Usefulness and acceptance of assessments of drivers with disabilities in simulation test rigs

Juan F. Dols¹, Björn Peters², Birgitta Thorslund³

¹ Institute of Design and Manufacturing, University Polytechnic of Valencia UPV, Camino de Vera, s/n. 46022 Valencia, Spain, Email (jdols@mcm.upv.es)
² Swedish National Road and Transport Research Institute (VTI), SE-581 95 Linköping, Sweden

1. AIM

The legal reference in the field of driving license in the EU is currently the 2006/126/EC Directive, which stipulates that driving licenses shall be granted only to those who meet medical requirements and pass a driving test. This Directive has recently been updated with the Directive EU 2015/653. Actually, there is a lack of knowledge in the application of validated procedures for assessing (potential) drivers of adapted vehicles. The objective of this paper it is to present experimental results of driving assessment procedures developed for assessing drivers with impairments –both motor and sensory-. This assessment is based on performing a series of practical tests in a static test rig and a low-cost driving simulator.

2. METHOD

A testing procedure was developed for the SERCO Simulator, designed and developed by the Institute for Design and Manufacturing (IDF) of the University Polytechnic of Valencia-UPV (Spain). A similar prototype, DTSS (Driver Test Station Simulator) has been developed by the Swedish adaption company Autoadapt and the Swedish National Road and Transport Research Institute (VTI). Both experimental tools are designed to be modular, portable and adaptive for assessing driver candidates with or without leaving their wheelchair during the driving process. Usability and acceptance tests of the developed procedure were carried out in Spain and in Sweden with groups of users, with different disabilities. The Spanish experiment included severely disabled users who need joystick-type controls for driving. The Swedish DTSS have been used in assessing drivers with Attention Deficit Hyperactivity Disorder (ADHD).

The assessment of a driver with physical disability requires the performance of two types of procedures: firstly, a fitness to drive assessment in a stationary vehicle or a low-cost simulator, and secondly, a driving ability assessment developed in an open track with a special adapted vehicle. Given the nature and type of assessment that must be done to evaluate the fitness to drive inside the stationary vehicle - or low-cost simulator-, to determine the residual capacities of a driver with severe disabilities, and taking into account that the driver must be fitted with Joystick devices suitable for his handicap, it was decided to use a low-cost simulation tool to replace the initial evaluation procedure held in a stationary real vehicle. By using this tool, it is possible to select the best technical aids and the measurement of any driver skills, safer and cost-saving for the driver as not to have to purchase a real vehicle.

2.1 Description of the SERCO experimemt

The experimental tool consists of modular, portable and adaptive equipment that allows assessment, both physical and sensory, training and rehabilitation of all types of drivers. Its is based on an interactive fixed-base low-cost driving simulator (Figure 1). A simulation computer provides the graphics performance required for the implementation of the simulation software; data collection in real time; wireless router; three-screen-display monitors 1.80x0.34 m with 120º of the field of view;: The equipment allows for collection of many variables, such as speed, location, azimuth or lateral speed, with a frequency of 10 Hz. In addition, the simulator has been instrumented by load cells to measure forces at brake pedal; potentiometers for measuring displacement in the three pedals; micro-switch for detected the gear-box lever position; encoder for measuring the steering wheel angle; and torque sensor for measuring forces on the steering wheel. Usually, the simulator is used for assessing drivers who drive with different standard technical aids, but for this experiment it has been updated by installing electronic technical aids -Joystick-type-, to apply the assessment procedure for users with severe disabilities.
The objective of the experiment was to verify if there is a significant difference between the evaluation performed by drivers with severe disability and drivers without, when using joystick-type technical aids. For this purpose, a control group (of drivers without disability) and an experimental group (of people with severe disabilities) were selected, who underwent an evaluation protocol with different types of driving exercises, selected from the full battery of tests available in the assessment software. The control group consisted of 16 subjects (15 men and 1 woman), aged between 21 and 54 years (mean of 24.5 years). Of these, 3 had no driving license, and the rest (13) had type B license. The experimental group consisted of 10 subjects (7 men and 3 women) with severe disabilities (1 with spina bifida, 5 with right side paralysis of the body due to a stroke, and 4 with leg disability due to muscular dystrophy moving on wheelchairs), aged between 19 and 70 years (mean age 40.7 years). Of these, 8 had a driving license. None of the drivers with disability had experience in driving vehicles equipped with joystick controls.

The software used for the simulation and driver’s assessment was the SoftSimCo V3.0 [22], licensed by the Polytechnic University of Valencia. The control and simulation software was designed to be used by a supervisor or evaluator, controlling the evaluation session remotely. Once the user had accessed the driver's cab and was ready to perform the assessment, the supervisor could perform various tests to assess their residual driving abilities. The tests were organized in sessions, so that several tests could be repeated periodically for the purpose of follow-up. The control software had a database for storing information about users, sessions and tests performed. The simulation software managed the virtual environment and its entities, processed the actions and forces that the user performed on the controls (steering wheel, pedals, levers, joysticks, etc.), executed the dynamics of vehicles, managed audio-visual resources and attended the actions of the control software.

In the experiments two telescopic arms with six degrees of freedom were mounted on both sides of the driver's seat, which allowed the installation of all types of Joystick devices, and a spatial regulation of their assembly. In the experiment, 4-way joysticks were used, capable of reproducing the steering movements (left-right), acceleration (forward) and braking (rearward) of the vehicle with the same control. The joysticks had a lever type grip, and corresponded to the HFX model of the company CH Products. As a signal adaptation, an APEM universal USB joystick interface, designed for use with any joystick with analog and/or digital outputs, was used. The interface incorporated a Joy-Warrior chip with 3 analog control inputs, 10-bit resolution, and up to 16 digital inputs for push-buttons.

In this paper, the results of the post-test satisfaction questionnaires of the control and experimental groups that participated in the experiment are shown: simulation sickness, mental work-load and virtual realism. All the satisfaction questionnaires obtained in the evaluation tests have been analyzed to know the degree of goodness that the simulator presents for both groups, and the knowledge of the significance in the perception that each of them have in the use of this type of experimental tools.

2.2 Description of the DTSS experiment

The aim of the study in the Driver Test Station and Simulator (DTSS) at VTI in Sweden was to examine differences in driving behavior between drivers with ADHD and a control group without
ADHD. 40 drivers diagnosed with ADHD and 20 drivers without ADHD participated. Before the test drive, participants filled in an informed consent and a questionnaire including demographics, diagnoses, medicines, and driving habits. After the drive, participants filled in a questionnaire on experiences from the test and the simulator both regarding comfort and driving performance.

Autoadapt’s DTS (Driver Test Station) is developed to test a driver’s strength, flexibility, behavior and reaction time in a safe and calm environment. The DTS is a measuring tool for conducting qualified tests of a person’s physical driving ability. It is used for testing basic functions such as steering, acceleration and braking in order to ensure that the driver is able to drive a vehicle safely. DTS has a height and resistance-adjustable steering wheel, and wheel and floor-mounted accelerator and brake controls. It has right and left accelerator pedals, and one brake pedal. There are retractable wheels for moving the DTS indoors.

The DTSS is a fixed based simulator based on DTS and integrated with VTI’s driving simulation software. In this study, the simulator used a visual system consisting of five 27 inch 144 Hz HD monitors, with a horizontal field of view of more than 180 degrees. Mirror views were integrated on the screens. Engine and road sound was presented using a 2.1 sound system. The simulator is powered by a simulation kernel computer which executes the scenario, collects experiment data, at up to 200 Hz, and presents the sound, while each monitor is connected to its own image generator. It is equipped with a steering wheel torque motor capable of generating realistic forces, brake and accelerator pedals, and a generic adjustable seat. See Figure 2 for DTS and DTSS.

The route included urban road, rural road and motorway. No secondary tasks were included and the data collected was driving speed, attention/ reaction time to other road users and a questionnaire. Scenarios are designed to assess risk taking, distraction, impulsivity, inattention, cognitive flexibility, and overconfidence. They include for example interacting with pedestrians when passing a bus at a bus stop, pedestrian crossings or at a school. Other road users also appear with whom interactions are needed, cyclist, cars behaving irrational.

Figure 2: DTSS is a DTS integrated with VTIs simulator software

3. RESULTS

3.1 Results from the SERCO experiment

The results obtained in the experiment to verify the usability and validity of the low-cost simulator SERCO have been based on the data acquisition carried out during the simulation process, and through questionnaires that have been fulfilled by the two groups of participants - control and experimental - to verify the simulator sickness tendency, mental work-load of the users and virtual realism goodness of the tool. The questionnaire to measure the simulation sickness of the subjects has been carried out considering the feeling perceived by them, both during and after the simulation session. Levels of response satisfaction have been weighted using a 7-level Likert scale, where the value “1” corresponds to the lowest level of appreciation and the value “7” to the highest level. All response levels shown in these graphs represent the mean values of the responses of each subject, for each group and for each question.

3.2 Results from the DTSS experiment

The age distribution and mileage driven per week in the groups are presented in table 3. In the ADHD group, many men are professional drivers (7 compared to 3 in the control group). If these are excluded the mileage is more even between the group. However still there is a trend that men with ADHD drive more compared to men without ADHD and that for women, the situation is the opposite, although none of this was significant. In the questionnaire, 5 pointed Likert type scales were used to rate driving. Before the drive the participants were asked
how much they enjoy driving (0= not at all to 5 = very much), how they would rate their driving skills and afterwards, how they would rate their driving performance (0= very bad to 5 = very good).

Table 3: Age distribution and mileage per week

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<thead>
<tr>
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<th>Age [years]</th>
<th>Mileage/week [km]</th>
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<tbody>
<tr>
<td></td>
<td>Mean  SD</td>
<td>Mean  SD</td>
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<tr>
<td>ADHD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>31.65 4.86</td>
<td>23.59 173.25</td>
</tr>
<tr>
<td>Men (Professional drivers excluded)</td>
<td>33.86 6.22</td>
<td>96 (39.72) 115.22 (21.66)</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>30.66 30.67</td>
<td>31.72 31.21</td>
</tr>
<tr>
<td>Men (Professional drivers excluded)</td>
<td>36.36 4.66</td>
<td>30.86 (24.63) 21.12 (14.04)</td>
</tr>
</tbody>
</table>

In the group with ADHD, the scores were slightly bit higher for all these measures, however this was not significant (Figure 3 left). To examine the user experience about the driving simulator, questions regarding realism, concentration, attention and simulator sickness were answered on 6 pointed Likert type scales (0 = not at all to 6 very much/good). The scores for realism as well as attention and concentration were high for both groups. The ratings of simulator sickness were average and the general feeling was high (Figure 3 right). Most common suggestions of improvements were braking and acceleration.

Figure 3: Left: Ratings of enjoyment of driving skills and driving performance. Right: User experience about the driving simulator after the drive.

4. CONCLUSIONS

The results obtained in the experiment to verify the usability and validity of the low-cost simulator SERCO as a tool for the assessment of drivers with severe disabilities, have shown after the analysis of data acquired from satisfaction questionnaires -fulfilled by the two groups of participants, control and experimental-, that the simulator sickness tendency, mental work-load and virtual realism goodness of the tool are satisfactory enough to consider this low-cost simulator as a very useful tool. These answers allow us to conclude that the tendency to simulation sickness perceived by users in this experimental tool is at low or very low levels, and affects equally to all the evaluated subjects, independently if they are disabled or not, so it can be considered as a very valid tool for the driver’s assessment.

In the DTSS experiment, the high ratings of attention and concentration indicate that the simulator is also a useful tool. It is also well accepted by the participants when it comes to realism and the general feeling reported is good. Acceleration and deceleration can be improved, which may also decrease the motion sickness.

The general conclusion is that this type of small simulators are useful and well accepted tools for assessments of drivers with disabilities, and fulfill requirements established by the new EU 2015/653 Directive.

Further steps appropriate to refine methods and make the simulators even more useful tools for assessments of drivers with disabilities would be to test other groups with different kinds of disabilities, and also to validate with other more advanced simulators.

The results obtained from SERCO and DTSS tools have been shown useful and with high acceptance from the users.

Keywords: driver assessment, driving simulation, disabled driver, test rigs