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DRIVING SIMULATORS FOR COMMERCIAL TRUCK DRIVERS - HUMANS IN THE LOOP

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Summary: This paper reports the findings of a research study that addresses differences in human performance outcomes based on various driving simulators, as measured by comparison of scores resulting from completion of the Virtual Check Ride System (VCRS), a simulator-based, blended learning Commercial Drivers License (CDL) application. The objective of the project was to examine human performance across four different levels of driving simulators and to determine if driving simulators can contribute to human performance improvement. Each level of simulator has a definite set of tasks that can be performed on it to enhance human performance. By identifying which level of driving simulator is the best fit according to the skill, knowledge, and attitude task element, we can now prescribe for diagnostic, testing, pre-hire, remediation, safety issues and advanced driving skills.

METHODS

Individual drivers were randomly selected to be placed into one of the four different simulators. Conditions and performance data were collected and compared. The same VCRS program was used cross-platform, thus all drivers navigated through the same scenarios, even though they did not use the same level of simulator. The data collected provided evidence that supports the hypothesis we generated.

We hypothesized that the full-motion-based 270-degree FOV realistic truck cab driving simulator would have the highest performance outcomes of all the driving simulators. The second hypothesis was that the drivers who completed the driving exercises on a non-motion-based simulator with 180-degree FOV and with moderate steering and visual feedback would perform better than those who used lower level simulators for the same task. Hypothesis three involved the VS Truck Sim (which is an accurate representation of a heavy truck cab including air brakes, but lacking the 180-degree FOV). We predicted drivers would not perform as well due to the lack of peripheral visual support even though the physicality of the cab was present. Hypothesis four focuses on the use of the single channel PC and Rabbit driving simulators. It is predicted that the lower the level of simulator, the lower the level in human performance outcomes.

However, our hypothesis is not quite as straightforward as that, as we do believe that there are different categories of outcomes, essentially dependent on the primary ingredients of the tasks being psychomotor or cognitive. Essentially, a psychomotor task will require a higher-fidelity simulator, while a task that is mostly rule-based or involves decision making can be accomplished on a lower-end simulator. This, of course, is also dependent on the conditions or

cues that are necessary (e.g., if being able to see hard left or right is required then clearly a single channel simulator will not be sufficient). This is really the focus of our research and methodology: to tease out across our matrix the empirical elements of performance that are appropriate for each type of system. As the cost-effectiveness of simulators is a major concern of users, this information should be critical to decisions based on user training needs.

Further, we note that it is beneficial that all driving simulator systems include the following four primary subsystems:

- Vehicle Dynamics
- Sound/Visual Systems
- Instructor Station
- Traffic

DESCRIPTION OF DRIVING SIMULATORS

Level 1 - PC Simulator. Runs same software as levels 2 and 3 with minor modifications. Single channel, lacks air brakes, and transmission and 180-degree FOV (see Figure 1 below). A steering system created by IST/UCF design and engineering teams replaced the joystick steering. A real 14” steering wheel and robust gear reduction allows two modes—car and truck. Production price was \$1,000. This steering system succeeds in making the driver feel more in control and in making the PC driving simulator seem more realistic as opposed to just a glorified games(see Figure 2 below). Production price with realistic steering system = \$6,000.



Figure 1. Level 1 PC Driving Simulator with Joystick Configuration



Figure 2. Realistic Steering System Configuration

Level 1 - FAAC Rabbit Simulator. The heavy truck cab lacks air brakes and transmission and 180-degree FOV. The simulator lacks a real feeling steering system for a heavy truck. Although realistic graphics and vehicle dynamics are included, we found the driver took longer to become submerged into the driving scenario on this simulator. List price \$25,000 (see Figure 3 below).



Figure 3. Level 1 FAAC Rabbit Driving Simulator

Level 2 - VS2 Truck Simulator. An accurate representation of heavy truck cab including air brakes, steering feedback, with manual and automatic transmission configurations. Lacks 180 degree FOV. List price \$65,000 (see Figure 4 below).



Figure 4. Level 2 VS2 Truck Driving Simulator

Level 3 - Patrol Simulator. An accurate representation of a Crown Victoria, this simulator is generally used for Police and Emergency Response drivers. It can be configured to emulate a heavy truck without air brakes or manual transmission systems. Added plus is the display of 180-degree FOV. List price \$160,000 (see Figure 5 below).



Figure 5. Level 3 Patrol Driving Simulator

Level 4 - Mark II Truck Driving Simulator. A Moog 6-DOF motion-based platform, air brakes, manual and automatic transmission configurations and 270 degree camera

projected FOV. Another added feature is the rearview mirrors. List price = \$500,000 (see Figure 6 below).



Figure 6. Level 4 Mark II Full-Motion-Based Truck Driving Simulator

CONCLUSIONS

Each level of simulator has a definite set of tasks that can enhance human performance. Being able to forecast or identify the types of human performance at each level of simulation is important because it provides information to operations managers on how to plan training based on what degree of performance they are trying to address and at what monetary cost. If the cognitive skills can be separated from the psychomotor skills portion of the human performance, the desktop simulator may indeed be a viable option at an affordable cost. However, for more advanced human performance, such as emergency procedures like reacting to skids, a higher-level of simulation appears to be necessary.

STUDY RESULTS

Our results indicated that hypothesis one was indeed supported. Human performance was the highest in the highest level of simulator. However, our findings show that there is no significant difference between the level three (180-degree FOV) and level two (VS Truck Sim with single channel FOV) simulator even though the degrees of freedom and cab reality are a factor. Our third hypothesis was partially supported in that the drivers did not perform well when the FOV was limited, although the comparison to the desktop simulator *showed no significant difference* with the exception of the steering systems. Hypothesis four, use of single channel PC and Rabbit simulators also known as level I simulators, offered slightly *higher human performance than expected*. This is important because of the major monetary difference between the different levels of simulators.

Refer to Figure 7 for a sample of the matrix used during this study and see Figure 8 for a sampling of average scores based upon simulator level.

CDL Driving Skills-Tasks KSAs	Knowledge Cognitive	Skills Psychomotor	Attitudes Affective	Level 1 Average Score	Level 2 Average Score	Level 3 Average Score	Level 4 Average Score	Comments/Criterion
Backing up	X	X		79	79	85	88	Recognizes the difference of backing up with and without a trailer. Can judge distance and speed relationship between vehicle and objects. Reverses the vehicle direction without contact with other vehicles, markers, barriers, etc.
Checks traffic conditions – uses mirrors								Mirror FOV limited on level 1 and 2 simulators (single channel).
Maneuvers the vehicle in the desired direction and repositioning the vehicle as needed without incident								Mirror FOV limited on level 1 and 2 simulators (single channel). Vehicle steering dynamics in turning on level 1 simulator not replicated with joystick steering. With added engineered steering using reduction gears, steering on level 1 can be replicated therefore becoming as robust as level 2 simulators.
Left & right turns		X		78	80	90	90	Demonstrates the ability to stay in lane, does not hit curb, uses mirrors and signals.
Checks traffic conditions – uses mirrors								Mirror FOV limited on level 1 and 2 simulators (single channel). Vehicle steering dynamics in turning on level 1 simulator not replicated with joystick steering. With added engineered steering using reduction gears, steering on level 1 can be replicated therefore becoming as robust as level 2 simulators.
Uses turn signals								Available on level 2-4 simulators. Currently designing steering column that has turn signals, on/off switch for the level 1 sim.
Positions vehicle for turn								FOV limits levels 1 and 2 single channel simulators
Executes and recovers from turn								FOV limits levels 1 and 2 single channel simulators

Figure 7. Sample page of comparison matrix

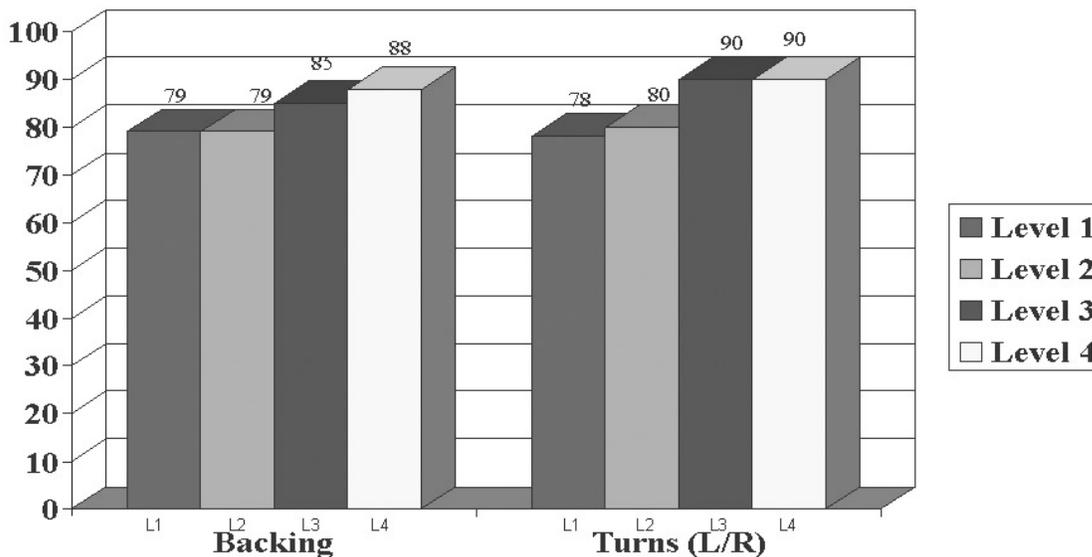


Figure 8. Average scores based upon simulator level

SUMMARY

In summary, although it does appear that not all levels of driving simulators are created equal, each can contribute greatly towards improving human performance. By identifying which level of simulator is the best fit according to a task element, we can now begin to prescribe levels of simulation for diagnostic, testing, pre-hire, remediation, safety issues and advanced driving skills.

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