" task (see chapter 2.3.3). The secondary task in the first research scenario was randomized. If the "n-back" task was the task in the first research scenario, the "arrow" task was presented in the second research scenario. Similarly, when "arrow" task was conducted during the first scenario, then the "n-back" task was presented during the second driving scenario.

2.1.1. The Method of preventing the impact of the simulator sickness on the tests results

The study used an SSQ (simulator sickness questionnaire) method originally developed by Kennedy et al. [2]. The Polish adaptation of the questionnaire was developed at the Motor Transport Institute by Niezgoda et al. and used successfully, in the EYEVID [3] and GEMS [4] [5] research projects.

The SSQ survey sheet consists of 28 questions in which the person participating in the study evaluates his/hers mental and physical state. The analysis of the survey takes place post factum, i.e. after the end result of SSQ survey is calculated. Based on this, the selection of the results which could have been affected by the simulator sickness, takes place, and they are discarded from further analysis. In the case of clear symptoms of the simulator sickness, the trainee might resign himself/herself from further participation in the studies.

2.1.2. Participants in a pilot study

6 drivers (3 women, 3 men) participated in a pilot study – the employees of the Motor Transport Institute. One person gave up the tests after adaptive driving, due to the worsening of the simulator sickness. The analysis of the results was carried out for 5 people (2 women, 3 men), aged 24 to 33. The participants were active and experienced drivers (having driving licenses from 6 to 15 years), driving vehicles every day or almost every day.

2.2. TEST EQUIPMENT

The planned studies related to the impact of the cognitive load on vehicle driving performance. The cognitive load was induced by the need to perform, while driving, a secondary task – not related to driving. Driving simulators have been successfully used in the studies of this type, e.g. in the study of the impact of conducting secondary tasks on the quality of driving [1]. To conduct the study a high fidelity AS 1200-6 simulator was used, additionally equipped with the device for the presentation of the "arrow" task while driving. No additional measurement devices were used, and all the parameters of driving and driver behaviour were recorded using the simulation program.

2.2.1. AS 1200-6 simulator

The study used high fidelity AutoSim AS 1200-6 simulator. This simulator is equipped with:

- full-size and fully functional cabin of the Opel Astra IV vehicle,
- system of 4 projectors displaying the image of the road on the cylindrical screen covering 200 ° field of horizontal view,
- system of 3 monitors serving as mirrors,

- a movable platform with six degrees of freedom, enabling to simulate the movements of the vehicle cab.

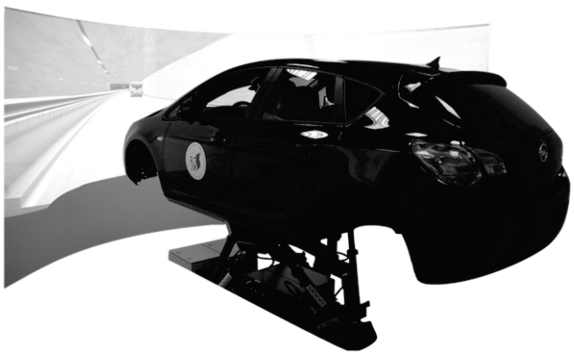


Fig. 2. Passenger car AS1200-6 simulator.
Source: Motor Transport Institute's materials.

The sound effects and vibrations of the car body and driver's seat are also generated in the cabin. Simulator's software allows full control of the weather conditions, the lighting and the behaviour of other traffic participants.

2.2.2. Set to perform the "arrow" task

The visual-manual task called – "arrow" task was carried out using a Kruger & Matz EDGE 1083 tablet installed in the cabin in place of the radio and vehicle air-conditioning controls (centre part of the dashboard), as presented in Figure 3.

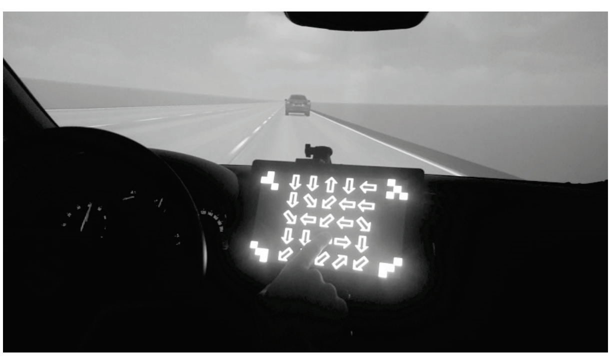


Fig. 3. The "arrow" task carried out during the research scenario.
Source: ITS's own.

The location of the tablet was such so that it was in the peripheral vision zone, beyond the sharp and accurate vision of the driver. This setting in order to properly perform the "arrow" task forced the driver's eyes activity off the road.

2.3. RESEARCH EXPERIMENTS

To conduct the research on the impact of cognitive load on the driving performance, 3 tasks were used. As a primary task – the task of driving a car –an adapted version of the 3VPT task was used. As additional ones two types of tasks were used: the auditory-vocal task – the "n-back" task (in which participants have to repeat the digits they heard, according to a variant of the task), and the visual-manual task – the "arrow" task (searching for the symbol in the field of view and pressing it as soon as possible). In both tasks, first performed were the least complicated of their versions, then the level of difficulty was increased. All of these tasks are described more precisely in the following sections.

2.3.1. The driving task - an adaptation of the 3VPT task

As the primary driving task performed during research scenarios, the adaptation of the task of driving in a three-vehicle column (a three-vehicle platoon task – 3VPT). Originally this task was developed for the OpenDS simulation platform. This task has been developed within the Driver Workload Metrics [6] project and identified as a "controlled" task.

For the purposes of this study, we developed a scenario compatible with the AutoSim simulation platform, modelled in its basic parameters on the 3VPT scenario. The task was to travel in a three-vehicle column as a middle car. The driver had to keep at a constant distance from the preceding vehicle. The preceding vehicle was driving at a constant speed of about 80 km/h and did not perform any manoeuvres. The road used in the script was straight, with a three-lane, one-way section, with the length of approx. 30 km. Each of the lanes had the width of 3.5 m.

2.3.2. The "n-back" task

The "n-back" task used in the study is a delayed digit recall task [7]. The task for participant is to repeat the series of numbers that the speaker told earlier. After each heard digit the participant had to repeat the number "n" before. The task had three levels of difficulty, from 0 to 2, wherein the 0-back task involved recalling the last heard number and 2-back is the repetition of a digit heard as the third from the end. The course of the speaker reading sequence and participant's responses for the sample sequence of numbers are shown in Table 1.

Table 1. An example of the numbers sequence for the different levels of difficulty of the "n-back" task.

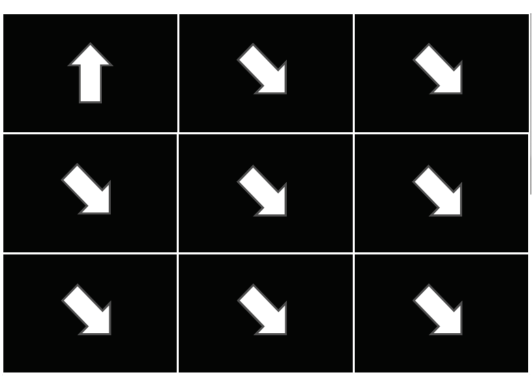
Lector:		3	2	6	7	1
Answer:	0-back	3	2	6	7	1
	1-back	-	3	2	6	7
	2-back	-	-	3	2	6

The "n-back" task began after stabilizing the driving. The consecutive levels of difficulty of the task were separated by 80 sec. pause, and for each level of difficulty the participants had carried out two series of 10 digits.

2.3.3. The "arrow" task

The "arrow" taskused in the study is an adaptation of the tasks developed by Engstrom et al. [8]. The participants in the course of the driving had to perform the task of, as quickly as possible, locating and pressing, on the touch screen tablet, an "upwards" pointing arrow. On each board there was exactly one such arrow. The task had a total of eight levels of difficulty, and it changed over with the size of the matrix on which the symbol was sought (from 3x3 to 6x6), and with the direction of other arrows in the matrix (two configurations: all other arrows pointing in the same direction, each of the remaining arrows pointing in any direction). Later in the article, for simplicity, the following configurations of the "arrow" tasks are called 3x3 consistent, 4x4 consistent, 5x5 consistent, 6x6 consistent for the task with the arrows pointing in the same direction and 3x3 different, 4x4 different, 5x5 different, 6x6 different for tasks in which the arrows are pointing in different directions. Sample boards are shown in Figure 4.

a)



b)

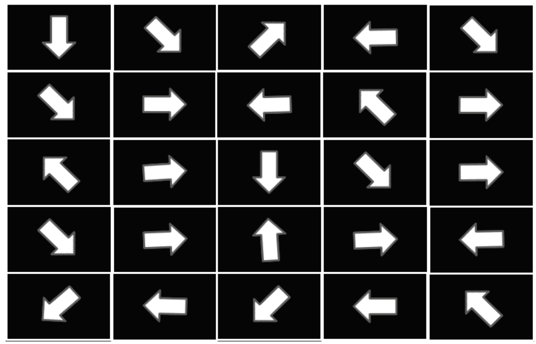


Fig. 4. Examples of boards in the "arrow" task: a) the lowest level of difficulty (3x3 consistent), b) medium level of difficulty (5x5 different). Source: ITS's own.

Each board was displayed for 3.5 sec and then there was a pause, during which the tablet screen remained black. The length of the pause was selected randomly from a range of 1.0 sec to 2.0 sec. Pressing the tablet (regardless of the correctness of the response) caused also the screen to go black, and the time interval was extended by the time of the unused exposure of stimulus.

After stabilizing the driving, participants first performed the task with arrows pointing in the same direction and successively increasing matrices. Then followed approx. 80 sec. pause, and a second series of boards began with arrows pointing at random, also successively increasing matrices. For each configuration, participants were presented with 8 task boards (total of 64 boards).

3. THE PILOT STUDY RESULTS

In a pilot study we analyzed the variability of selected parameters of vehicle's movement, due to the increasing difficulty of tasks. The analyzed parameters were: standard deviation of the position of the vehicle in the traffic lane, and the standard deviation of the vehicle's speed. In addition, the results of additional tasks performed in a form of changing number of mistakes in carrying out the subsequent tasks were presented. Due to the small number of participants tested, the results were presented only to identify possible trends in the behaviour of participants and the statistical significance of the results was not analyzed.

3.1. SELECTED RESULTS OF THE "ARROW" TASK

"Arrow" task was performed to identify the effects of the visual-manual task on the driver. Figures 5, 6, 7 and 8 show successively averaged analysis results of more variables for the entire test of the examined persons.

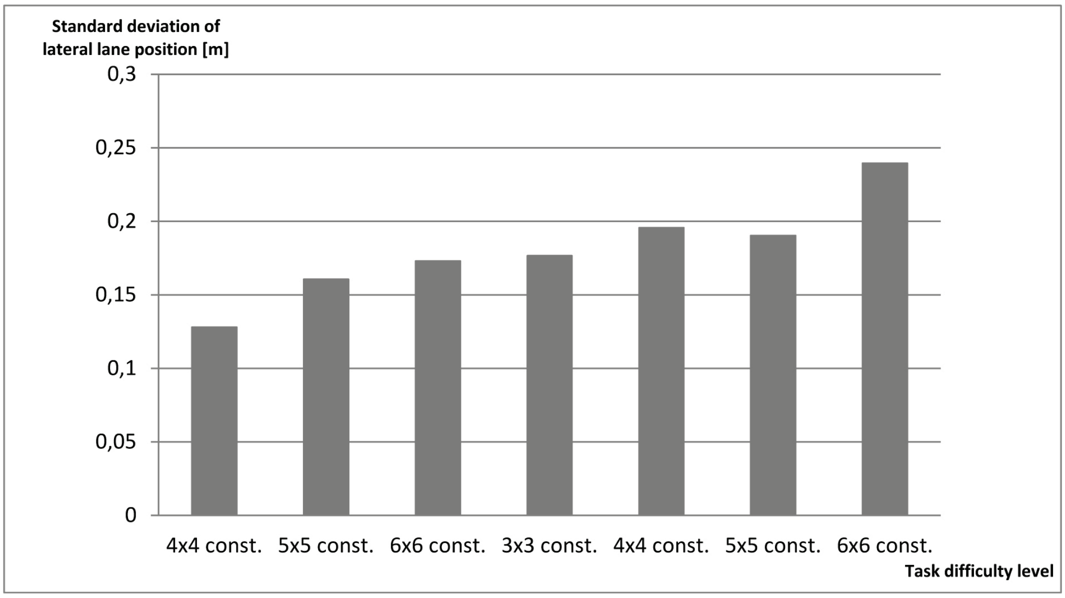


Fig. 5. Standard deviation of lateral lane position during "arrow" task.
Source: ITS own.

The analysis of the standard position deviation in the traffic lane indicates that there may be a relationship between this parameter and the increasing level of difficulty of the additional task. The parameter value increases from 0.128 for the 4x4 consistent task, to 0.239 for the 6x6 different task. The outcome for the 3x3 consistent task amounting to 1.287 was removed from the analysis, which may have resulted from not stabilizing the driving track by the drivers before performing this task. It is therefore necessary to consider the introduction, in the simulation scenario, of the longer driving section, before commencing the task or mechanism for evaluating the driver performance stability.

The preliminary analysis of the standard deviation of the vehicle speed does not clearly indicate the uniform tendency of the parameter change due to the difficulty level of the additional task performed. Certain tendency can only be seen between the results of 5x5 consistent (0.833 km/h) and 6x6 different (2.077 km/h). This parameter requires a more detailed analysis after having conducted the main research. Higher figures of the

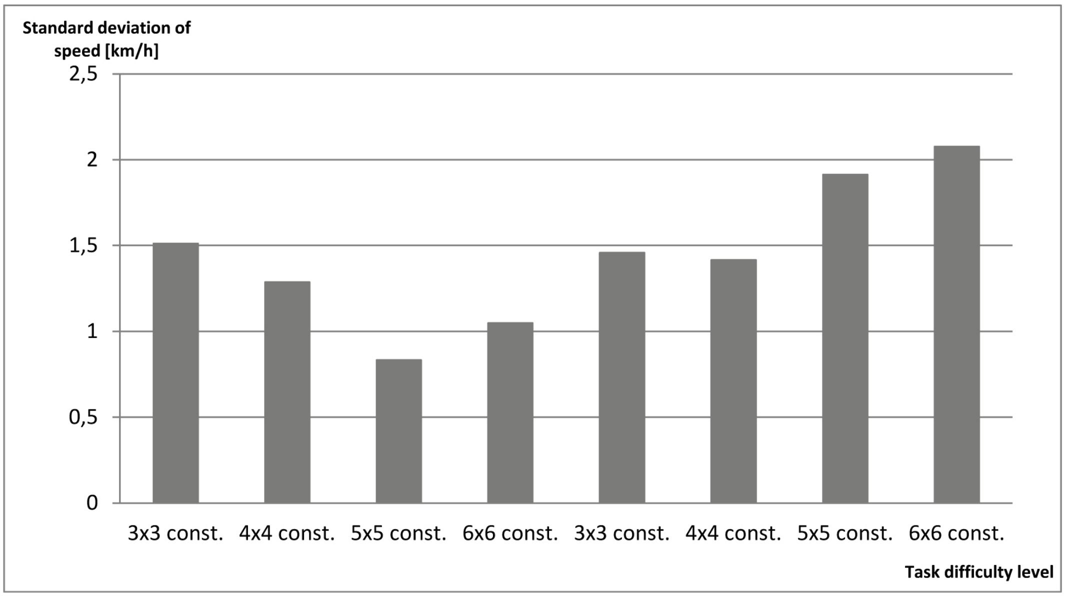


Fig. 6. Standard deviation of vehicle's speed during "arrow" task.
Source: ITS's own.

standard deviation of speed for the 3x3 consistent and 4x4 consistent tasks may result from not stabilizing the driving by the driver before their execution.

For the analysis of the number of errors made by drivers it was assumed that the error is both wrong click of the arrow on the tablet screen, as well as not clicking on any arrow. The analysis of errors made by the drivers during the execution of the “arrow” task indicates that for the tasks of 3x3 consistent to 4x4 different a number of errors remains at a similar level, but it increases significantly for tasks 5x5 different and 6x6 different. Based on these results it can be assumed that the cognitive capabilities limit of the research participants was just between tasks 4x4 different and 5x5 different and after crossing this edge, the quality of performing the additional task dropped. This hypothesis, however, ought to be confirmed in further studies.

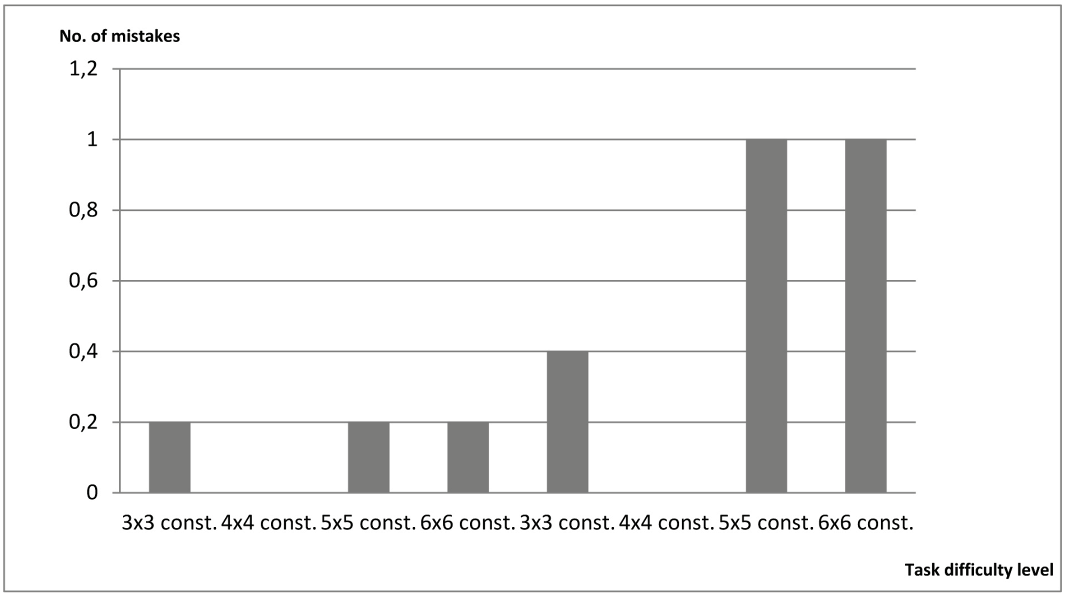


Fig. 7. Number of mistakes in secondary task during “arrow” task.
Source: ITS’s own.

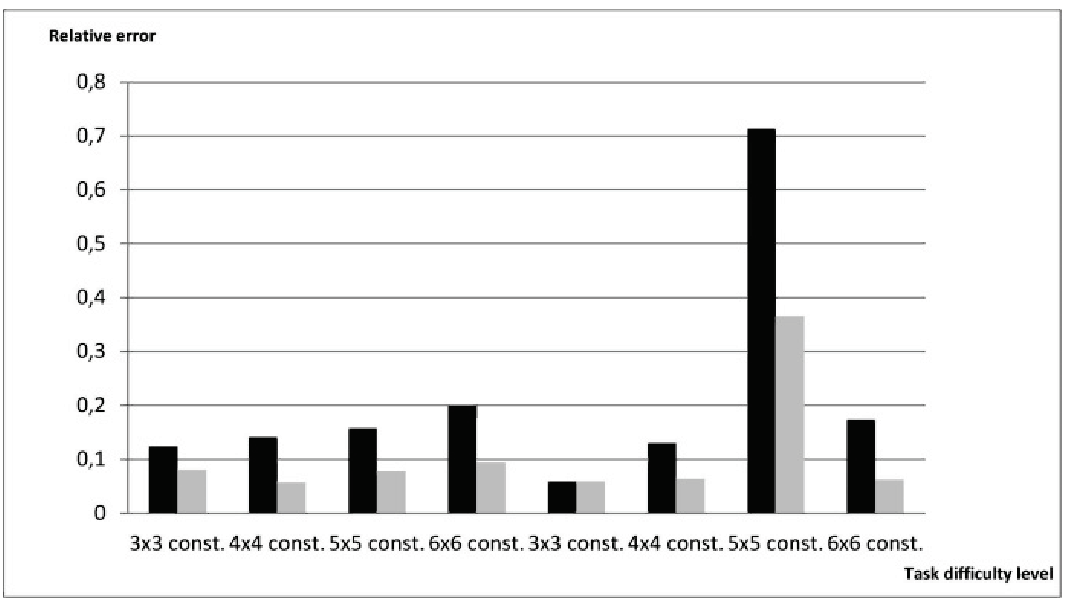


Fig. 8. Relative error of secondary task execution during the “arrow” task (black – novice drivers, light grey – experienced drivers).
Source: ITS’s own.

As a relative error of the additional task performed was assumed relative distance between the centre of the arrow and the place of pressing the arrow by the driver. In a preliminary analysis we took into account only the distance without differentiation of the axis in which there was a shift. The analysis has revealed no trend of changing this parameter due to the level of difficulty of the additional task. The significant increase in the value of the parameter visible at a task 5x5 different should be further analyzed in the proper studies.

3.2. SELECTED RESULTS OF "N-BACK" TASK

The "n-back" task purpose was to identify the impact of performing auditory-verbal task on the driver. Figures 9, 10 and 11 show the results of the analysis of subsequent variables successively averaged over the entire test of participants.

Preliminary analysis of the standard deviation of the position in the traffic lane does not indicate the existence of a clear impact of the level of difficulty of the task on the standard deviation of the vehicle position in the traffic lane. A high value (1.173m) of the parameter for the lowest level of

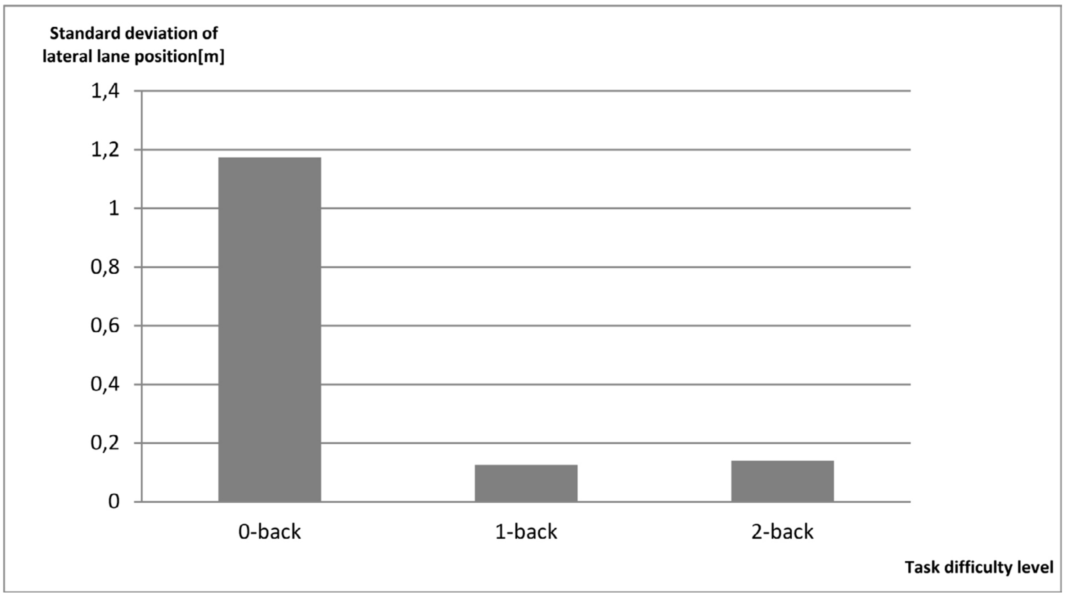


Fig. 9. Standard deviation of lateral lane position during "n-back" task.
Source: ITS's own.

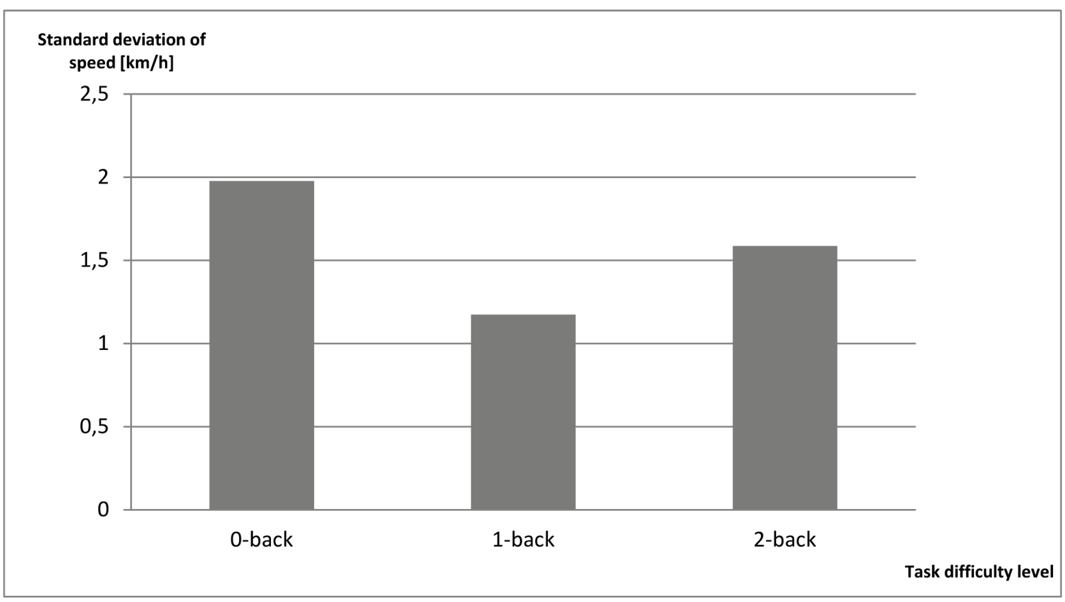


Fig. 10. Standard deviation of speed during "n-back" task.
Source: ITS's own.

difficulty of the task may indicate that the driving track was not stabilized before performing the task commenced. Between tasks 1- back and 2 - back there was a slight increase in the value of the parameter. The impact of the level of difficulty of the “n-back” task on the position of the vehicle in the traffic lane should be reviewed further in the course of proper research.

Analysis of the standard deviation of the vehicle speed does not indicate clearly the existence of a trend of the parameter change due to the difficulty level of the performed additional task. A high value of the parameter for the 0-back task may, however, result from unstabilized driving while performing this task. At the same time the increase of the parameter value between 1-back and 2-back tasks suggests that the parameter may be dependent on the level of difficulty of the additional task, however, this conclusion should be verified by the appropriate study.

4. RESEARCH SUMMARY AND CONCLUSIONS

The studies carried out on 6 people suggest that there may be a correlation between performing additional tasks and the quality of driving. This is indicated by the results of the standard deviation in the traffic lane position and standard speed deviations changing with the difficulty level of the task (except for the difficulty level 1 of the task).

The applied levels of difficulty of both tasks are sufficient to achieve, in the study, a desired exceeding of the cognitive capabilities of the driver. The tasks 5x5-different and 6x6-different, and 2-back have clearly had higher number of observed errors made by drivers than lower levels of the task difficulty. The results indicate achieving the desired effect of quality "deterioration" of performing a secondary task as well as the primary task – the driving. This effect is related to the achievement of the level of difficulty of both tasks, exceeding the cognitive capabilities of the driver. This effect is necessary for the verification of research hypotheses.

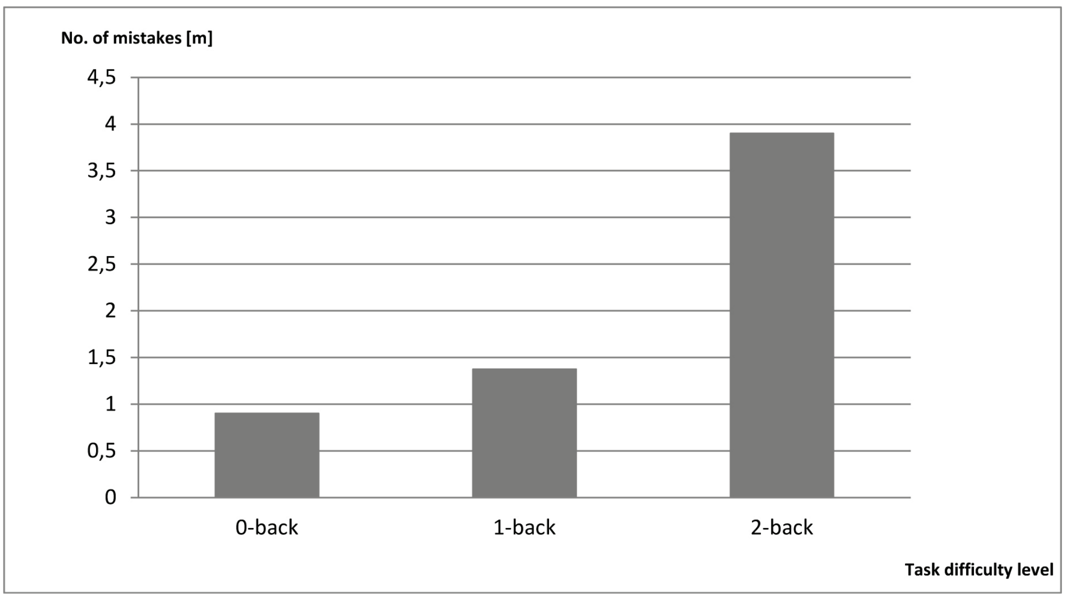


Fig. 11. Number of mistakes in secondary task during “n-back” task.
Source: ITS’s own.

For the analysis of the number of errors made by drivers it was assumed that a mistake is, both, speaking out the wrong number as well as the lack of the driver’s response. The analysis of the errors made by the drivers during the execution of the “n-back” task indicates that the average number of errors made, at subsequent levels of difficulty of the task, increases. There was no sharp increase in the number of errors made that could clearly indicate exceeding the driver’s cognitive capability level, but it cannot be ruled out that such a limit will be observed in the appropriate study.

The pilot studies have shown the need to modify procedures for conducting further driving studies. For both tasks – “n-back” task and “arrow” task - a significant difference was observed in the results of the standard deviation of the position in the traffic lane (for the task 3x3-consistent – 1.287 m and for the task 0-back – 1.173m) compared to the results for the other difficulty levels of both tasks. Such a result suggests two possible causes of this effect: commencement of the task started prior to stabilizing the movement of the vehicle by the driver, or the execution of the first secondary tasks is linked to starting to shift the attention between the task of driving and the additional task, which with the first effortcauses significant disruption in the quality of the driving task. In connection with the first-mentioned cause one can recommend to extend the time from starting to drive to start performing the task while driving, which will increase the chances of stabilizing the driving by the driver. In connection with the second cause, it seems appropriate to begin the additional samples of task that will not be taken into account in the analysis of test results.

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