

Developing a Validation Methodology for Educational Driving Simulators and a Case Study

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Abstract. The aim of this study is to develop a methodology for validating driving simulators in terms of simulator usability. The methodology was used to validate a truck simulator designed for training truck drivers about economic fuel consumption. The participants were eight truck drivers. Interview and observation methods were used to gather data. The results of the study showed that drivers did not have difficulty to recognize the parts of the driving simulator. Also, they stated that driving the simulator was easy. However, they said that they had some difficulties to use some systems of the simulator.

Keywords: Driving Simulators, Validation, Usability.

1 Introduction

Simulators are designed in order to present effects which real models have. Driving simulators are getting more and more popular today. The sectors used driving simulators are automotive industry, military, academic research fields, government, space, recreational computer markets and medical sector [1]. They are, especially, used for training and experimentation purposes [2]. It is emphasized that use of simulation provides achieving training and design at lower cost, controlling experiments again and again and evaluating vehicle designs [3]. A driving simulator is superior to in-vehicle testing for three reasons as “Safety”, “Equipment Cost” and “Experimental

Control” [4]. Also, the driving simulators provide safe and economical testing driving performance [5].

The driving simulator research studies include studies of simulator validation [6] [5] [7], effects of simulators to learning [8] [9] [10], usability of simulators [11] [2] simulator sickness [12], evaluating drivers’ performances by driving license bureaus [1] and driver workload [13]. However, there is limited study that investigated the validation of driving simulators although the validation of a simulator is important for designing good simulators. Also, simulator validation should be taken into account because “The success of a man-in-the-loop real time simulator depends upon how well it meets the design goals which is determined via a process called Validation.” (p. 1) [14].

There is confusion on types and methods used for the simulator validation [6] [15]. For example, validation types in Psychology as “construct, content and criterion validity” are used for simulator validation [6]. Physical Correspondence and Behavioral correspondence are the two aspects of simulator validity which are generally focused in the literature [4]. On the other hand, validity can be divided as internal and external validity [16]. Some literature review studies which focus on different validity concepts also show the confusion on simulator validation concepts, types and methods. Simulator validation concepts are summarized as “Accuracy, Algorithmic validity, Believability, Conceptual (face) validity, Construct validity, Content validity, Criterion (predictive) validity, Educational validity, Empirical validity, Empiricism (objectivism, foundationalism, verificationism), Event validity, External validity, Hermeneuticism, Internal validity, Operational validity, Plausibility, Positive Economics, Rationalism, Realism, Relativism (Conventionalism), Representational validity, Validation, Verification and Verisimilitude.” [16]

In the scope of this study, the reviewed literature on the validity concept and classification used for simulators shows that there is not a precise validity classification for the simulators which include usability issues. For that reason, the aim of this study is to develop a validation model which includes simulator usability can be used for driving simulators. To do this, the validation concepts and classifications as well as driving simulator validation and usability studies were reviewed. So, the important parameters to validate a driving simulator were defined. Moreover, the developed validation model was used to validate a truck simulator designed for economic fuel consumption and safe driving trainings in terms of usability issues. How the developed model can be used was shown with a research based approach. So, the important parameters that were taken into account while choosing the appropriate methods and how the simulator validation study can be conducted was shown in a practical way.

1.1 The Proposed Simulator Usability Validation Model

In the literature, there is an agreement that there are not precise simulator validation definition and simulator validation models which propose usability types and methods for each type. Also, there are many simulator usability studies in the reviewed literature, usability are not mentioned in the validation studies [11] [2]. However, it should be taken into account because it may affect the behavior of the users as well as success of the simulation. The driving simulators’ properties should be considered in the usability validation studies because they are different than other computer based

applications in that they represent a real life model and provide a real life experiences although they are designed on computer and have a virtual environment. For that reason, the representation of real life experiences, modeling, people’s behaviors while using the simulators, people’s perceptions on them, simulator design models used and purposes of simulators designed are the main concepts and issues related to the simulator validation. Some of them are connected with the simulators’ own physical characteristic parallel to simulator design purpose while some of them connected with user behaviors and perceptions. Therefore, the data collection methods used for simulator usability are defined as interview and observation. So, the information about the users’ perception on if they have difficulty in recognizing and/or using any parts of the simulator can be obtained.

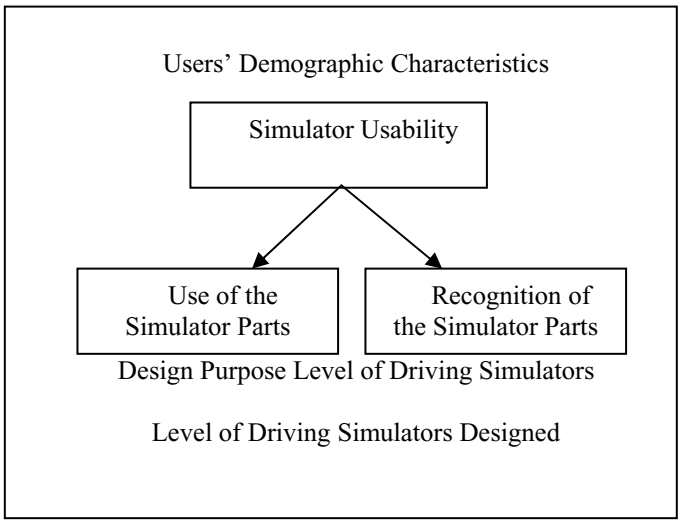


Fig. 1. Simulator Usability Model

Moreover, driving simulators have different parts as steering gear, gas pedal, gear-shift, break, speed indicator, gasoline indicator, turn signal indicator lamp and so on. The researchers should focus on important parts parallel to driving simulator aim and their usability issues. Also, they should prepare the instruments for each part. Since the parts of the driving simulators are important, our model has two components as “Use of the Simulator Parts” and “Recognition of the Simulator Parts”.

The factors that may affect the results of validation research should be considered while conducting a driving simulator usability model. For that reason, the defined factors are placed in our model. One of the factors was purpose of designing the simulator. The purposes of designing driving simulators are defined as Research, Training, and Screening [1]. Moreover, it is stated that simulator validity should be determined by taking into account of design purpose [17]. The other factor is that level of the simulator in a simulator classification structure wanted to be validated. Although there is no implication about the importance of defining validation by considering level of the simulator in the reviewed literature, level of the simulators are important

in the simulator validation model proposed in this study because identification of the level of a driving simulator is important in order to know which skill, knowledge and attitude task elements can be best fit to it. Also, it shows the capabilities of the simulators. The level of the simulators is connected with the quality of them [18]. For that reason, while defining the validation methods, one should consider the capabilities of the simulator. The other factor that may affect the results of the validation research is users' demographic characteristics such as age, gender, being novice or expert and so on [6]. For that reason, the proposed simulator validation model has also this factor as a component.

2 Methodology of the Study

The study aimed to develop a methodology and validate a truck simulator related to usability issues. The qualitative approach was applied to gather data. Eight volunteer drivers were participated to the study. While four of them are truck drivers, four of them are semi-trailer drivers in real life. All of them stated that they had not used a simulator before. All drivers navigated through the same scenarios and they used the simulator in two areas in the simulation environment: 1) at hill 2) in city. The following scenario was developed for driving simulator sessions:

1. Selecting the starting point:
 - a. from beginning of the hill to end of the hill (3,5 km);
 - b. from the beginning of the city center to the end of the city center (2,5 km)
2. Selecting vehicle load: no load
3. Selecting traffic density: medium vehicle density
4. Selecting the weather: sunny

The methodology provides a step by step system for the researchers who aim to investigate validation of a simulator. The methodology has 5 steps:

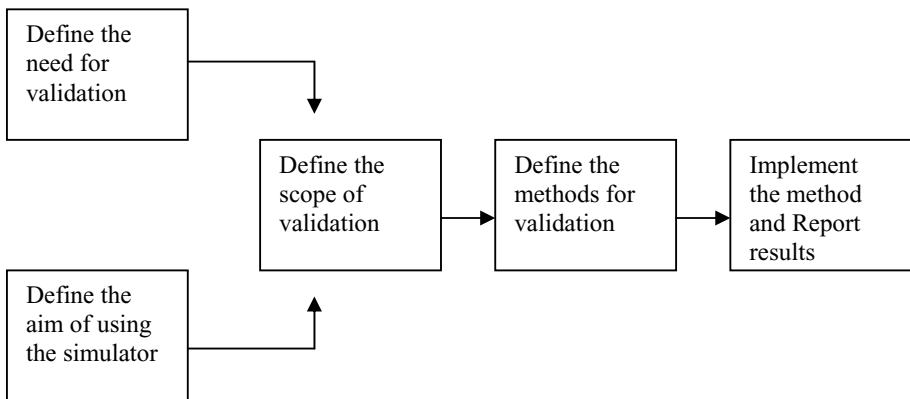


Fig. 2. The steps of the validation methodology

Firstly, before stating the validation investigation, the aim of using the truck simulator was taken into account: the truck simulator would be used for educational purposes and accordance with this purpose which parts usability should be investigated was defined. Secondly, the scope of the validation is categorized as “User perception on simulator”, “reality of the simulator”, “usability of the simulator”, “simulator sickness” and in this study, the usability of the truck simulator was chosen as study scope. Next, the methods of simulator use validity which is defined process assessing how much the driving simulators are user friendly regarding to reality and user perception were applied. According to the chosen method, the instruments were prepared. Finally, the data were gathered and results were reported.

2.1 Materials Used in the Study

Interview Form. Interview form consisted of 10 questions on usability of the simulator. The questions were prepared by benefiting from the literature on simulator validation studies and revised by an expert.

Observation Form. Observation form was prepared to enable researchers to focus on important actions of the drivers while they were using the simulator. Two researchers observed the drivers while they were using the simulator according to observation form. They focused mainly on usability issues.

The Truck Simulator. The truck simulator is developed to train drivers on economic fuel consumption. The parts such as steering gear, gas pedal, gearshift, break, speed indicator, gasoline indicator, turn signal indicator lamp and so on in the simulator are the same as those in real trucks. The simulator visual system consists of 3-LCD screen, it has 120-degree horizontal field of view and 2 degree of motion platform (Figure 3.)



Fig. 3. The Truck Simulator

3 Results

The interview questions were prepared to investigate if the drivers have difficulty in recognizing and using the parts of the truck simulator. The drivers were asked that whether they had difficulty while using the truck simulator and if they did what the reasons were. The observation data consisted of two researchers' observation notes according to the observation form. Also, there were three cameras used to validate the observation notes taken by researchers. One camera was placed to record the simulator screen. Another one was placed to record the drivers' feet actions. The last one was placed to record the drivers' facial expressions.

3.1 Recognition of the Simulator Parts

To investigate how much the truck simulator is a user friendly technology, the drivers were asked if they have difficulty in recognizing the steering gear, gas pedal, gear-shift, break, signals, lights, speed indicator and rpm indicator of the truck simulator.

All of the drivers stated that they could easily recognize parts of the simulator. They stated that these parts were the same as the ones in real trucks. One driver stated that

"The parts of the simulator are exactly the same ones of the real truck. Anyone can easily recognize them."

The observation data also supported the result of the interview results. According to the observation results, the drivers could easily find the parts of the simulator that they needed to use. Only, they could not understand the type of the gearshift. For that reason, the trainer had to explain the type of the gearshift and how it works.

Moreover, the drivers were asked how driving the truck simulator is similar to driving on real truck. All the drivers stated that driving the truck simulator is similar to driving a real truck in about 80 percent. They also pointed out that the differences were stemmed from the computer environment of the simulator and they were not getting used to that environment. They stated that the similarities were stemmed from their using steering wheel, gas pedal, gearshift, break and signals while driving the truck simulator as a real truck. One driver stated:

"Driving the simulator is similar to driving a real truck because I used steering wheel, gas pedal, gearshift, break and signals to driving it but I does not use computer. Maybe for that reason, I cannot say that the driving experiences in the simulator was the same as driving a real truck"

Five drivers stated that the view field of the truck simulator was perfect and two drivers pointed out that it was much better than real trucks. All the drivers stated that people, buildings, vehicles, roads and traffic signs in the simulation environment were the same with ones in the real environment. The observation results also support the interview results in that the drivers obeyed the traffic rules, used signals while passing other vehicles and waited people while crossing the street.

3.2 Use of the Simulator Parts

The drivers were asked if they had any difficulty while using the gear, gas pedal, gearshift, break, signals, lights, speed indicator and rpm indicator of the simulator. So, the parts of the truck simulator that the drivers had difficulty while using and what type of difficulty they had met were defined.

According to the interview results, the drivers had difficulty in using steering wheel, gas pedal, gearshift and break. Also, according to the observation results, all of the drivers had difficulty while using steering wheel and seven drivers had difficulty while using gearshift.

Five drivers stated that the steering wheel was so sensitive to their actions and they had difficulty in keeping the truck simulator on the roadway. According to the observation results, the drivers had to rotate the steering wheel at the left and right direction too much. For that reason, they lost the simulator control and went on the opposite side of the road. One driver stated:

“Driving the simulator is similar to driving a real truck. However, the steering wheel of the simulator is so sensitive. I lost the control of the simulator. I think it happens because it is a computer environment”

The gearshift of the simulator was also difficult to use according to four drivers. While three drives stated that they could not change to second gear, one driver stated that he could not change to fifth gear. Also, none of the drivers could understand the type of the gearshift. However, all the drivers who pointed out that they had difficulty while using gearshift stated that it was stemmed from their not getting used the computer environment.

Moreover, three drivers stated that although they could easily keep the real truck rpm at an appropriate level, they could not do this while using the simulator. The drivers pointed out that this stemmed from the lack of adjustment in the gas pedal. They said that when they stepped on the gas, the simulator rpm suddenly jumped.

Another problem that the drivers stated was in the brake system. Three drivers pointed out that the brake was giving late response to their actions. For that reason, they had difficulty in controlling the truck simulator. One driver stated:

“There is a break system, however, it does not give a feeling that the vehicle is stopping. You do not understand that you are slowing down without looking at the speed indicator”

Also, the drivers stated that they did not meet any problem due to the people, other vehicles, traffic signs and buildings in the simulation environment. According to the observation notes, only one driver had an accident because a pedestrian hit the truck while the driver waited at the traffic lights.

4 Conclusion

There are many sectors such as automotive industry, military, academic research fields, government, space, recreational computer markets and medical sector which

use simulators today [1]. They use the simulators, especially, for training purposes [2] because simulators decrease the cost of training as well as provide a safe environment for the users [4] [3]. But, the success of the training with simulator depends on how well the simulator meets the design goals and it is determined through validation studies [14]. Moreover, simulators are different than the real life tests or other computer applications and for that reason, validation models and types used for real life tests or computer applications should not be used for validating simulators [6]. Therefore, this study aimed to propose a validation model in terms of usability of the driving simulators and validate a truck simulator according to the proposed model.

The simulator usability model consists of two parts as “Use of the Simulator Parts” and “Recognition of the Simulator Parts”. The factors that may affect the results of the validation process are defined. These factors are design purpose of the driving simulators [17], level of the simulators and users’ demographics. According to the Simulator Usability Validation model defining the parts of the driving simulator and taking the user perception on its usability are important.

A truck simulator was validated by using the Simulator Usability Validation model. It is a high level simulator. The researchers followed a step by step system to conduct the study as “Define the need for validation”, “Define the aim of using the simulator”, “Define the scope of validation”, “Define the methods for validation” and “Implement the method and Report the results”. Firstly, before conducting the study, the design aim of the truck simulator had been taken into account: the truck simulator was designed to train the truck drivers on economic and safe driving. Secondly, reality and usability were chosen as the scope of the validation study. Thirdly, face validity which is defined as what is the target population perception on the resemblance degree between the truck simulator and the real truck. The instruments which were prepared by taking into account the chosen method were a questionnaire, an interview form and an observation form. Finally, the data were gathered and results were reported.

Eight volunteer truck drivers participated to the study and all drivers drove the truck simulator twice. The same scenario was used through their first driving and second driving. Firstly, they drove it by their own. Secondly, a trainer helped them while driving the truck simulator. Two researchers observed the truck drivers through the drivers’ first and second driving in addition to three cameras. After driving, the drivers were interviewed.

According to the interview results, the drivers found driving the truck simulator was similar to driving a real truck since they used the steering gear, gas pedal, gearshift, break, signals, lights, speed indicator and rpm indicator through driving. Moreover, they stated that the steering gear, gas pedal, gearshift, break, signals, lights, speed indicator and rpm indicator of the simulator were the same ones in real trucks. However, they pointed out that they had difficulty in using steering wheel, gas pedal, gearshift and break parts. According to five drivers the steering wheel was so sensitive and for that reason, they could not control the truck simulator. Moreover, three drivers pointed out that the rpm indicator showed high levels due to the gas pedal. Three drivers stated that there was a problem in break system because it was giving late response to their actions. Moreover, four drivers found difficult to use gearshift of the simulator. However, according to them it was stemmed from their not getting used the computer environment.

In the future work, we plan to implement this model to other driving simulators. Also, we plan to replicate this study with a new and large samples.

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