

Video game simulation on car driving: Analysis of participants' gaze behavior and perception of usability, risk, and visual attention

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ABSTRACT

The present article discusses video game simulation applied to research on driving a car. It presents an investigation into the eye movements and perceptual aspects of the research subjects on their interactions in the experimental condition. Investigations into how interactions occur in this interface are important for the development of research. From the perspective of cognitive ergonomics, the objective was to investigate the opinion of the participants on usability, risk, and visual attention and to register the eye movements necessary to control the vehicle in order to complement analyzes of the reported opinions. Applying simultaneous methods of analysis, especially able to explore brain activity such as through visual attention, is important to understand interactions in the human-machine interface. The results demonstrate that eye movements (duration and number of fixations in areas of interest) are similar to non-simulated traffic situations. The usability of the simulator control interfaces are considered to be little similar to non-simulated conditions and modify the mode of driving the vehicle. Despite the reduced immersion provided by the simulator, the perception of risk is present, although very subjective. The reported perception of where visual attention is maintained during vehicle driving is consistent with eye movement tracking records.

Keywords: Visual attention, Simulator video game, Usability Visual attention, Simulator video game, Usability

INTRODUCTION

Human interactions with machines can be investigated by means of several methods, with the resulting data affected by different levels of consciousness of decision making and task performance involved. Therefore, understanding how human interactions with research instruments occur is relevant for scientific purpose. In this context, the present article analyzes participants' perception of usability, risk, and visual attention involved in simulated car driving in video game. The objectives were to (i) identify the participants' opinions on

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usability, risk, and visual attention, and (ii) record the ocular movements necessary to control the vehicle in order to complement the reported information.

Applying simultaneous methods of analysis is decisive to understand complex interactions at the human-machine interface. Cognitive ergonomics emphasizes cognitive aspects of human behavior at work and in everyday environments using perceptual, cognitive and motor activities monitoring techniques to study aspects of human behavior in relation to technology and work, which include visual attention, mental workload, motor control, memory, human-automation interaction, and adaptive automation (Angelo, 2017).

An automobile driving simulator is any device capable of reproducing, in virtual environments, real situations of control of a vehicle (Baldwin & Ford, 1998). These simulators are classified as basic level, intermediate level, and high fidelity (Granda *et al.*, 2011). According to these authors, basic level simulators (which include the model discussed in the present article) are composed of a desktop, steering wheel, and pedals and the image is generated on one or more screens. Video game simulations, especially those with traffic situations, make possible to actively explore the road and promote interaction with the environment (Beullens *et al.*, 2011). However, the use of driving simulators is not a concern-free methodology (Konstantopoulos *et al.*, 2010).

In particular, simulations seek similarities with "reality"¹. In simulated automobile driving, verbal feedback from users regarding their experience in this task, such as characteristics of vehicle use, risk, and similarity to the reality of traffic may complement more automated aspects of the task such as visual perception and movements necessary to control the heading direction of the vehicle. In short, different methods applied simultaneously may favor a better understanding of the complexity of the phenomenon under investigation. In this vein, the purpose of the present study was to explore distinct aspects of perception resulting from participants' interactions with the video game driving simulator. More specifically, both participants' opinion on driving simulator experience (via Likert scale) and participants' visual attention certain areas of interest in the visual scene (via gaze behavior) were obtained regarding their interaction with simulation apparatus.

1. METHOD

1.1. Participants

Ten participated, both sex, in the study with a mean age of 28.3 years and standard deviation of 6.24. The inclusion criteria were being the holder of a national driver's license (CNH -

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Brazilian) for more than four years; reporting no visual *deficit* or having vision corrected to normal; not presenting motor or neurological sensory impairment; and not being experienced in any type of video game.

1.2. Materials and equipment

The game *Gran Turismo* was executed on a Play station 2 and projected on to Bem Q (MX720) multimedia equipment on a screen (Projectile - Infinity model) of 204 centimeters x 154 centimeters. The game was setup in the arcade - time trial mode. The *Original circuits - Autumn Ring Mini* route was chosen and the car used was a Ford Ka '01, with sports tires and without any driving aid.

The control interface of the vehicle in the simulator (video game) consisted of a steering wheel, manual transmission of gears, and control pedals (brake, clutch, and accelerator) of the brand *Logitech*, model G-27.

Eye movements were registered by means of an *eye tracker* from *Applied Science Laboratories (ASL)*, model H6. This is a monocular system with an accuracy of half a degree of visual degree. The sampling rate of the cameras is 60 Hz.

Opinions of the participants on the perceptual aspects of their interactions with the simulator were collected through a Likert questionnaire, which is a statement to which the participant responds through a criterion that can be objective or subjective. The aim is to measure the level of agreement or non-agreement with the statement. Seven levels of responses (Figure 1) were used, addressing three domains: usability, risk, and visual attention.

1	2	3	4	5	6	7
Completely disagree						Completely agree

Figure 1 - Model of the Likert scale used in the data collection.

2. PROCEDURES

The study was carried out at the Laboratory of Information, Vision, and Action (LIVIA), Department of Physical Education, Faculty of Sciences of the State University of São Paulo (UNESP), Bauru Campus. The research was approved by the local ethics committee.

Initially, participants were given information about their voluntary participation in the research and signed the free and informed consent form. Afterwards, the participants

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positioned themselves seated in a chair two meters from the projection screen. The positions of the control pedal and steering wheel were adjusted for each participant.

An adaptation period of practice (three minutes) was allowed in the simulator, after which the *eye tracker* was positioned on the head of the participants and calibrated. Then the task started, which consisted of driving the car and completing the pre-established course three times in the shortest time possible. At the end of this task, participants were instructed on how to answer the questionnaire regarding perceptual aspects of their simulator interactions. After responding to the questionnaire, the experimental protocol was completed.

3. DATA ANALYSIS

Four areas of interest (AOIs) on the visual field were determined (Figure 2), for which the number and duration of eye fixations were analyzed. This procedure was performed through the software *ASL Results Plus (version 1.8.2.18)*. These areas corresponded to: AOI 1 = road; AOI 2 = speedometer; AOI 3 = rear view mirror and time; and AOI 4 = any part of the visual field that was not considered an area of interest (outside).

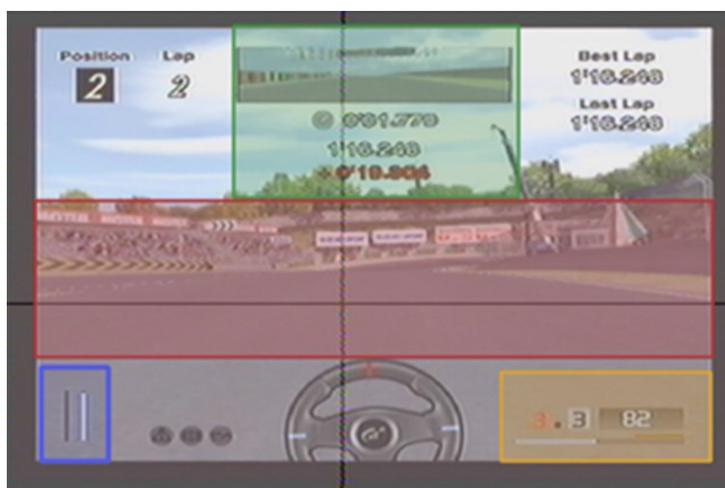


Figure 2. Areas of interest in the visual field.

4. STATISTICAL ANALYSIS

The means of the frequency and duration of ocular fixations were obtained in each area of interest. Fixation detection criteria were a minimal duration of 100 milliseconds and the spatial limit of 1 degree (Land, 2016). The data were submitted to analysis of variance (ANOVA). Bonferroni probability adjustments and Greenhouse-Geisser degrees of freedom adjustments were adopted when necessary. The level of significance was set at 0.05 for all

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analyzes. Post-hoc analyzes were performed using the Tukey LSD Test. The Likert item analysis was calculated according to the total responses of the participants from levels 1 to 7. Table 2 presents the mean and standard deviation calculated for each question.

5. RESULTS AND DISCUSSION

Table 1. Number and duration of eye fixations by area of interest.

Area of interest	Mean (M) frequency of fixations	Standard deviation (SD)	Mean (M) duration of fixations	Standard deviation (SD)
1 –OUTSIDE	93.7	15.8	30.8	5.7
2 – ROAD	400.3	24.4	160.7	10.4
3 – Speedometer	7.9	3.3	2.5	1.4
4 – Rear view mirror and time	65.2	15.2	24.9	6.2

Table 1. Likert items and mean responses from participants.

Domains	Questions	Mean response	Standard deviation
1. Perception on Usability	A - Controlling the car to stay on the road on the simulator is similar to a real traffic situation.	4.57	4.49
	B - The simulated and real traffic situations are similar.	6.28	4.36
	C - Controlling the car on the simulator is similar to a real traffic situation.	4.71	4.49
	D – In the simulator I modify my way of driving in relation to a real traffic situation.	6.85	7.98
	E - The physical characteristics of the simulator do not resemble a real car.	6.42	6.88
2. Perception of risk	A – I feel more insecure driving in the simulator than in a car in test situations.	7.14	7.05
	B - When I leave the route I have the sensation of discomfort.	8.42	9.52
	C - In a real traffic situation my perception of risk is high.	9.00	12.43
	D - The probability of being involved in an accident in the simulator is zero.	6.00	5.15
	E - Perception of changes in car speed in the simulator is similar to a real situation.	5.00	5.15
3. Perception of visual attention	A - My visual attention is there, but my conscience is elsewhere.	4.00	3.85
	B – When I drive my eyes are fixed on the road.	7.28	6.96

The purpose of the present study was to explore distinct aspects of perception resulting from participants' interactions with the video game driving simulator. Their opinion on driving

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simulation experience (usability, risk, and visual attention) and their visual attention to specific areas of interest (gaze behavior) were obtained regarding their interaction with simulator apparatus. Results have shown the complementary nature of these two types of information; opinion on their simulator experience and gaze data tended to reciprocally confirm each other as following discussed.

Firstly, it is worth of note that studies with driving simulators are particularly relevant in Brazil due to the mandatory use of these devices in driving schools since the beginning of 2016. As these devices explore the main sensory pathways of users (Andersen, 2011), realistic profiles of drives.

Behavior can be drivers can be obtained in simulators. However, investigating how these sensations are perceived and how users react to them is a matter of scientific debate. In this sense, combining eye movements and perceptions regarding usability, risk, and visual attention in their interactions with the simulator offers stronger basis for interpreting this bidirectional link between continuous, obtained during the task, visual attention mechanisms and cognitive representation analysis, obtained afterward. Both aspects are influenced by the level of virtual immersion provided by the visual interface and by the interactions with the simulator control interfaces.

In laboratory studies automotive simulators are used to offer several advantages such as low cost, easy data collection, maximum safety for test participants and multiple possibilities of experiments under controlled conditions. Simulators are interactive systems and allow for the recording of several behaviors related to the performance of drivers, as well as the manipulation of vehicle characteristics, scenery and traffic, offering different speeds, trajectories and traffic difficulties conditions (Easa, 2005, 2006).

To test possible perceptual and motor adaptations to increased driving speed, Angelo (2017) studied 30 volunteers who drove cars by at least three years, completing at least 15,000 km driven, with experience in highways. These participants were male and female, aged between 21 and 45 years. The task consisted in driving the car simulator at different speeds, (50-60km/h, 80-90km/h and 110-120km/h) for 3 minutes while eye movements were recorded.

An eye tracker Applied Sciences Laboratories (ASL, model H6) City Car Driving simulator (Forward Developmentes) were used traffic intensity was set to 10%, and weather to a sunny day. Results revealed that, with the increase in vehicle speed the motor oculomotor system

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was compelled to increase the efficiency of attention and information processing, favoring longer and spatially closer fixations. The applied questionnaire, similar to the one used in the present study, showed that 100% of the participants corroborated the idea that using the simulator is similar to the situation of natural traffic driving.

Eye movements data of automobile drivers obtained in simulators can help to identify attentions distractors. Carizio, et al (2016), investigated twenty automobile drivers between 18 and 40 years of age, male and female, divided into groups of novice and experienced drivers. Novice drivers were characterized as individuals with less than 15,000km of total driving experience, while experienced drivers were participants of more than 30,000km of total driving experience. It has been indicated that after a distance of 30,000 kilometers of driving practice, motorists learn to use peripheral vision more effectively (Lehtonen, 2014). Kinematics of the eye measurements were taken of each participants as they drove in a driving simulator, at speeds between 80-120 km/h, in daylight, on a linear trajectory, in low level traffic. Results showed that the use of the cellular device concomitant to the act of driving (hand-held and hand-free conditions) is associated with a greater number of fixations, as compared to a no-cell control condition. Talking on the cell phone disturbed attention due a decrease in eye's stability; increased number of fixations with shorter durations tended to hamper the ability to obtain relevant visual information for safe driving. In terms of fixation duration data, this was essentially the same result obtained in the present study, when participants exhibit greater visual attention on the front measured by gaze fixations. This was also corroborated by information from the questionnaire, showing relatively high score "(M = 7.28) to the sentence When a direct my eyes are fixed on the Road".

Particularly, video game simulations do not promote high levels of immersion and interaction as compared to newer technologies (e.g., virtual reality); this video game simulator, consisting of desktop, steering wheel, pedals, and one or more screens is characterized as basic level (Granda *et al.*, 2011). However, they are capable of generating driving conditions similar to studies on real, natural roads (Tornros, 1998). Favorable factors for the use of simulators are greater experimental control and lower cost and risk (Kemeny & Panerai, 2003).

The results of the present study demonstrate that the participants perceived similarities between simulated and non-simulated traffic situations. However, the usability of control interfaces to maintain the simulator vehicle on the road was perceived as unrealistic. In general, controlling the vehicle in the simulator was also perceived as little similar to reality.

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The usability aspects of the simulator, according to the opinions of participants, modified their way of driving in relation to the non-simulated condition.

The perception of risk was present during the experiment, despite the reduced immersion provided by the simulator. However, the probability of being involved in a simulator tends to be considered small, which shows that there is no great perception of risk. In contrast, in a real traffic situation, the perception of risk is clearly high. A difficulty to be considered in driving simulation is the behavior of the driver, which will not be the same as there is no risk involved (Reimer *et al.*, 2006).

Results demonstrate that participants perceived greater insecurity driving in the simulator than driving in a test in a non-simulated situation. They also showed that the participants felt uncomfortable losing control and going off the road in the simulator. In real traffic situations, feelings of insecurity and discomfort when leaving the planned route may suggest that a risk situation was perceived. However, this scenario becomes very hypothetical, especially for interactions in this type of simulator. Evidence from previous studies suggests that there are different types of awareness of hazards and perception of risk when driving vehicles, consequently when the task of the participants is to identify the risks in a simulator, the main process involved is the awareness of danger rather than the perception of taking the risk (Borowsky & Oron-Gilad, 2013). Thus, it is important to consider that in experiments with simulators of this nature the perception of risk is contains considerable subjectivity and data on this aspect may not correspond to reality.

It is possible to infer that to directly explore the perception of risk in a study it is necessary to use simulators with more sophisticated immersive resources, possibly even capable of generating the sensation of physical presence of the user in the virtual environment. An analogous example can be observed in research on braking reaction time. For this approach the use of at least mid-level simulators is recommended (Allen *et al.*, 2008).

When addressing the issue of risk in studies with this type of simulator, it appears to be more methodologically plausible to explore user behavior, without reaction to the activation of mental processes related to the consciousness of taking risks, rather than exploiting user behavior in risk situations. It is important to note that these settings are not opposed to research that addresses risk performed in basic level vehicle driving simulators. In fact, these virtual experiences interact directly and indirectly with the cognitive and emotional processes that regulate the perception of risk (Ciceri & Ruscio, 2014). Aspects related to risk perception are present even in less interactive conditions than simulations; traditional

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research methods use the presentation of videos with scenes of risk recorded from the visual perspective of the driver (Mackenzie & Harris, 2015) and the presentation of photos also from the driver's perspective, such as for the analysis of user decisions in situations where risk is involved (Underwood *et al.*, 2011).

Participants tended to consider that while driving on the simulator their eyes remained fixed on the road. Eye movement results showed that the road was the area of interest with the highest frequency of gaze fixations. Therefore, there is evidence that the participants' perception of where their visual attention is concentrated is consistent with what they actually observe. In a non-simulated condition, there is also evidence that the area with the highest concentration of gaze fixations is the road, especially when the driver is moving at high speed (Janelle *et al.*, 1999). It is important to note that the participants of the present study were instructed to complete the three laps of the course in the shortest possible time. Therefore, they drove the vehicle at high speed, considering individual abilities and perception of speed.

The user perception of their visual attention is representative of what they actually observed and the selective similarity of visual attention between the simulated and non-simulated conditions are aspects that corroborate the applicability of basic level simulators for visual attention research. These simulators are applicable in research on visual attention. Entertaining interactive video game simulations enable the user to actively explore the road and interact with the traffic environment (Beullens *et al.*, 2011). These virtual experiences interact directly and indirectly with the cognitive and emotional processes that regulate visual attention (Ciceri & Ruscio, 2014).

The tendency of the participants was to consider that their consciousness was maintained in places where visual attention was concentrated. This is also a favorable aspect to the use of basic level simulators applied to visual attention research, since it demonstrates that visual interactivity with the simulator interface often promotes information processing. This is important, since "it is possible to fix an object without extracting specific information about it, which implies that looking (fixation in the fovea) and seeing (extracting information) are different processes" (Abernethy, 1988; Vickers, 1996; 1996).

6. FINAL CONSIDERATIONS

The small affinity of the physical control resources of the simulator provides little resemblance to reality. This aspect, according to the perception of the participants tends to modify the way of driving.

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The perception of risk, interpreted as resulting from direct exposure to a risk condition as such, tends to be little evident. In the type of simulator in question, risk judgments tend to be based on preconceived mental processes.

Participants' perception of where visual attention is maintained is consistent with the registered gaze pattern of movement. The mental concentration and area of concentration of the visual attention seem to be connected for the extraction of information.

In the context of video games, providing links between drivers' opinion on driving simulation and actual gaze behavior is a valid contribution to cognitive ergonomics science. In particular, parameters on the perception of participants on their interactions in the experimental condition are necessary to contribute to methodological procedures, in order to ensure the validity of the results. In this sense, more in-depth studies involving comparisons with other types of simulators are necessary to establish more conclusive considerations about the best applications of basic level simulators in research.

ENDNOTES

¹ The term reality is in quotation marks as, strictly speaking, it refers to both the simulated situation and the non-simulated situation. In the present context, "reality" opposes the simulation and refers only to the non-simulated situation.

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