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SIMPLIFIED CAR SIMULATOR USAGE IN HMI RESEARCH IN CHOSEN ACTIVE SAFETY SYSTEMS CONDITIONS, FOR SEMI-AUTONOMOUS VEHICLES

Car simulators are an extremely important tool, allowing to test drivers in an environment similar to real driving conditions. Such a research provide many useful information for designing either driver aiding systems or systems use by driver. The newest car simulator can apply accelerations to the driver which are near to real ones (up to 0.8g), they have 6 degrees of freedom and move around 10m across the hangar (in which they are kept), but high price and space needed to build such a device complicate access to such a simulator. Aim of presented article is intended to show, that relatively simple car simulator can be used in many different researches with volunteers, and how results of such a research can be used in developing active safety systems

INTRODUCTION

Car simulators are an extremely important tool, allowing to test drivers in an environment similar to real driving conditions. Such a research provide many useful information for designing either driver aiding systems or systems use by driver. Moreover, car simulators simplify optimization process for existing solutions and they are much more safe for driver and driving environment than tests in a real driving conditions. Furthermore, a research environment can be designed particularly for needed test, while in real driving tests variability of it needs to be taken into consideration. Advantages of a simulator research was well known in 60s of XX century, which began development of car simulators in UCLA, GM Styling Staff, Cornell Aero Labs and Volkswagen [1][2][3]. Further development in 70s and 80s, lead to more sophisticated devices, developed (among others) in Road and Traffic Research Institute in Sweden, in VPI in Wierwille, in Institute of Perception (IZF-TNO) in Nederland, FAT in Germany and in FHWA [4][5][6][7]. This lead to simulator in Daimler in Berlin which was described as next generation simulator, and further development in Sweden and research funded by NHTSA in USA (in National Advanced Driving Simulator – NADS) created current simulators [8][9][10][11][12][13][14]. The newest car simulator can apply accelerations to the driver which are near to real ones (up to 0.8g), they have 6 degrees of freedom and move around 10m across the hangar (in which they are kept), but high price and space needed to build such a device complicate access to such a simulator. Below, short review of research, made in different laboratories will be presented. Research had form from questionnaires to simulators with various complexity level. This review allow to verify an opinion about value of such a research. At the end simple simulator from Warsaw University of Technology, which will be used in further research, will be presented.

1. RESEARCHES

1.1. Questionaires

Many simulator research refers to Human Machine Interface (HMI). One of the groups decided to verify level of car automation consciousness among occupatns. Moreover their predictions about future of transport in case of automation were checked – it gives an idea of level of trust which occupant have to, recently widely developing, autonomous driving systems. The studies [22] relied on send 705 questionnaires, gathering an analyzing 118 answered questionnaires. Results were as follows:

55.8% of tested people said that cars are controlled only by human now, 36,9% said, that control lays between human and computer in fraction 75/25, few answers said that control lays with the computer. In case of visions of future (predictions about year 2020) control fraction of human / computer were predicted: 100/0 – 17.9%, 75/25 – 32.4%, 50/50 – 25.8%, 25/75 -19.5%, 0/100 – 4.4%. Furthermore the most people says, that steering will be domain of human (69,8% for 100/0 and 75/25), but minority predicts parking as a maneuver in human hands (37,8% for 100/0 and 75/25). Results for braking: 47,2% predicts that people will have full (100/0), or nearly full (75/25) control of it (although 100% of respondents have car with ABS). 64,1% of respondents said that people should monitor autonomous driving systems to make sure if they are working correctly. Occupants were also asked about reliability of automated systems in their cars. 84,5% said that there was never, or nearly never any failure, 13,4% declared that such a failure sometimes happens and 2,1% said that it often happens. Questions referred to following systems: Rain sensor, autonomous braking while car is stopped, navigation, light sensor (autonomous switching on lights), parking assistant and cruise control.

1.2. Speech dialog system

Human Machine Interface research for improving safety of using driver aided devices, such as a navigation or a phone can be also realized in car simulator – driving environment is similar to real one and cognitive workload is also similar (base on physiological indicators [29][46]). Information between human and device can be transferred by hand (manually, usually by touch or buttons, less popular by muscle tenses via EMG sensors [28]) or by voice. Manual control device may be a source of a diffuse and create necessity of taking driver sight out of a road – as shown in [20][21] it may decrease focus and has negative influence on efficiency of driving. Therefore, voice controlled devices are developing.

In research in Daimler in Germany [18] two type of voice controlled systems were taken into account – first with dialog with a device and second with command-type conversation. The main difference between them is that in command-type conversation, in one communicate, only information that was asked by a system may

be given. Dialog is more flexible, because occupant can provide more than one information in one communicate. For example:

1. Command-type communication:
   "Book a hotel"
   "Where should I book a hotel?"
   "In London"
   "On what date?"
   "…"
2. Dialog communication:
   "Could you book a hotel, please?"
   "Of course, where?"
   "In London, from tomorrow to the next day"
   "…"

Tests were made in which occupants were to book a hotel only using SDS (speech dialog system). One group was to use only command-type communication, other with use dialog communication. Then different settings of graphic interface (GUI) were tested, and their influence on effectiveness of communication.

In testes 25 participants took a part in 2 sessions within 3-5 days. In the first group participants tested both types in option with and without GUI. In second one only dialog communication was tested with GUI and GUI with human avatar. Each participant watched a movie with explanation of SDS and had his / her own instruction when and where to book a hotel ("Imagine, you and one of your colleagues are currently on the way to Cologne for a two-day meeting. You need two single rooms for these two nights which you have not booked, yet. Your appointment takes place in the city center of Cologne, where you would like to spend the two nights. Please look for a matching hotel for those nights."[18]).

During experiments following questionnaires were used:
- Preliminary interview, when basic demographic information was collected (such as sex, age, etc.)
- SASSI – questionnaire testing subjective usability evaluation of tested system [19]
- DALI – cognitive workload questionnaire [47]
- The final interview, where participants marked SDS in scale 1-10

Results of this research were as follows:

1. 78% of all cases was possible to solve using commands and 71% using dialog
2. Average time of completing task with command-type communication was 93,1s (85,2 with GUI, 100,9 without GUI), and with dialog communication 94,3s (89,9 with GUI and 98,7s without GUI)
3. Command-type option took average 30,1 tours and dialog option 27,3. There was no significant difference between options with GUI and without
4. Significantly more misunderstands appeared in dialog version (9,6% vs 4,0%). It was caused by non-grammar expressions in common language used by participants
5. In opinion of participants the least diffusive was command-type option without GUI, but there was no significant difference between this, and rest of the tested settings
6. There was significant difference in time of glance on the device between option with and without GUI (with GUI was longer), but there was no difference in this time between modes

There was no significant difference in effectiveness of dialog mode with GUI with and without human avatar

1.3. Traffic signs

During communicating with driver by signs, drivers interpretation of them should be taken into account. Although traffic signs are used commonly and are extremely important, it occurred that part of them is misinterpreted by drivers from all around the world [23][24][25][27]. It was proved, that despite long text signs are interpreted slower than symbol signs, short, one-word signs are interpreted faster (especially, when a sign is not well known to a driver). Research was made [26] on group of 48 students having driving license for more than 2 years and that were fluent in language of research. Tests were made on the same 30 sings that were used for previous researches about sign misinterpretation.

Although simulator used in this tests was much simpler than simulators in previously shown researches, results had a measurable benefit. Signs were displayed on 19" screen, they had diameter of approximately 10cm. Font size for text signs was 32.

First, participants became acquainted with signs, and they marked how familiar they are with each sign in scale 0-10. Then signs were displayed on a screen, and participant task was to recognize them and describe. In marking description used scale [-2,0,1,2], where:

2 - proper answer

1 – answer incomplete (for example for sign with railway at an acute angle to the road, description "railway at a road")

0 – wrong answer

-2 – answer of the opposite meaning (for example description "end of the 30km/h limit" for "beginning of the 30km/h limit")

Results:
- 53,1% properly described symbol signs
- 90,8% properly described text signs
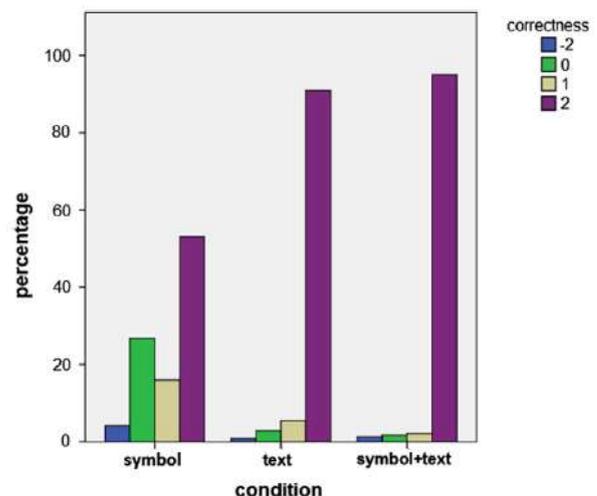- 95,2% properly described signs with symbol and text

Fig. 1. Compared results of correctness of traffic signs describtion [26]

Moreover mean reaction time (time which took participants to confirm the sign recognition) for text signs was much slower than for symbol signs (2,49s vs. 5,75s). For signs combined by both types this time was 2,78s. Based on results, the most effective method of transferring information is one with symbol and text. It is the most important, when sign is not often met by a driver.

1.4. Cognitive workload in a real car

Car simulator may be used for detailed driver testing and checking influence of a cognitive workload on a physiological parameters of tested participants. In some of simulator researches information about steering wheel angle, pedals positions, engine revolutions or switched gear is saved with such data as driver reactions, pulse, galvanic voltage of skin or pupil changes. Physiological parameters may be useful for a design and optimization of interfac-

es [44], therefore it was started to use them in aircraft pilot tests [45] as well as drivers [29][46].

Following researches were made on car drivers in cars [29] as well as in a simulator [46]. Firstly results of experiments in real car will be presented [29]

It is known, that increasing driver's cognitive workload causes:
1. Increased reaction time [30][31]
2. Decreased ability of danger detecting [32][33]
3. Lateral control disorders [32][34]
4. Physiological arousal [35][36]
5. Many visible behavior changes [37][38][39][40]

In the future systems will probably monitor driver state to estimate workload level [41][42] and to adapt automation level to the workload. In that way control over the vehicle may be continuous and reliable [43].

Research [29] was made in group of 20 men and 16 women in age between 60 and 75 years old. Participants of this experiments were driving on a highway and had two tasks:
1. Imagining a time on analog watch and estimating if angle between hands is acute or other,
2. Listening to a 30 seconds blocks of 10 random numbers, with time gap between them of 2.25s, and repeating penultimate number

After a test participants were asked to estimate difficulty level in scale 1-10. Level was marked as average (respectively) 4,25 and 3,61.

There was 86,57% of proper answers to the first task and 91,44% for the second one. Neither of measurements have shown statistically significant difference in efficiency of driving (speed, micro-accelerations and steering wheel movement were measured). Significant differences were noticed in:
1. Gaze during completing tasks, compared to driving without additional task. There was no significant difference in gaze between tasks
2. Heart rate – similar, there were differences between driving and driving with task, but there was no significant difference in heart rate between tasks

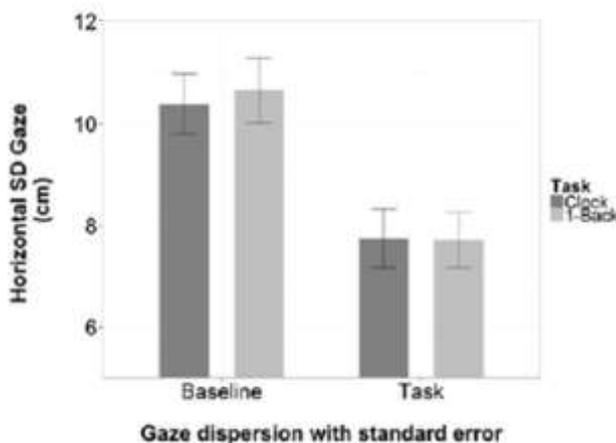Combined results were presented in figures (figure 2 and figure 3)

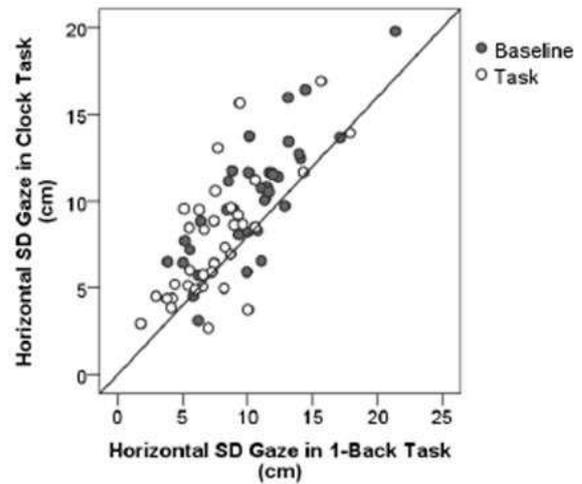**Fig. 2.** *Horizontal gaze during single task driving and during Clock and 1-back segments [29]*

Fig. 3. *Correlation of SD gaze during the Clock and 1-back segments of the drive [29]*

1.5.   Cognitive workload in a simulator

Other research [46] had similar form to previously described, but participants age was between 25-35 (M-27,9, SD=3,13) in the first group and between 60-69 (M=63,2, SD=1,74) in the other group. 30 men took part in this experiment with an equal number in each age group. Tests were made in simulator with following experiment structure:

First there was 10 minutes of initial driving to allow participant to get use to the simulator environment. Then there was a break, when participant was acquainted with rules of task, and could practice it till level of completing task was higher than minimum required for further experiments. Task was to listen to a 30s lasting record with 10 random numbers and repeat first, second or third number from the end. After this break a simulation was resumed. Minutes 5 and 7 were used as a base point for measurements (heart rate, skin conductivity). At 7:30 there was 18 seconds recording with reminding rules of a task, after which random difficulty level was chosen.
Each next task was preceded by 2 minutes of break. 30 seconds after the last task there was a 2 minutes for relax. The results are clearest in form of figures (figure 4, 5, 6 and 7):
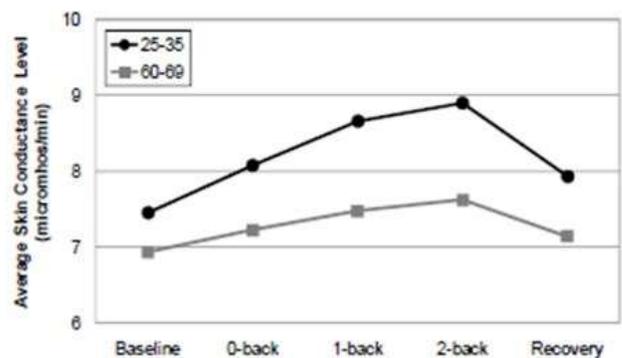
Fig. 4. *Mean physiological arousal as a function of task level: heart rate [46]*
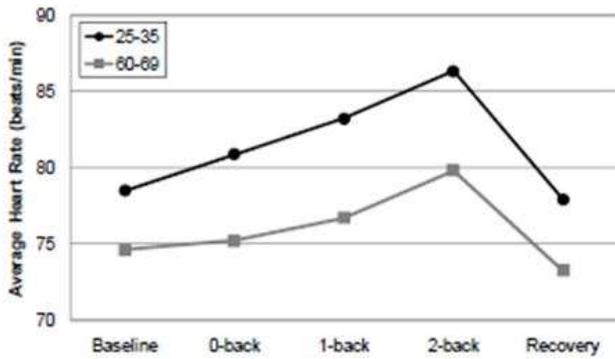
Fig. 5. Mean physiological arousal as a function of task level: Skin conductance level [46]
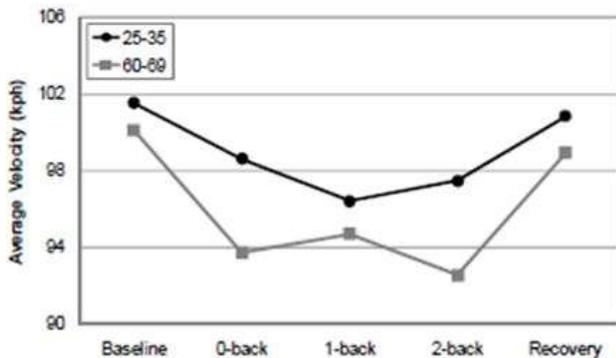

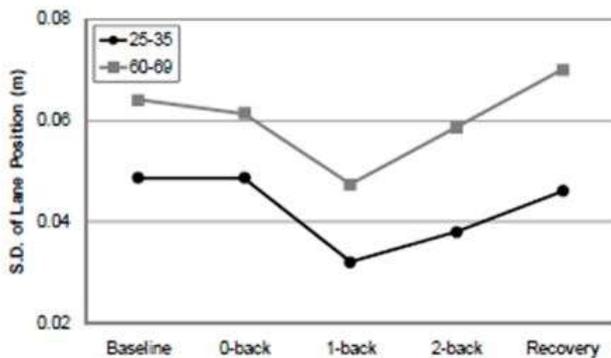*Fig. 6.* Driving performance measures as a function of task level: Average velocity [46]

Figure 7. Driving performance measures as a function of task level: Standard Deviation (SD) of lane position [46]

As shown, a research made either in simulators or during analyzing situations comparable to driving in some conditions (for example research of signs recognition) are opening wide research possibilities. From this tests also follows, that it is important to measure not only physiological reactions, but also subjective senses of participants using questionnaires, which provides researchers a participants view on developing systems. It allows to optimize systems in the most effective and safe way.

At the Warsaw University of Technology, during aDrive[1] project, simplified simulator, connected with active safety systems testing software was built.

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[1] project aDrive - PBS3/B6/28/2015 project within Applied Research Program of The National Centre for Research and Development

2. SIMPLIFIED SIMULATOR

2.1. Testing stationary description

The testing stationary is assembled of:
1. The main PC with Processor: 3.60GHz (8 CPUs), memory: 16384MB RAM, Video Card with memory 4GB.
2. Three monitors connected to the PC,
3. Steering Wheel and pedals

Pic.1. The testin station

2.2. Testing scenario description

Test scenario has been build based on the Darpa Urban Challenge competition. Part of the urban area has been reconstructed in PreScan software environment. This area has many obstacle objects as buildings, trees and infrastructure. During experiment driver can ride on the road network with crossings and roundabouts. Area B from DARPA Urban Challenge. Reconstructed area marked by red square and reconstructed area of the DARPA Urban Challenge in PreScan. Scenario has set frequencies for generating visualization to 20Hz, for the controller to 200 Hz, sensor 5 Hz and Simulation Core to 20Hz


Pic. 2. Photo of DARPA Urban Challenge Competition area (left) and the same area made in PreScan software (right)

2.3. Vehicle model

Vehicle to simulate has been selected from PreScan library – Audi A8. The car has been equipped in 3D simple dynamics and steering wheel controller. Visualization of wheel movements and rotation also has been turned on, to check off-road condition and 3D movement. Car has 2 Lane Marker sensors above front wheels and one AIR sensor in the middle. World visualization provided to the human driver is based on 3 Human Views rotated by -70, 0 and 70 degrees.

To give a driver feedback about off - road condition steering wheel has haptic signal. This signal is related to number of wheels off the road and velocity of the car.
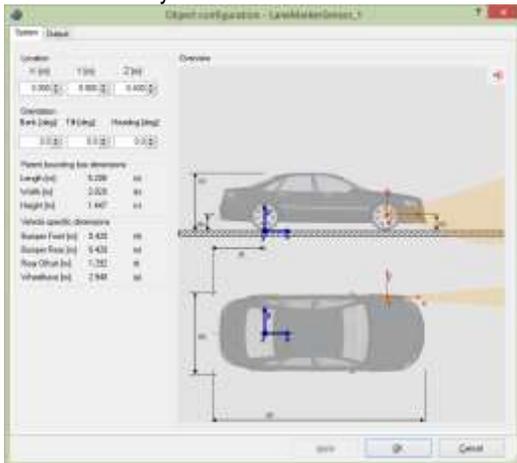
Pic. 3. Lane Marker Sensor placement
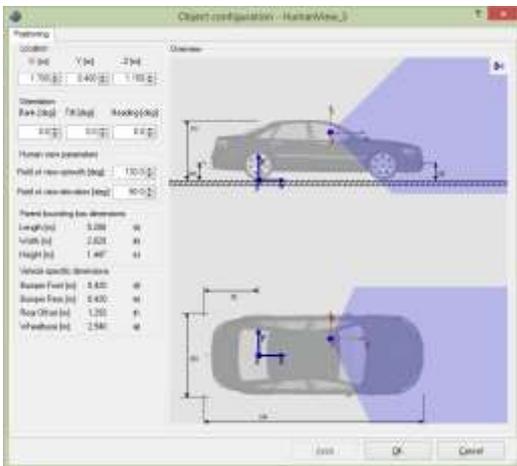
Pic. 4. Human view placement

2.4. Performance test of the station

Number of tests has been performed. The scenario can be run in the real time condition. The velocity feedback has been shown on the Simulink display, and located to the right from the steering wheel on the dash board.

During tests the maximum area of the scenario has been determined as a 2000 [m] x 2000 [m] square. Also the Frequency of the Core and visualization has been set to 20Hz. The scenario cannot have too much objects like buildings and trees. Also if scenario has a human actors, the size limitation needs to be more restricted.

Pic. 5. City crossroad in PreScan software

2.5. User tests of the station

A lot of different tests can be performed in such a setup. The simplest ones has been performed with 8 persons. During each test the driver should observe the scenario, and try to drive the road network. As the experience of driving in simulator is different than driving real car, every person had time to get used to the simulator. At the end of each test the driver share his experiences with the simulation, but there have been no questionnaires yet . The performance was good for every person, force feedback from the steering wheel was sufficient, real time has been achieved and there was no delays between decision of making a manoeuvre and performing it by a simulated car. The overall view on the sense of speed while driving was not realistic (lowered). Possible reason of this may be lack of sound of engine, wheels, airflow noise and other components of sound inside a car – total silence was something, that driver was not used to. This issue will be improved in next generations of the simulator (already in progress). Also the mirrors will be added, to allow occupant to observe road condition and make driving more realistic.

Pic. 6. Driver during a test

2.6. Development plans

As the station is in early development phase there is a plenty of upgrades to do. There will be three mirrors added – left, right and rear. Also sound of the engine will be implemented. Driver needs a car shaped seat to feel more like in the real vehicle. Rotation of the screens also need to be updated.

SUMMARY

The testing station that has been created can be run in real time with complicated scenario, what was the main issue of the first development phase. Also The limitations of the scenario has been known. There is a need to continue work especially with driver feedback.

The first phase of the station development has been finished with successfully build of the configuration and real time scenario.

ACKNOWLEDGEMENTS

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