Influence of a Serious Video Game on the Behavior of Drivers in the Face of Automobile Incidents

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***Abstract*—The primary objective of this research was to enhance driver behavior during incidents through the use of a serious video game. The study employed a true experimental design. The research population consisted of an unspecified number of drivers from the city of Trujillo. Sixty drivers from Trujillo were randomly selected, with 30 assigned to the control group and 30 to the experimental group. The experimental group utilized a video game developed in Unreal Engine 5.2.1., observation forms were used to gather information, and the collected data were subsequently analyzed and processed using the statistical software Jamovi v2.4.11. The results revealed a decrease equivalent to a 43.75% reduction in the number of action mistakes, a 51.14% reduction in the number of intention mistakes, a 31.4% decrease in the number of traffic law violations, and a 42.92% reduction in the number of aggressive attitudes. In conclusion, the use of a serious video game significantly improved driver behavior during incidents.**

***Keywords*—Videogame; serious; behavior; driving; incidents**

I. Introduction

Mobility is an essential need for human beings, which requires transportation systems to make it possible. The arrival of the pandemic presented new and additional challenges in addition to existing ones, for example, inappropriate driver behavior. Since December 31, 2019, when the first case of COVID-19 was reported in Wuhan, the world has fought against the spread of this disease, which reached Latin America and the Caribbean at the end of February 2020. Since then and until 2023, the governments of the region have taken various measures that have directly or indirectly affected mobility and its characteristics [1].

The World Health Organization [2] stated that worldwide, road traffic accidents caused almost 1.3 million preventable deaths and an estimated 50 million injuries per year. Similarly, the Andean Community (2020) mentioned that, in 2020, the number of road traffic accidents in the community constituted by Bolivia, Colombia, Ecuador and Peru decreased by 32.3% compared to 2019, from 328,418 to 222,340. It also mentioned that, in Peru, traffic accidents decreased by 40.2% compared to 2019, going from 95 800 to 57 335.

In addition, the Road Safety Directorate [3] indicated that in the last four years, a total of 12079 traffic accidents were registered in the province of Trujillo, which generated 137 deaths and 13961 injuries. During that period, the accident rate was increasing, in contrast to 2020, where a decrease of 50.6% was observed compared to 2019. It is important to note that although the COVID-19 pandemic contributed to the decrease in traffic accidents in 2020, the trend in the province of Trujillo has been increasing in recent years, which requires more effective measures to improve road safety and driver behavior. The measure that was proposed is a serious video game.

Video games have become a very useful tool due to their capacity to provide interactive content and to transmit audiovisuals in real time, and their global interactivity capacity allows them to be used in various fields, such as education, medicine, advertising, collective communication and art, among others. In Latin America, Mexico and Brazil were the main generators of video game revenues, while Peru ranked sixth in the list with a figure of US$152 million [4].

A serious video game is distinguished from entertainment games, because its main purpose is educational or informative. These games have a great influence on the way players interact cognitively, emotionally and socially, which increases their motivation and commitment. Gamification of an environment can encourage people to engage in tasks that might otherwise seem repetitive, to experience failure, and to try again despite the risk. Furthermore, in the workplace, the incorporation of serious games can provide many benefits for companies, such as improved employee retention and recruitment, increased program adoption, and better overall job performance [5]. Given the aforementioned arguments, the following general research question was asked: How did the use of a serious video game improve drivers' incident behavior in Trujillo, 2023?

The theoretical justification for this research is based on [6] who mentioned that serious games are simulated representations of reality, in which a fictitious scenario is constructed based on real problems. Since it is a game environment, there is the ability to adjust variables and explore different scenarios without causing any harm in real life. And in study [7] who stated that safe driving involves carefully examining the visual environment in order to identify and differentiate relevant stimuli for smooth performance.

The methodology used in this research was justified for several reasons. Random sampling made it possible to obtain a representative sample of drivers in the city of Trujillo, which guaranteed generalizable and applicable results in broader contexts. The use of observation cards captured drivers' behavior in real time while driving, providing objective information on the indicators, number of action errors, number of intention errors, number of traffic law violations, and number of aggressive actions. In addition, the face-to-face evaluation during actual driving ensures greater ecological validity when confronted with real-life situations.

This research was relevant in practice, since it sought to address an important problem in road safety. The development of the serious video game aimed to improve the behavior of drivers in the city of Trujillo and contribute to the reduction of accidents and reckless behaviors on the roads. The implementation of experimental and control groups allowed us to rigorously evaluate the effectiveness of the video game in modifying the behavior of drivers. These results were useful in designing interventions and training programs aimed at improving road safety and reducing driving risks.

The research on improving driver behavior in Trujillo through a serious video game was socially relevant. Since road safety is a major concern, and it is essential to implement effective strategies to encourage responsible driving behaviors, the proposed video game has the potential to educate drivers and raise awareness about the consequences of their actions behind the wheel, promoting safer behaviors. This can have a positive impact on reducing accidents, injuries and human losses, improving the quality of life in the Trujillo driving community.

Therefore, the research "Serious video game to improve the behavior of drivers in the event of incidents in Trujillo, 2023" was undertaken. The main objective was to improve the behavior of drivers in the event of incidents through the use of a serious video game in Trujillo in 2023, with the specific objectives of reducing the number of action errors, reducing the number of intention errors, reducing the number of traffic law violations, and reducing the number of aggressive attitudes.

The main hypothesis was: if a serious video game was used, then the behavior of drivers in Trujillo in the year 2023 would be significantly improved; and the specific hypotheses were: if a serious video game was used, then the number of action errors in Trujillo in the year 2023 would be decreased, if a serious video game was used, then the number of action errors in Trujillo in the year 2023 would be decreased; then the number of intention errors decreased in Trujillo in the year 2023, if a serious video game was used; then the number of traffic law violations decreased in Trujillo in the year 2023 and if a serious video game was used; then the number of aggressive attitudes decreased in Trujillo in 2023.

II. Related Work

As background, the research [8] titled "The impact of gamification and serious games on driving under unknown traffic rules", aimed to evaluate the impact of gamification elements in driving simulators on road safety in unknown traffic situations. A quantitative and qualitative experimental approach was used, with a sample of 14 people. The results showed that, when driving without a gamification element, there were 13 cases of driving against the flow of traffic and 15 cases of misuse of the signal indicator. However, when driving with the gamification element, these errors were reduced to 1 case of driving against the flow of traffic and 6 cases of signal indicator misuse. In conclusion, serious games and gamification were effective in decreasing driving errors in unfamiliar traffic situations.

III. Theoretical Framework

A. Serious Video Game

Type of game designed for a purpose other than simple entertainment; their focus is usually educational or goal-oriented. The serious ones share similarities with simulation genres, since they seek to offer more realistic representations and provide teachings about real-life situations [9].

In addition, the serious game incorporates, in this way, a specific purpose that transcends mere entertainment, and this objective may be related to education, the generation of changes in attitude, the development of new competencies or skills in the player in a specific context, among other things History, Geography, Mathematics or the understanding of social issues. What is essential is that, at the end of the experience, the player has acquired a new knowledge, skill or attitude that he or she did not have before [10].

B. Driver Behavior

The analysis of human behavior in driving is essential to achieve a deeper understanding of the traffic phenomenon, since it is people who make crucial decisions, among them the choice of route, type of vehicle, vehicle maintenance, and traffic regulations, besides being the direct performers of actions when driving a vehicle in different situations. The human factor involves several aspects of the human psyche, considering the relevance of each one of them in the performance as drivers. Although the observable manifestations are usually gestural, movement or linguistic, their cause is due to the complex interaction of multiple factors, among them psychophysical, emotional and cognitive aspects, which complicates the study of the roots of human driving behavior [11].

C. SUM Methodology

The SUM methodology is a derivative of SCRUM, taking advantage of the popularity of agile methodologies, especially in contexts of fast, precise and optimized programming, as is the case of video game development. Its central purpose is to achieve efficient and cost-effective development of high-quality software, with a constant focus on continuous process improvement to optimize its efficiency and effectiveness [12].

IV. Material and Methods

A. Research Typology

Applied: The essence of applied methodology is problem-solving, focus on applying specialized knowledge from one or several areas to specific contexts. Its primary goal is to provide practical solutions to specific needs in social or productive fields. This methodology is centered on identifying and resolving a particular problem or question, dedicating itself to the research and consolidation of knowledge for practical application [13].

B. Research Design

Pure experimental, the key feature is evaluating the effects of an intervention, whether preventive or corrective. This involves carefully selecting a group of individuals and obtaining their prior consent. Participants are then randomly divided into two or more groups, including control and

experimental groups. This design is fundamental in understanding the impacts of various interventions [14].

C. Variables and Operationalization

1) Independent variable: Serious video games are a virtual representation of reality, in which a fictitious scenario based on real situations is recreated. In these games, the player assumes a specific role within the situation and is responsible for solving the challenges present in the scenario. Through interaction and decision-making, the player seeks to find effective solutions to the problems posed. These games allow users to develop skills and acquire practical knowledge by facing situations similar to those they would encounter in the real world [6]. A driving simulation video game will be used by the experimental group of 30 people. A nominal scale will be used.

2) Dependent variable: Driver behavior is safe driving that requires a detailed examination of the visual environment to identify and distinguish stimuli that are relevant to smooth driving. In addition, the driver must be able to select relevant stimuli from the context in a specific traffic situation, even when such stimuli are hidden or disguised in a complex visual field. In summary, safe driving involves the ability to interpret and respond appropriately to visual stimuli in different traffic scenarios. [7]. The driver behavior variable was measured through four indicators, which are: Number of action errors, the number of intention errors, Number of traffic law violations, and the number of aggressive attitudes, which shall use the ratio scale.

D. Population, Sample and Sampling

1) Population: The target population refers to the set of individuals who are relevant to the main problem or objective of the study; these individuals represent the group to which the results are intended to be generalized. The target population is characterized by its general demographic and clinical features. The study population is a specific group within the target population that is chosen according to the criteria defined in the research protocol. This selection is made with the purpose of carrying out the study in a more accessible and controlled manner. It is important to keep in mind that the study population may have particular geographical and temporal characteristics that make it suitable for the purposes of the research [15]. In this case, the study population consists of all drivers residing in the city of Trujillo.

A sample is defined as a portion or subset of representative elements extracted from a larger set, known as the population or universe. This selection is made randomly and is meant for scientific observation, with the goal of obtaining results that are applicable to the entire universe under investigation within established limits of error and probability specific to each situation [16]. In the context of the research mentioned, the sample consists of 60 drivers randomly selected from the city of Trujillo, divided into control and experimental groups, each comprising 30 drivers. Biases were prevented, and representative results for the population were guaranteed with randomized sampling.

E. Data Collection Techniques and Instruments

In terms of data collection techniques and instruments, non-participant observation is a method where no direct contact is established between the researcher and the subjects under study. This technique is particularly utilized in administrative fields to observe employees in a company, ensuring that their tasks are carried out without impacting their productivity or performance [14]. This research employs observation as its primary data collection technique.

The observation sheet, facilitates the systematic recording of behaviors, enabling an accurate assessment of the information collected. This tool allows the observed behaviors to be documented in an organized manner, which is essential for an adequate and comprehensive assessment of the information collected [17]. For this research, four observation sheets were made for the indicators: the number of action errors, the number of attention errors, the number of traffic law violations, and the number of aggressive attitudes.

F. Procedures

In this study, random sampling was utilized to select participants. A total of 60 drivers from the city of Trujillo were chosen through a random process to be part of the study. Once selected, these drivers were further randomly divided into two groups: a control group and an experimental group, with each group comprising 30 drivers. The assignment of drivers to each group was carried out using a random assignment process in Excel. This approach was chosen to ensure that both groups were comparable in terms of demographic characteristics and driving experience. The research flowchart presented in Fig. 1.

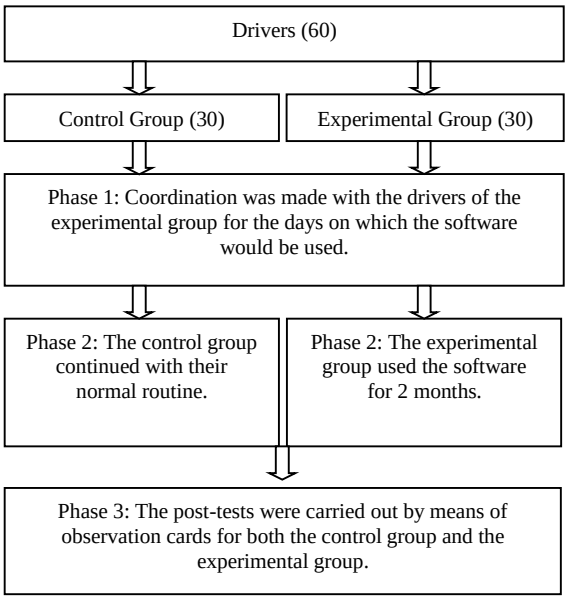


Fig. 1. Research flowchart.

The focus of the study was on a serious video game designed specifically to improve driver behavior in Trujillo. The experimental group was given access to this video game and received instructions on its proper use. They were also allowed a certain period to practice with the game before undergoing evaluations. In contrast, the control group did not receive any additional intervention; they continued their

regular driving routines without access to the video game. This setup allowed for a comparison between the two groups, aiming to evaluate the specific impact of the video game on the drivers' behavior.

For the study, observation sheets were developed containing several specific indicators to evaluate the behavior of drivers in Trujillo during incidents. These indicators included the number of action errors, which recorded the mistakes drivers made while executing specific actions. Another indicator was the number of intention errors, capturing errors in decision-making and action planning while driving. The sheets also tracked the number of traffic law violations, noting any infractions drivers committed relative to current traffic rules and regulations. Additionally, the number of aggressive attitudes was evaluated by observing behaviors. The evaluation of driver behavior was conducted in person while driving in real traffic conditions. The evaluators used observation sheets for data recording, and then a descriptive and inferential analysis was performed between the experimental and control groups, using statistical techniques to identify significant differences in the indicators assessed. A detailed analysis of each indicator was conducted to identify patterns and trends in driver behavior. This process evaluated the effectiveness of the video game in improving driver behavior in Trujillo. The results helped to understand the impact of the video game and could inform strategies to promote safer driving in the city.

To carry out this study, random sampling was applied to select the research participants. Since 60 drivers were randomly selected to participate in the study, once they were selected, they were randomly divided into two groups: a control group and an experimental group. Each group was composed of 30 drivers. Then, the assignment of drivers to each group was done through a random assignment process in Excel to ensure that the groups were comparable in terms of demographic characteristics and driving experience.

The experimental group used a serious video game designed specifically to improve driver behavior in the city of Trujillo. The drivers in the experimental group were given access to the video game and were instructed on its proper use; they were allowed to practice with the video game for a certain period of time before performing the evaluations. The control group did not receive any additional intervention and continued with their normal driving routine without access to the video game. This allowed comparison of the results between the experimental group and the control group, thus evaluating the specific impact of the video game on the drivers' behavior.

G. Development through SUM Methodology

1) Concept phase: During this period, the conceptual document was drafted, which provides a detailed description of the video game, addressing aspects such as its distinctive attributes, genre, game mechanics, setting, narrative, target audience, and the sources that served as inspiration. A detailed explanation of some of the aforementioned features is provided below.

2) Game vision: A driving video game will be developed, that allows the user to learn how to behave while driving, in a 3D environment, focusing on the educational and driving simulation video game genres.

3) Technologies: Visual Studio IDE, C++ programming language, Unreal Engine, and Blender.

4) Architecture: The architecture used in this research consists of a logic module, animation module, player module, game objects and resources module and finally a graphical interface as shown in Fig. 2.

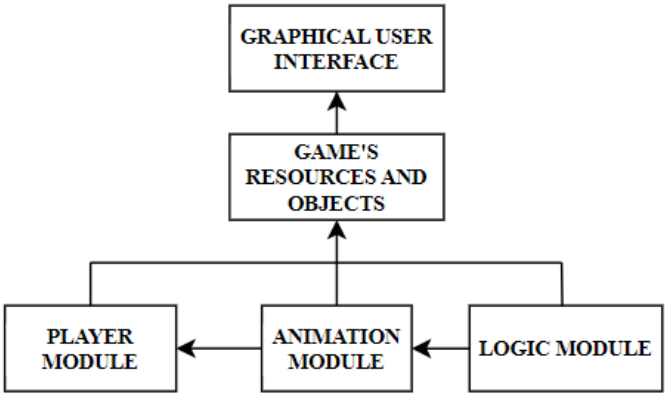


Fig. 2. Video game architecture diagram.

5) Planning phase: In this stage, the fundamental document of the project is prepared. This includes a detailed explanation of the work performed, the rationale of the project, the parties involved, quantifiable goals, functional requirements in Table I, and non-functional requirements in Table II. It also includes assumptions and other relevant components. In addition, both the activity plan and the project budget are detailed in this document.

6) Functional Requirements.

Code	Description
RF01	Interactive scene with situations of action errors.
RF02	Interactive scene with situations of intention errors.
RF03	Interactive scene with situations of traffic law violations.
RF04	Interactive scene with situations of aggressive actions.
RF05	Show the correct actions or decisions for each situation.

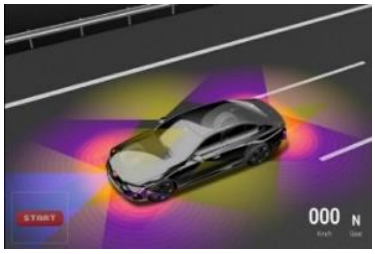
[a] Source: Own work

TABLE I. NON-FUNCTIONAL REQUIREMENTS

Code	Description
RNF01	Compatibility with the largest number of devices, whether laptop or desktop pc.
RNF02	Spanish language.
RNF03	Simple gameplay.

[b] Source: Own work

TABLE II. VIDEOGAME SCREENSHOTS

Videogame	Remarks
	Main start view
	Main scenario in which the player can freely roam the city.
	Decision making interface in which the user is suggested a situation.
	Action error interface, when the user makes a mistake when interacting with the scenario, 1 point will be automatically deducted.

[c.] Source: Own work.

7) Elaboration phase: The aim of this stage is to carry out the implementation of the video game. This involves adopting an iterative and incremental approach, ensuring the development of a functional version of the video game at the conclusion of each iteration.

a) Iteration 1: As can be seen in Fig. 3, it started with small scenery: one vehicle and six buildings, the road, and boundary markers; the vehicle can be controlled in any direction. The third-person camera follows the vehicle and performs the necessary movements when the player turns.

b) Iteration 2: As shown in Fig. 4, actors were implemented in the scenario to be used as collisions that activate the messages on the screen; each one will disappear as soon as the driver finishes interacting with the interface. In Fig. 5, control of the vehicle will be returned, and the driver will be able to continue.

c) Iteration 3: As shown in Fig. 6, a new vehicle was implemented, which will be an extra that will fulfill the function of generating traffic in the scene. Several functionalities were programmed, including stopping at the traffic light when it is red or following a specific route.

d) Iteration 4: As shown in Fig. 7, the scenario was completed with 4 blocks, 2 extra vehicles, 4 traffic lights with their logic of lights and interactions presented in Fig. 8, and a coordinated building aesthetics. All interaction points were placed, sound to the main vehicle, and the corresponding messages on screen.

Fig. 3. Progress of the first iteration.

Fig. 4. Progress of the second iteration.

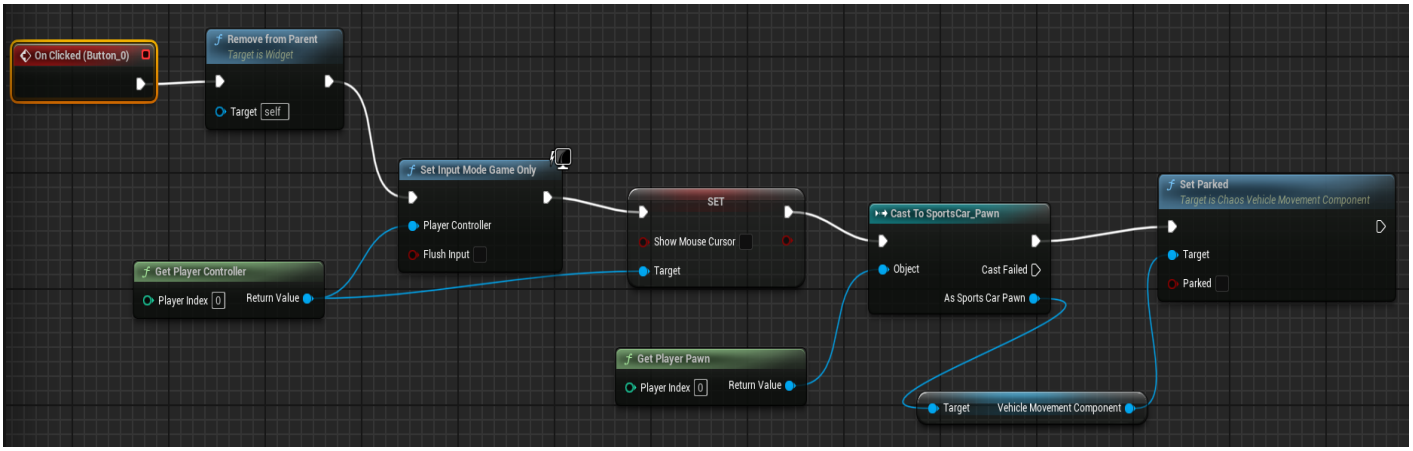


Fig. 5. Programming (Blueprints) interface in unreal engine 5.2

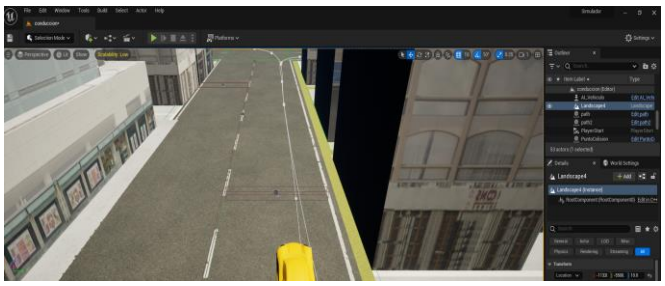


Fig. 6. Progress of the third iteration.

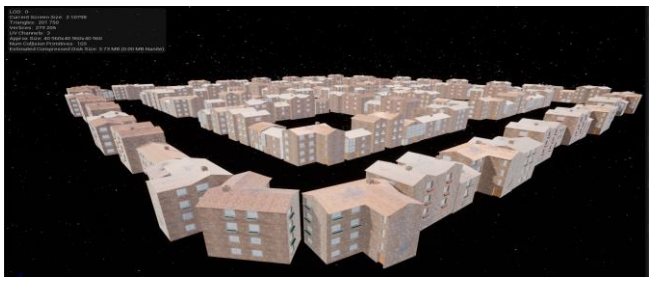


Fig. 7. Progress of the fourth iteration.

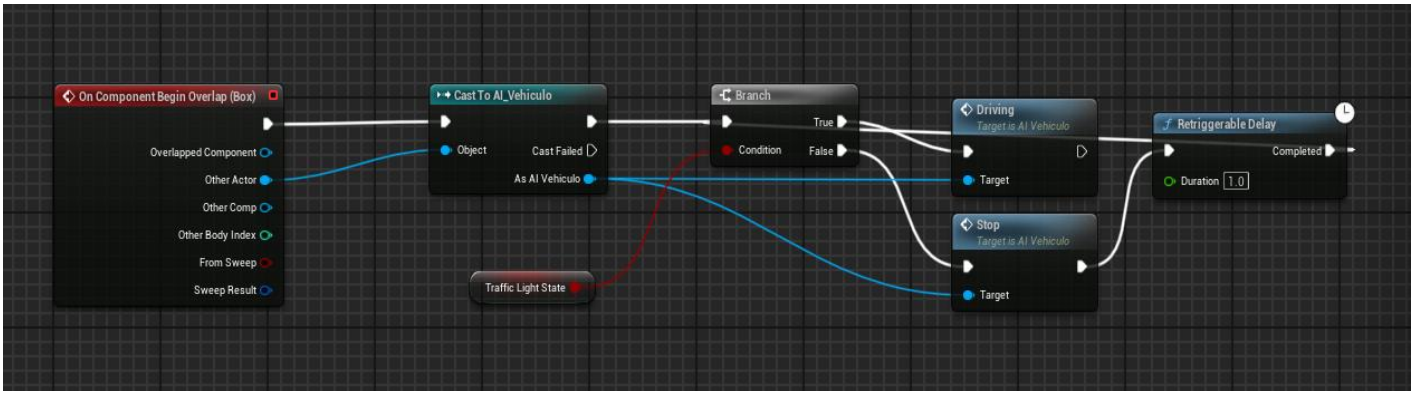


Fig. 8. Programming (Blueprints) traffic light interaction in unreal engine 5.2.

8) Beta phase: At the end of the development, we proceeded to package and install the video game on different computers with the Windows operating system. Several failures were found at the time of packaging the software, which generated a time of verification and error correction. After doing so, we proceeded to the packaging.

Performance and playability tests were started, which were correct in mid-range devices (GTX 1060 dedicated graphics card, 16GB RAM).

Performance and playability tests on low-end devices (no dedicated graphics card), failed.

a) Errors: When running the video game, the textures failed and the scenery was not displayed completely. At the moment of joining the player and an extra vehicle at a traffic light, the extra vehicle did not move again.

b) Fixes: Faulty textures were changed and the error of the extra vehicles was corrected.

9) Closing Phase: In this phase, we proceeded to launch the final version of the video game using Unreal Engine 5.2, accompanied by the enumeration of the lessons learned throughout the process. Some of these lessons include:

a) When working with Unreal Engine, it's crucial to carefully choose the version for development due to the potential for significant changes between different versions. It is advisable to consult the official documentation thoroughly before selecting a specific version, as this can affect various aspects of game development.

b) Creating a video game from scratch is a complex and challenging task that requires a considerable amount of information and practice for optimal development. Each aspect, from game mechanics to interactions within the game environment, needs careful planning and execution, as shown in Table III. Game executable can be found at https://acortar.link/wgI7ba

TABLE III. DESCRIPTIVE ANALYSIS FOR ALL INDICATORS

Research Indicator	Average		P	N < Average			% < Average		
	GC	*GE*		*GE*	*MP*	*GC*	*GE*	*MP*	*GC*
NEA	3.2	1.8	2	11	11	30	36.67	36.67	100
CEI	4.83	2.47	2	16	8	29	53.33	26.67	96.67
NVLT	2.23	1.53	2	16	16	28	53.33	53.33	93.33
CAA	4.73	2.7	2	17	7	26	56.67	23.33	86.67

[d] Source: Own work

H. Data Analysis Methodology

In this section, the specific hypotheses for the indicators of the dependent variable were established. For the indicator of the number of action errors, the alternate hypothesis (Ha) was that if a serious video game is used, it will decrease the number of action errors in the post-test of the experimental group (CEAGE). This was compared to the post-test sample of the control group (CEAGC). Regarding the indicator of the number of intention errors, the alternative hypothesis (Ha) was that the use of a serious video game would decrease the number of intention errors in the post-test of the experimental group (CEIGE). Compared to the post-test sample of the control group (CEIGC). For the indicator of the number of traffic law violations, the alternative hypothesis (Ha) stated that using a serious video game will reduce the number of traffic law violations in the post-test of the experimental group (CVLTGE). This is compared to the control group post-test sample (CVLTGC). Lastly, for the indicator of the number of aggressive attitudes, the alternative hypothesis (Ha) is that if a serious video game is used, the number of aggressive attitudes in the post-test of the experimental group (CAAGE) will decrease. This is compared to the control group post-test sample (CAAGC).

Descriptive analysis: An analysis of the data collected in this research was carried out. The data obtained in the experimental group were tripled to perform the calculations, and the average of the data collected for each indicator was obtained, both from the control group and the experimental group. An acceptable goal was then established based on the background or the goal expected by the entity. The amount of data that exceeded the average of the control group was counted, as well as the average of the experimental group and those data that exceeded the established goal, and the corresponding percentage was calculated for these results. In addition, a table of descriptive statistics was generated using the software Jamovi for each indicator.

Inferential analysis: At this point, normality tests (Shapiro-Wilk) and histograms were performed for each indicator using Jamovi software. As a result of the normality tests, if both variables were normally distributed, then parametric tests were

Applied (T-Student), and if any of the variables were abnormally distributed, nonparametric tests were applied (Mann-Whitney U). And it was defined whether the null hypotheses were accepted, or if otherwise the alternative hypotheses were accepted.

V. RESULTS

In this section, the main point was the descriptive analysis, with which the results were interpreted. The corresponding mean values were obtained using the Jamovi statistical software, and the decrease in the data of the experimental group compared to those of the control group was identified and presented. The second point was the inferential analysis, in which normality tests and hypothesis testing were performed for each indicator. You can access the database at the following link: https://figshare.com/s/1fa9139817410ca889c7

A. Descriptive Analysis

Table IV provides data on the average number of errors and violations committed by drivers in the control group (CG) and the experimental group (GE) in their respective post-tests. For action errors in the CG post-test, 36.67% were lower than their average, another 36.67% were lower than the target, and all 100% were lower than the CG's average.

TABLE IV. NORMALITY TEST STATISTIC SHAPIRO-WILK BY INDICATOR

Nº	Research Indicators	Statistic		p	
		GC	*GE*	*GC*	*GE*
1	Number of Action Errors	0.943	0.798	0.112	<.001
2	Number of Intent Errors	0.962	0.923	0.345	0.035
3	Number of Traffic Law Violations	0.852	0.732	<.001	<.001
4	Number of Aggressive Attitudes	0.947	0.861	0.145	0.001

[e] Source: Own work

In terms of intention errors in the CG post-test, 53.33% were lower than their average, 26.67% were lower than the target, and 96.67% were lower than the CG's average

Regarding traffic law violations in the GE post-test, 53.33% were lower than their average, another 53.33% were lower than the target, and 93.33% were lower than the CG's average. This data suggests a significant variation in the performance of drivers in both groups across different types of errors and violations.

B. Inferential Analysis

According to the data in Table V, for the indicator Number of Action Errors (NEA) in the Control Group (CG), the p-value was 0.112. This indicates that the data were normally distributed, as the p-value was greater than 0.05. In contrast, in the Study Group (SG), the p-value for NEA was less than .001, showing that the data were non-normally distributed, as the p-value was less than 0.05. This led to the application of a non-parametric test when one of the groups showed a non-normal distribution.

TABLE V. HYPOTHESIS TESTING STATISTICS U DE MANN-WHITNEY BY POSTTEST INDICATOR

Nº	Research Indicators	Statistics	p
1	Number of Action Errors	290	0.007
2	Number of Intent Errors	147	< .001
3	Number of Traffic Law Violations	277	0.003
4	Number of Aggressive Attitudes	190	< .001

[f.] Source: Own work.

For the Quantity of Intention Errors (CEI) indicator, the p-value for the CG was 0.345, indicating that its data were normally distributed, as the p-value was greater than 0.05. However, for the SG, the p-value was 0.035, which indicated non-normal distribution of data since the p-value was less than 0.05. Again, this necessitated the use of a non-parametric test when data in one of the groups were non-normally distributed.

Similarly, for the indicator Number of Traffic Law Violations (NVLT), its p-value was <.001 for the CG, which proved that its data were non-normally distributed, and for the SG, its p-value was <.001, which proved that its data were non-normally distributed, which allowed identifying that since both groups were non-normally distributed, a non-parametric test would be used.

Similarly, for the indicator Number of Aggressive Attitudes (CAA), the p-value for the CG was 0.145 greater than 0.05, which established that its data were normally distributed, and for the EG the p-value was 0.001 less than 0.05, which determined that its data were non-normally distributed, which allowed us to identify that when one of its groups was non-normally distributed, a non-parametric test was used.

According to the data obtained in Table VI for the Number of Errors of Action Indicator (NEA) its p-value was 0.007 less than 0.05, there was sufficient statistical evidence to reject the null hypothesis (Ho) and accept the alternative hypothesis (Ha); for the Number of Intention Errors Indicator (CEI) its p-value was <. 001 less than 0.05, there was sufficient statistical evidence to reject the null hypothesis (Ho) and accept the alternative hypothesis (Ha); for the Number of Traffic Law Violations Indicator (NVLT) its p-value was 0. 003 less than 0.05, there was sufficient statistical evidence to reject the null hypothesis (Ho) and accept the alternative hypothesis (Ha); for the Number of Aggressive Attitudes Indicator (CAA) its p-value was <.001 less than 0.05, there was sufficient statistical evidence to reject the null hypothesis (Ho) and accept the alternative hypothesis (Ha).

VI. DISCUSSION

From the results obtained, it was evident that with the use of a serious video game. The number of errors of action, the number of errors of intention, the number of traffic law violations, and the number of aggressive attitudes were reduced. This demonstrates that the use of a serious video game significantly improved the driver's behavior.

Regarding the main goal, which sought to improve the behavior of drivers in the event of incidents through the use of a serious video game in Trujillo in 2023, it was determined that it did indeed improve the behavior of drivers. This was evidenced by the decrease in the average of all indicators measured; the results are similar to the research [8], in which the effectiveness of gamification elements in driving simulators on road safety in unknown traffic situations was assessed and proven.

Regarding the first indicator, which is the number of action errors (CEA), the total average was 3.2 in the control group and 1.8 in the experimental group, which showed a reduction of 1.4 action errors. In addition, it was evident that of the 100% average action errors of the control group, the average of the experimental group equals 56.25%; this proved a 43.75% reduction of action errors after implementation. The results were generally comparable with the research [8], which presented a 13–1 decrease in the number of action errors. It should be noted that the author Useche [18] defines action errors as errors in the execution planned by the driver, which can manifest themselves in terms of observation, execution, or incorrect judgments and do not involve intentional actions.

Regarding the second indicator, which is the number of intention errors (CEI), there was a total average of 4.83 in the control group and 2.47 in the experimental group, which showed a reduction of 2.36 in intention errors. In addition, it was evidenced that of the 100% average intention errors in the control group, the average in the experimental group equaled 48.86%; this proved a 51.14% reduction in intention errors after implementation. The results were generally comparable with the research [19], which presented a decrease of 40%, 30%, 25%, and 30% in the number of errors. It should be noted that the author Useche [18] defines intention error as errors in the attention or memory processes that hinder the proper execution of the driving task.

Regarding the third indicator, which is the number of traffic law violations (NVLT), a total average of 2.23 was obtained in the control group and 1.53 in the experimental group, which showed a reduction of 0.7 traffic law violations. In addition, it was evidenced that of the 100% of the average traffic law violations in the control group, the average in the experimental

group equals 68.60%, which proved a 31.4% reduction of traffic law violations after implementation. The results are generally comparable with the research [20], who obtained that a video game can help in the understanding of laws by up to 90%. It should be noted that the author Useche [18] defines traffic law violations as intentional violations of traffic rules, laws, or codes, which are deliberate actions.

Regarding the fourth indicator, which is the number of aggressive attitudes (CAA), a total average of 4.73 was obtained in the control group and 2.7 in the experimental group, which showed a reduction of 2.03 aggressive attitudes. In addition, it was evidenced that of the 100% average aggressive attitudes of the control group, the average of the experimental group equals 57.08%; this proved a reduction of 42.92% aggressive attitudes after implementation. The results are generally comparable with the research [21], which found that cab drivers are more likely to commit aggressive attitudes, with a 98% chance during the year. It should be noted that the author Useche [18] defines aggressive attitudes as manifestations of hostility directed towards other road users or driving patterns strongly linked to aggressive behavior by the driver.

Finally, it was concluded that with the use of a serious video game, the behavior of drivers in the city of Trujillo 2023 was improved.

VII. LIMITATIONS

During the development of the research, several limitations arose that influenced the process and the obtaining of comprehensive results. Among the most prominent limitations was the availability of the drivers, whose work schedules sometimes made it challenging to coordinate the tests efficiently. This variable, in turn, was affected by traffic variability at specific times when post-tests were conducted, introducing an unpredictable element that could have influenced the consistency of the data collected.

Another significant limitation was the time constraint for data collection. The need to collect relevant information in a limited period of time may have impacted the completeness of the research, limiting the amount of data that could be collected and analyzed in detail.

In addition, the need on the part of the researcher to acquire knowledge of new video game development software was identified. This limitation not only added a learning curve to the project but also implied dedicating additional time to becoming familiar with the necessary tools. This factor may have impacted the efficiency of the implementation of certain parts of the study.

Finally, limitations were found related to the hardware used for the execution of the video game. These constraints could have affected the quality and accuracy of the results obtained, since the performance of the hardware can directly influence the execution of the software and thus the user experience and the data collected.

Taken together, these limitations underscore the inherent complexity of the research and highlight the importance of addressing these challenges strategically to mitigate their impact on the validity and reliability of the findings.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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