ISBN: 978-628-96613-1-6. ISSN: 2414-6390. Digital Object Identifier: https://dx.doi.org/10.18687/LACCEI2025.1.1.627

Car Simulation of Drunk Driving Behavior

Gustavo Alomia[1]; Andrea Pilco[2]; Viviana Moya[3]; Nataly Marles[4]
[1,4]COMBA R&D Laboratory, Faculty of Engineering, Universidad Santiago de Cali, Cali 76001, Colombia,
nataly.marles00@usc.edu.ec, gustavo.alomia00@usc.edu.ec
[2,3]Facultad de Ciencias Técnicas, Universidad Internacional Del Ecuador UIDE, Quito 170411, Ecuador,
anpilcoat@uide.edu.ec, vimoyago@uide.edu.ec

Abstract*– Drunk driving remains a leading cause of traffic crashes worldwide. To better understand impaired driving behaviors, this study utilized a driving simulator to compare two scenarios: one where participants consumed alcohol and another where they drove without alcohol's effects. A virtual environment replicating the city of Palmira, Colombia, was created using geospatial data provided by GIS and procedural modeling techniques to enhance realism, including the customization of characteristic buildings. Autonomous non-player characters (NPCs) were integrated using NavMesh agents, and external controllers such as a steering wheel and pedals were employed to replicate real driving conditions. The simulation evaluated driving behaviors, focusing on the blurred vision and delayed steering responses associated with alcohol consumption. Thirty students participated in the study, driving a predefined 3-kilometer route. Participants were divided into two groups: those who consumed alcohol and those who did not. A difference of 1 minute and 25 seconds in driving time was observed between the two groups, with alcohol consumption contributing to slower response times and impaired visibility. A post-simulation questionnaire assessed participants' perceptions of the simulation. The environment's realism received an average score of 4.8/5, while the simulation's immersion was rated at 3.7/5. This experiment highlights the potential of virtual simulations in studying impaired driving behaviors.

***Keywords*—Driving simulation, Unity, Drunk driving, Interactive system, NavMesh.**

I. Introduction

Virtual Reality (VR) has turned into an innovative technology across a wide variety of applications, including realism of impaired behaviors, like drunk driving imitation. Healthcare applications of VR originated in the '90s after realizing that medical staff required the use of visual aid during operations [1]. Furthermore, VR has been developing by adding new elements such as graphic displays, sensors, and integration into the different fields.

The use of virtual reality (VR) has significantly enhanced medical practice. As demonstrated in study [2], VR-based environments allow medical students to practice procedures in a safe, controlled setting, reducing the risk of errors and improving their skills before working with actual patients. In the field of mental health, study [3] highlights the effectiveness of VR exposure therapy in treating anxiety disorders and phobias. Furthermore, the integration of VR with cognitive behavioral therapy (CBT) for chronic pain management has shown positive outcomes, including improved mood, emotional regulation, and overall motivation, thereby enhancing patients' quality of life. Another important application of VR systems was found in flight simulation, where pilots practiced flight control as well as critical scenarios such as combat operations, emergency procedures, and landings. Similarly, ground combat training represented a vital use of VR technology, allowing soldiers to navigate and respond to diverse terrains and environments. This immersive training enhanced their preparedness and decision-making skills in a variety of real-world combat situations [4].

According to traffic simulations, study [5] employed costly 360-degree projection systems to provide high visual fidelity, a full field of view, and immersive experiences. VR has also been used to simulate and immerse users in a variety of scenarios. These include not only environmental or situational simulations but also the modeling of behaviors of individuals, groups of people [6], or even animals [7]. A further application related to public safety involved the simulation of drunk driving scenarios in virtual environments [8]. This approach leveraged modular frameworks to replicate real-world complexities, incorporating behaviors such as aggression and alcohol impairment within autonomous vehicle simulations.Further to this, based on the requirement for realism, driver behavior models were proposed, incorporating virtual characters such as conservative and alcoholic drivers in self-automated traffic systems. This study emphasized interactivity through variability and unpredictability within simulations, greatly improving overall user realism and interaction in the simulated environment [9]. In a similar vein, a study on the effects of monotonous task related fatigue in monotone driving environments will help to explain the effects of sustained driving. It is suggested that their measures of lateral position and steering control can be used in adding up the impacts of fatigue and alcohol influence on driving activities [10].

VR technologies have played a significant role in creating educative resources aimed at controlling drunk driving. For instance, a simple virtual reality simulation has been developed to illustrate how alcohol affects cognitive and motor capacities using low-cost devices. This tool temporarily reduces users' reaction ability and perception to provide statistically measured data on the consequences of drinking and driving [11]. Building on this, an enhanced metaverse immersive system was proposed, incorporating haptic feedback and authentic driving control styles. This approach recreated progressive alcohol impairments, encouraging participants to engage in reflective learning, thereby demonstrating the capability of VR in education [12]. Similarly, in simulation-based research, effort has been directed towards finding out new approaches of evaluating and estimating otherogenic activities of drivers. To detect drinking drivers, machine learning was incorporated to analyze driver monitoring camera data, recognizing gaze and head movements. The model demonstrated high levels of accuracy in both moderate and severe cases, enabling the design of real-time DUI detection solutions for large-scale implementation [13].

Furthermore, psychological and demographic characteristics, including sensation seeking, have been analyzed in relation to driving behavior within virtually created environments. These studies have briefly examined moderated factors contributing to impaired driving behavior, paving the way for person-tailored prevention strategies [13], [14]. It is noteworthy that the addition of improved VR technologies has advanced the simulation realism and user engagement still more. Latency optimization and head-tracking were utilized in the development of 'driving simulators' using Unity 3D integrated with Oculus Rift. Such advancements help provide a more advanced observation of impaired driving situations than physical screen-based systems [15]. Additionally, virtual-stationary walking assist systems have been implemented to integrate navigation with assist features and immersive exposure in Unity as needed, without jeopardizing user safety. These techniques could be applied to enhance spatial orientation in impaired driving simulations [16].

Implementation of educational interventions using VR has also been systematically reviewed to enhance their effectiveness. Using VR simulations in an experiment, it was found that positive framing is more effective in fostering constructive behavioral changes than negative framing. This suggests that designing and developing educational tools must incorporate proper design approaches with the aim of enduringly altering learner behavior [17]. Furthermore, research on reaction times when sober or affected by alcohol has been used as reference to validate simulation results. Some studies suggest severe delays in response time, fully supporting the use of real-time feedback in drunk driving applications [18].

The advancement of simple drunk driving simulators has reached the next level. For instance, a study effectively used features like manipulated image skewing and delayed feedback to emulate alcoholic disability. The system also incorporated participant debriefing after the simulation, which significantly enhanced its pedagogical value and effectiveness in traffic safety campaigns [19]. Lastly, the consideration of ecological contexts, including urban and rural traffic conditions, in the simulation of drunk driving has been emphasized. Additionally, the work has been generalized to the urban context, potentially allowing for a broad overall assessment of impaired behaviors [6]. Based on the guidelines for providing directions to manage intersection traffic safely and efficiently, a study sheds light on traffic flow enhancement under conditions that deem a driver incompetent to avoid dangerous and reckless behavior [20]. In [21] specifically addresses the challenges associated with obtaining driver's licenses, including significant expenses, geographical limitations, and potential accident risks. This research integrated VR headsets, a Logitech G29 controller, and a computer running Blender and Unity software to create a realistic driving simulation. It simulates three essential assessments required for practical driver's license tests: forward and backward driving, reverse parking, and interaction with pedestrians. Data collected from an experimental trial with 11 participants showed high satisfaction with the simulation, with 70.5% stating that the virtual experience can effectively develop the skills necessary for the driver's license examination. The study [22] presented an immersive training system for the improvement of the driver's ability to predict dangers in driving situations using VR technology. It provides drivers with a realistic training environment with 360° videos viewed through VR headsets. The system allowed users to practice various dangerous scenarios in an environment that simulates real driving conditions, also introducing functionality to select danger points with a controller and implement voluntary training schemes. This configuration enables training in a highly interactive state while expressing multiple indices numerically, so users understand the effect of the training. The experiments conducted demonstrated that this system was more effective in improving the driver's danger prediction capability than previous systems.

Previous research has addressed specific aspects of driving simulations, such as licensing tests, hazard prediction, or general-purpose research platforms with limited environmental fidelity. In contrast, this study adopts a comprehensive approach by integrating real geospatial data, procedural modeling techniques, and virtual reality to generate context-aware, highly realistic urban environments. This methodological integration enables more accurate simulation and enhances the study's applicability in educational, preventive, and behavioral research contexts.

These contributions also form the foundation for designing complex simulation systems with tools such as NavMeshAgent in Unity, which is capable of emanating dynamic navigation and mimicking behaviors in virtual space.

The contributions of this research are as follows:

1) For the creation of the simulation environment, Geographic Information System (GIS) was used to capture and map the streets of the city of Palmira, Colombia.
2) Two types of NPC agents were developed: one representing pedestrian and another representing vehicles, facilitating interaction in the simulated environment.
3) NavMeshAgent defined navigation routes and enabled agents to interact within the environment.
4) Two differentiated scenarios were presented. The drivers' behaviour when deciding to drink or not drink alcohol was observed, allowing the different consequences in the simulation to be analysed.

The structure of this paper is as follows: Section II describes the methodology used for the environment design and its implementation. Section III presents the simulation results and user experience. Section IV provides a discussion of the findings. Finally, Section V outlines the conclusions drawn from this study.

II. METHODOLOGY

To create the virtual environment for the driving simulator, the urban corridor spanning 31st Street to 37th Street and from Carrera 40 to Carrera 44 was selected as the study area. The methodology utilized for this process is detailed below in the Software and Hardware section.

A. Software

The selection of software tools was guided by precision and performance criteria, incorporating a suite of cutting-edge technologies. The chosen technology stack includes Unity 2021.3 LTS as the development engine, OpenStreetMap for geographic data capture, CityEngine for urban modeling, MakeHuman for character modeling, AvatarSDK for facial generation, and Mixamo for animation systems. The following software section outlines the specific implementations within the virtual environment, as detailed below.

1) Geographic Data Capture:

The collection of geographic data for the virtual environment was conducted using OpenStreetMap, a collaborative mapping platform that provides detailed information about the urban infrastructure of a specific region. The process began with exporting data from OpenStreetMap for the city of Palmira in OSM (OpenStreetMap) format. This data included detailed representations of streets, intersections, buildings, and other urban elements. Subsequently, the OSM data was converted into a format compatible with the Unity development engine. This transformation was carried out using CityEngine, which allowed for the customization of buildings and other urban elements.

2) Urban Elements, NPC Modeling, and Facial Generation:

The modeling process integrated the creation of urban elements and non-playable characters (NPCs) to accurately simulate the environment and interactions in a vehicular simulation. Urban modelling was performed using CityEngine, applying a methodology for generating 3D urban structures from .OSM data and leveraging architectural generation rules (CGA) as described in [23]. This approach enabled the creation of distinctive buildings, textures, and elements that faithfully represent the identity of Palmira. Additionally, supplementary elements such as traffic signs, traffic lights, and trees were selected and adapted from Unity's Asset Store to enhance the virtual environment. The NPCs were categorized into three groups, all generated with models and animations from Mixamo:

- Civilians: A total of 20 civilian NPCs were included, designed to simulate common behaviors in an urban environment. Each civilian is surrounded by a Capsule Collider, which, upon collision with the player's vehicle, triggers a message indicating a traffic violation, followed by the activation of police NPCs and sound effects simulating an arrest.
- Police Officers: Four police officers were integrated, which, once activated, pursue and surround the player's vehicle.

A custom guide character, created using MakeHuman and AvatarSDK, constitutes the user's first interaction with an NPC in the simulator. MakeHuman was utilized to generate a detailed body model, while AvatarSDK allowed for the creation of a realistic 3D facial model based on photographic input.

3) Implementation of Movement Routes:

NPC navigation within the virtual environment was implemented using Unity's NavMesh Agent system, following [24] implementation methodology for pathfinding algorithms. The system was configured to create a dynamic crowd simulation where civilian NPCs actively circulate within a 20-meter radius of the main player's camera. The configuration process included:

- Generating a navigation mesh from the urban model.
- Defining walkable areas for different types of agents.

The integration of these processes with the utilized tools is illustrated in Fig. 1. The simulation of drunkenness was implemented using a custom shader that reproduced visual distortions and spatial perception alterations. The operation of the algorithm is described in the Fig. 2.

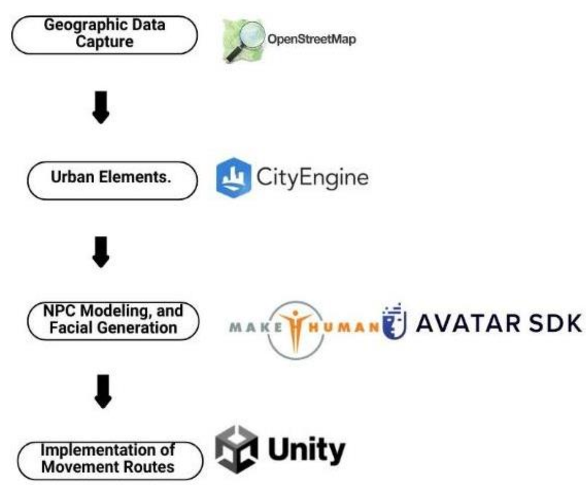

Fig. 1. Integration of processes and tools.

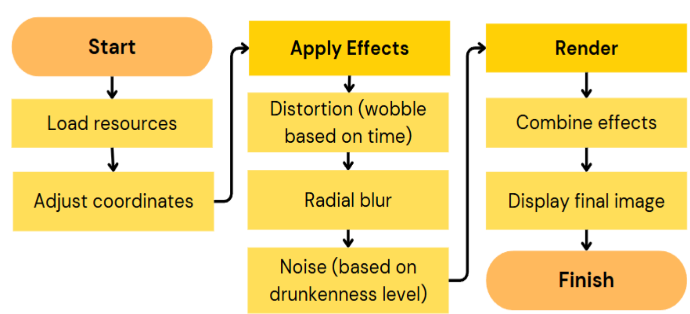

Fig. 2. Flowchart of application of drunkenness visual effects.

B. Hardware

The primary specifications include an Intel Core i5-7200U processor, designed to efficiently handle simultaneous simulation and rendering tasks. The system is equipped with 16 GB of RAM, ensuring smooth performance in managing complex virtual environments and advanced graphical operations. Additionally, it features an NVIDIA GeForce GTX 1050 Ti graphics card, providing reliable support for high-quality visuals and demanding graphic-intensive applications.

1) Projection System and Interaction Devices:

The simulator is designed to operate in two main modes. Video Wall Projection uses a video wall to replicate the image processed by the main system, providing an expanded and high-quality display. Users can interact with the simulator using peripherals such as a keyboard and mouse or a Logitech G920 steering wheel and pedals, specifically designed for driving simulations.

For complete immersion, HTC Vive VR glasses were integrated, offering a resolution of 2160 x 1200 pixels (combined across both screens), a refresh rate of 90 Hz, and a field of view of 110 degrees. Motion sensors are integrated with the VR glasses to track 360-degree movements for precise motion tracking. As illustrated in Fig. 3 and Fig. 4, the HTC Vive glasses can be used alongside the Logitech G920 steering wheel and pedals. Alternatively, users may choose to interact via a keyboard and mouse, adapting to different user profiles and educational or research objectives.

Fig. 3. Execution of the simulator using virtual reality glasses and video wall simultaneously.

Fig. 4 complements the above, showing the hardware structure of the simulator. The virtual reality headset provides an immersive view of the environment, while the Logitech G920 steering wheel and pedals allow real-time vehicle control simulation. The management of these peripherals is handled by a computer that ensures synchronization with the virtual environment.

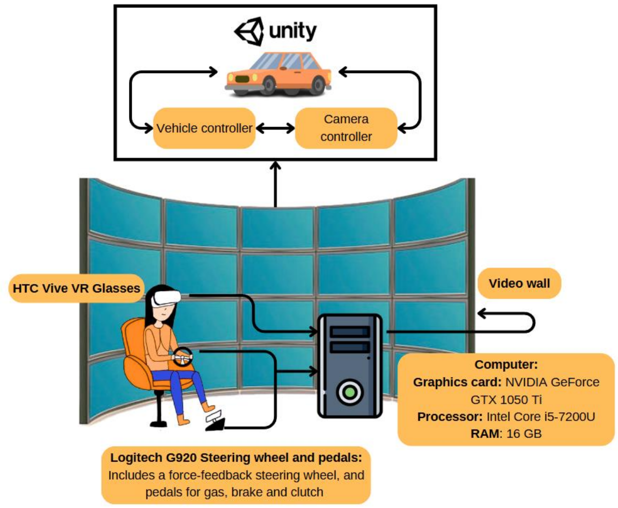

Fig. 4. Hardware integration.

C. Sample Population

The sample consisted of 30 volunteer students from Universidad Santiago de Cali (Colombia), aged 19 to 25, including both males and females. A non-probabilistic, intentional sampling approach was used, focusing on individuals familiar with social drinking scenarios and with demonstrated affinity for virtual reality tools. All volunteers were informed about the objectives of the study and gave their consent to participate in the simulation tests

III. Simulation Results

The simulation's first scenario takes place in a bar, where two options are presented to the user: to consume alcohol or abstain. If the user decides to drink, they may later get drunk and choose to drive a car. Once the driving simulation begins, the user will experience blurred vision and slower reaction times, making vehicle control significantly more challenging. These effects allow the user to experience various behaviors. Fig. 5 illustrates the simulation process and its outcomes. The detailed results of the simulation are provided below.

A. Custom Scenario

The environment was designed to replicate an area of Palmira, incorporating its streets, buildings, churches, and 1traffic lights. To enhance realism, additional elements such as Non-Player Characters (NPCs), including pedestrians, were included. The environment also features a car that the user can drive while testing the platform. To further enrich the driving simulation experience, a steering wheel is used as an external hardware device. Additionally, the simulation includes a life bar that indicates whether the character can continue participating based on their performance within the simulation as shown in Fig. 6.

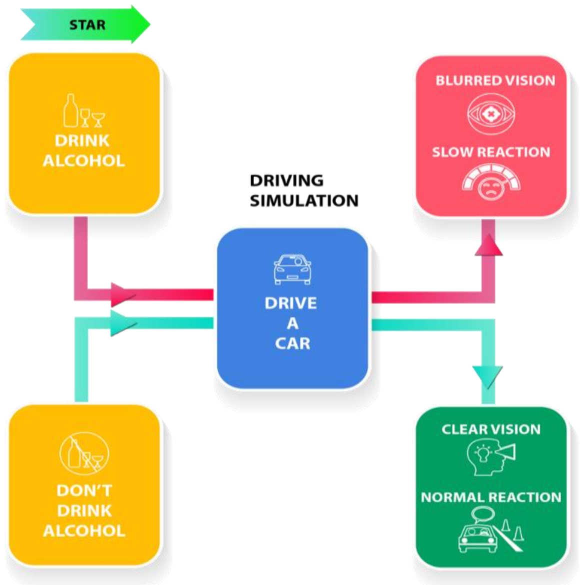

Fig. 5. Flowchart of simulation process and outcomes.

B. Behaviors

When the user chooses to drive after getting drunk, the simulation introduces blurred visibility of the streets, simulating impaired vision as shown in Fig. 7. In contrast, if the user decides not to consume alcohol, the streets and traffic signs remain clearly visible during the driving simulation, as illustrated in Fig. 8, which highlights the difference in street visibility.

Fig. 6. Custom scenario used for the car simulation.

Additionally, when the user is drunk, attempts to brake using the external pedals or steer with the wheel result in a 3-second response delay within the simulation. Conversely, when the user is sober, braking and steering actions have no response delay. If a collision occurs during the driving simulation such as hitting a traffic sign or colliding with another car the life bar decreases. However, if the user runs over a pedestrian, or if the driver has multiple collisions causing the life bar to deplete entirely, the simulation ends immediately.

Fig. 7. Blurred street visibility in the simulation.

Fig. 8. Clear street visibility in the simulation.

C. Use case scenario

The simulation includes a predefined route of approximately 3 kilometers, representing the journey from the bar to a home. To evaluate the simulation, the time it takes for the user to complete the defined route will be measured. The participants were asked to choose their initial simulation options based on their typical behavior after attending a party. Specifically, they were prompted to decide whether they would consume alcohol and get drunk at a party or not.

Of the participants, 12 students chose the option indicating they do not consume alcohol, while 18 students selected the option indicating they drink and get drunk during a night out. The 12 students who opted not to consume alcohol proceeded to the driving simulation along the predefined route. The driving times recorded for participants who chose to abstain from drinking alcohol, traveling from the bar to the home, are presented in Table I. The times are expressed in minutes and seconds, with an average driving time of 2 minutes and 30 seconds. The 18 students who selected the second option also participated in the driving simulation; however, only 15 of them completed the simulation successfully. Three participants were unable to finish as they accidentally ran over a pedestrian due to impaired visibility and the delayed reaction time of the brakes (pedals). For the 15 students who completed the simulation, the average time to drive from the bar to the home was 3 minutes and 55 seconds, as shown in Table II.

TABLE I

TIME FROM BAR TO HOME FOR SOBER USERS

Student	Gender	Time
1	Male	2 min 30 sec
2	Male	2 min 10 sec
3	Male	2 min 0 sec
4	Female	2 min 20 sec
5	Female	2 min 30 sec
6	Male	3 min 30 sec
7	Male	3 min 30 sec
8	Female	2 min 0 sec
9	Female	2 min 30 sec
10	Female	3 min 0 sec
11	Male	2 min 0 sec
12	Male	2 min 0 sec
	Mean Time	2 min 30 sec

D. User experience

The user experience (UX) evaluation of the simulation aimed to assess its realism and usability among participants. Thirty students from the University of Santiago de Cali (USC) who tested the simulation completed post-simulation questionnaires. Fig. 9 presents the participants' results, the realism of the environment was rated an average score of 4.8 out of 5. The usability of controls received a score of 4.5 out of 5, indicating that most participants found the interface intuitive and easy to use.

TABLE II

TIME FROM BAR TO HOME FOR DRUNK USERS

Student	Gender	Time
1	Male	3 min 50 sec
2	Male	4 min 0 sec
3	Female	3 min 40 sec
4	Female	3 min 50 sec
5	Female	4 min 30 sec
6	Male	4 min 0 sec
7	Male	4 min 30 sec
8	Female	4 min 0 sec
9	Female	3 min 30 sec
10	Male	4 min 0 sec
11	Male	4 min 0 sec
12	Male	3 min 50 sec
13	Male	3 min 45 sec
14	Male	3 min 55 sec
15	Female	3 min 25 sec
	Mean Time	3 min 55 sec

The use of a steering wheel as an external hardware device scoring 4.7 out of 5 for its contribution to immersion and replicating real-world driving experiences. However, participants who experienced the drunk driving phase noted significant challenges, including delayed braking and impaired visibility, which were intentionally designed to simulate real-life consequences. This aspect received a score of 3.9 out of 5.

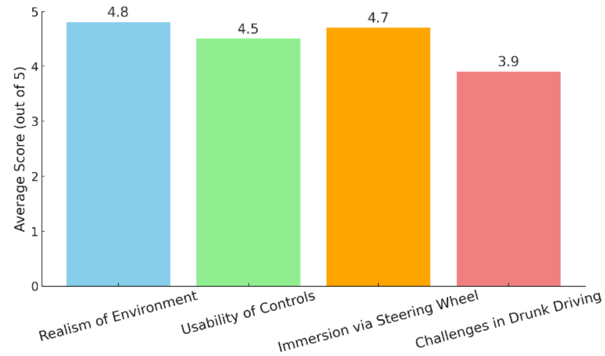

Fig. 9. User Experience Questionnaire Results.

IV. DISCUSSION

The effects of blurred vision and delayed control responses implemented in the virtual environment successfully simulate the impact of alcohol consumption on driving behavior. However, the traffic system despite being composed of autonomous NPCs lacks realistic behavior and does not adapt dynamically to the user's actions, which limits the overall immersion and realism of the scenarios.

To enhance this experience, future work will focus on integrating Machine Learning techniques. By applying Neural Networks and Reinforcement Learning, NPCs could learn to make decisions based on prior interactions within the simulation. This would enable more realistic traffic behavior, such as adaptive speed adjustments, responsive lane changes, and reactions to unexpected player maneuvers.

V. CONCLUSIONS

The Simulation of Drunk Driving was developed using a realistic representation of an area in Palmira, Colombia, incorporating Non-Player Characters (NPCs) to enhance immersion. A steering wheel and pedals were implemented as external hardware devices to provide an authentic driving experience. The simulation focused on replicating two key impairments caused by alcohol consumption: blurred visibility and delayed reaction times. Blurred vision was simulated through a visual blur effect, while delayed reactions were implemented by introducing a 3-second response delay for inputs from the steering wheel and pedals.

Thirty students participated in the study and tested the simulation. To begin, participants were asked whether they usually consume alcohol at parties, and their response determined the conditions of the simulation. The driving time along the predefined 3-kilometer route was evaluated for each participant. The participants were divided into two groups: those who consume alcohol and those who do not. A 1 minute and 25 second difference in driving time was observed between the two groups. This attributed to the impaired visibility and delayed reactions experienced by participants in the group that chose the option indicating alcohol consumption. A post-simulation questionnaire was administered to all participants to evaluate their perceptions of the simulation. The realism of the environment was rated highly, with an average score of 4.8/5, while the immersion provided by the simulation received a score of 3.7/5, reflecting the effectiveness of its design in replicating real-world conditions.

Following formal meetings with the Palmira Transit Authority, which has approved the results of this research, an implementation protocol has been established for educational centers, driving schools, and rehabilitation programs for traffic offenders. This deployment leverages the demonstrated benefits of driving simulators which, according to scientific evidence, immediately improve critical skills such as adjustment to stimuli, lane maintenance, and speed regulation, especially in novice drivers [25]. The implementation includes structured sessions where participants experience normal driving and subsequently simulation under the effects of alcohol, allowing direct comparison of performance in both conditions. Educational campaigns utilize quantitative data collected during the simulations, specifically the difference of 1 minute and 25 seconds in reaction time observed in the current study, to objectively demonstrate the effects of alcohol on safe driving ability.

Looking ahead, the project aims to incorporate Artificial Intelligence (AI) techniques, specifically in the area of Machine Learning, to develop an AI-driven traffic system within the simulation. This enhancement will introduce dynamic traffic scenarios, increasing the complexity and risks associated with driving under the influence.

REFERENCES

[1] O. Halabi, S. Balakrishnan, S. P. Dakua, N. Navab, and M. Warfa, “Virtual and Augmented Reality in Surgery,” *in Lecture Notes in Electrical Engineering*, vol. 674, pp. 257–285, 2020.

[2] S. Shaik, A. Jevin, B. Pajila, R. Siva and R. Kumari, “Exploring the Applications of Augmented Reality and Virtual Reality in Medicine,” pp. 212–222, 2024.

[3] C. Z. Wu, J. Q. Zheng, Z. F. He, and S. C. Wang, “Application and Prospect of VR Technology in the Treatment of Autism,” in Proceedings - 2021 3rd International Conference on Machine Learning, Big Data and Business Intelligence, MLBDBI 2021, Institute of Electrical and Electronics Engineers Inc. pp. 704–707, 2020. doi: 10.1109/MLBDBI54094.2021.00139.

[4] Y. Huang, “Research on the Application of Virtual Reality Interventions in Medicine,” in Proceedings - 2024 Asia-Pacific Conference on Software Engineering, Social Network Analysis and Intelligent Computing, SSAIC 2024, Institute of Electrical and Electronics Engineers Inc., pp. 603–605, 2024. doi: 10.1109/SSAIC61213.2024.00121.

[5] G. Silvera, A. Biswas and H. Admoni, "DReye VR: Democratizing Virtual Reality Driving Simulation for Behavioural & Interaction Research," 2022 17th ACM/IEEE International Conference on Human-Robot Interaction (HRI), Sapporo, Japan, 2022, pp. 639-643, doi: 10.1109/HRI53351.2022.9889526.

[6] M. Xu, X. Xie, P. Lv, J. Niu, H. Wang, C. Li, et al., “Crowd behavior simulation with emotional contagion in unexpected multihazard situations,” *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, vol. 51, no. 3, pp. 1567–1581, 2019.

[7] A. Pilco, X. Luo, A. A. Navarro Newball, C. Zúñiga, and C. Lozano-Garzón, “Procedural Animation Generation Technology of Virtual Fish Flock,” in 2019 International Conference on Virtual Reality and Visualization (ICVRV), pp. 233–237, 2019.

[8] T. Shihabi and R. Mourant, “Toward more realistic driving behavior models for autonomous vehicles in driving simulators,” *Transportation Research Record*, vol. 1843, no. 1, pp. 41–49, 2003, doi: 10.3141/1843-06.

[9] S. Wright, N. J. Ward, and A. G. Cohn, “Enhanced presence in driving simulators using autonomous traffic with virtual personalities,” *Presence: Teleoperators and Virtual Environments*, vol. 11, no. 6, pp. 578–590, 2002, doi: 10.1162/105474602321050712.

[10] R. Rossia, M. Gastaldia, and G. Gecchelea, “Analysis of driver task-related fatigue using driving simulator experiments,” in Procedia - Social and Behavioral Sciences, pp. 666–675, 2011. doi: 10.1016/j.sbspro.2011.08.074.

[11] C. Masterton and A. S. Wilson, “A case study of a virtual reality-based drink driving educational tool,” *Multimed Tools Appl*, vol. 83, no. 18, pp. 55351–55363, May 2024, doi: 10.1007/s11042-023-17658-y.

[12] M. A. Gambito, M. Fazio, A. Ruggeri, A. Celesti, and M. Villari, “Immersive experiences in the metaverse to contrast drunk driving,” in Proc. 2024 IEEE Symp. Comput. Commun. (ISCC*)*, pp. 1–6, 2024. doi: 10.1109/ISCC61673.2024.10733690..

[13] K. Koch et al., “Leveraging driver vehicle and environment interaction: Machine learning using driver monitoring cameras to detect drunk driving,” in Conference on Human Factors in Computing Systems - Proceedings, Association for Computing Machinery, Apr. 2023. doi: 10.1145/3544548.3580975.

[14] U. Ju, J. Williamson, and C. Wallraven, “Predicting driving speed from psychological metrics in a virtual reality car driving simulation,” *Sci Rep*, vol. 12, no. 1, Dec. 2022, doi: 10.1038/s41598-022-14409-1.

[15] T. Abrar, and H. Ali, “Integration of Oculus Rift based Virtual Reality with Unity 3D in a Driving Simulator Internship Report Integration of Oculus Rift based Virtual Reality with Unity 3D in a Driving Simulator,” 2016, doi: 10.13140/RG.2.1.5167.0648.

[16] K. Kanamori, N. Sakata, T. Tominaga, Y. Hijikata, K. Harada, and K. Kiyokawa, “Walking assist method for VR zombie,” in Proc. 2019 12th Asia Pacific Workshop on Mixed and Augmented Reality (APMAR), pp. 1–7, 2019. doi: 10.1109/APMAR.2019.8709270..

[17] C. A. Cutello, M. Gummerum, Y. Hanoch, and E. Hellier, “Evaluating an Intervention to Reduce Risky Driving Behaviors: Taking the Fear Out of Virtual Reality,” *Risk Analysis*, vol. 41, no. 9, pp. 1662–1673, Sep. 2021, doi: 10.1111/risa.13643.

[18] K. Čulík, A. Kalašová, and V. Štefancová, “Evaluation of Driver’s Reaction Time Measured in Driving Simulator,” *Sensors*, vol. 22, no. 9, May 2022, doi: 10.3390/s22093542.

[19] I.-K. Hong, J.-B. Ryu, J.-H. Cho, and W.-S. Lee, “Development of a driving simulator for virtual experience and education on drunk driving,” *Advances in Transportation Studies*, pp. 139–148, 2011, doi: 10.4399/978885484657913.

[20] Y. Matsumoto and G. Peng, “Analysis of driving behavior with information for passing through signalized intersection by driving simulator,” *Transportation Research Procedia*, pp. 103–112, 2015. doi: 10.1016/j.trpro.2015.09.060.

[21] P. Kruachottikul et al., "Car Drive Simulation in Metaverse with VR Glasses for Testing Driver’s License," 2023 First International Conference on Advances in Electrical, Electronics and Computational Intelligence (ICAEECI), Tiruchengode, India, 2023, pp. 1-5, doi: 10.1109/ICAEECI58247.2023.10370994.

[22] H. Suto, X. Zhang, X. Shen, P. Raksincharoensak, and N. Tsumura, “Virtual-Reality-Based Training System for the Improvement of the Driver’s Ability to Predict Dangers in Driving Situations,” *Journal of Electrical Engineering*, vol. 8, pp. 8–16, 2020. doi: 10.17265/2328-2223/2020.01.002

[23] G. Alomía, D. Loaiza, C. Zuñiga, X. Luo, and R. A. Cacheda, “Procedural Modeling Applied to the 3D City Model of Bogota: A Case Study,” *Virtual Reality & Intelligent Hardware*, vol. 3, 2021, pp. 423–433. doi: 10.1016/j.vrih.2021.06.002.

[24] Z. He, M. Shi, and C. Li, “Research and application of path-finding algorithm based on unity 3D,” in Proc. 2016 IEEE/ACIS 15th Int. Conf. Comput. Inf. Sci. (ICIS*)*, pp. 1–4, 2016.

[25] S. Krasniuk, R. Toxopeus, M. Knott, M. McKeown, and A. M. Crizzle, “The effectiveness of driving simulator training on driving skills and safety in young novice drivers: A systematic review of interventions,” *Journal of Safety Research*, vol. 91, pp. 20–37, 2024, doi: 10.1016/j.jsr.2024.08.002.