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The Impact of Gamifications and Serious Games on Driving under Unfamiliar Traffic Regulations

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Abstract: Drivers face many challenges when driving under unfamiliar traffic regulations, which may lead to a reduction in road safety. The need to adjust to different traffic rules could be a major factor toward a safer drive. Gamification is a promising way to enhance the user engagement in non-game tasks. In this paper, we hypothesize that gamification can improve driving performance and minimize the number of driving errors when driving under unfamiliar traffic regulations and thus enhance road safety. A game was designed to provide gamification elements in a simulated driving environment with unfamiliar traffic regulations where the players were motivated to reach the target with no errors. In the experiments, 14 participants who were not familiar with the designed traffic regulations were asked to drive a car simulator in two scenarios. The first scenario had no gamification elements, whereas the second one included gamification elements. The results indicated that gamification significantly helped the participants to drive in the correct traffic flow with the proper use of vehicle configuration. Our findings show that gamified simulation is a reasonable method to adjust the required driving performance and behavior to safely drive under unfamiliar traffic regulations.

Keywords: gamification; serious games; road safety; unfamiliar traffic environment

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1. Introduction

When driving under unfamiliar traffic regulations—as is often the case when driving overseas—the interaction among the driver, vehicle, and road environment can be very challenging and can, therefore, lead to safety concerns. The New Zealand Ministry of Transport report revealed that adjusting to New Zealand traffic rules (i.e., keep-left traffic regulation) was a challenge for drivers who inhabit keep-right countries (e.g., the United States of America and China) [1]. The challenges included determining the correct traffic flow, the incorrect use of vehicle controls, and remembering to keep left. As a result, such drivers were often involved in intersection collisions, single-vehicle collisions, driving off the road, and head-on crashes.

International drivers in New Zealand have been involved in a relatively large number of serious vehicle accidents. Therefore, Page and Meyer [2] provide some solutions to increase drivers' safety. These solutions include presenting prominent signage near airports and attractive tourist places and educating international drivers about traffic regulations using training videos and audio messages.

More recently, to address this problem, Driver Safety Australia started road safety training programs using driving simulators in Queensland to put students and fleet drivers in realistic Australian on-road situations that offer a vast array of training possibilities and a range of driving conditions [3]. Similarly, another simulator, MyDriveschool in

Victoria, offered to teach teenagers potentially lifesaving driving skills from home during the COVID-19 pandemic in 2020 while tests were cancelled and delayed for several months, leaving a backlog of prospective P-platers [4].

There are examples of driving simulators in other parts of the world. For example, in the Netherlands, the ANWB driving course, one of the largest driver training schools, has integrated simulator training in their entire basic driver-training program, using a pro-jected environment and a mock-up of a real car [5].

In earlier studies conducted by [6], it has been suggested that driver simulators can be very useful for the training of higher order skills that are performed at the knowledge-based level and require all steps in perceptual and cognitive processes (such as perception, diagnoses, prognosis, decision, and action). However, later studies cast some doubts on the usefulness of driver simulators such as [7] and [8] in terms of the acquisition of higher order skills. According to [7], although splitting up tasks into part tasks and mass repetition of part tasks helps to speed up the learning process, it does not help knowledge retention. Christie and Harrison [8] argue that situational awareness is the product of a wholistic experience rather than education, and it is not useful to split up the tasks and train them separately.

In this paper, our goal is to evaluate the impact of gamification elements used in driving simulators on road safety when driving under unfamiliar traffic regulations (i.e., keep-left traffic regulations for drivers who only have experience in driving in a keep-right traffic regulations). Gamification is adding game elements and game mechanics into nongame environments to engage users to interact with the other elements in the simulation while achieving a goal. These include points, leaderboards, badges, levels, and challenges. Gamification is often used to motivate people to reach particular achievements, such as completing a certain task, performing a certain action, or solving a certain problem, and can indirectly change behavior toward a specific issue (e.g., eco driving) [9].

While research on gamification and serious games has increased in the last few years, there are few studies that address gamification and drivers' safety. Thus, this article examines the use of gamification in driving, particularly when driving under unfamiliar traffic regulations, through an empirical study. The study evaluates driving safety in a simulator supported by gamification elements. Therefore, this paper contributes to a better understanding of the difficulties of driving under unfamiliar traffic regulations and the effects of gamification and serious games on diminishing those difficulties, thus improving the road safety in unfamiliar traffic regulations.

This paper is organized as follows. It starts by reviewing the relevant literature on gamification, serious games, and driving simulators (Section 2), while Section 3 reviews the related work. Subsequently, Section 4 describes the implemented simulated driving environment and gamification elements. Section 5 introduces the conducted experiments, while Section 6 comprehensively presents the experimental results and Section 7 evaluate the effectiveness of gamification in terms of improving the road safety when driving under unfamiliar traffic regulations. Section 8 addresses the limitations of this study and concludes the work.

2. Background

2.1. Gamification

Gamification refers to the "use of game techniques in non-game contexts to motivate user engagement" [10]. In terms of software design, gamification attempts a process of "incorporating game elements into non-gaming software applications to increase user experience and engagement" [10]. Gamification provides an interactive learning experience which can motivate the users to achieve optimal outcomes (e.g., [11,12]). Gamifications are also used for better user engagement and satisfaction with a new environment or changes of surroundings in different contexts such as tourism [13] and organizational environments [14,15].

In driving, gamification approaches, especially feedback, are the preferences to encourage young drivers for safer driving behavior [16]. These approaches are various. Some use smartphones to receive feedback on driving scores (e.g., [12,17,18], while others use physical platforms for training in a driving simulator (e.g., [19]). Additionally, some studies use visual feedback [12], while others use auditory feedback [20]. While providing ambiguous feedback may distract drivers [10], useful feedback may improve their performance. For instance, Alyamani et al. [21] proposed a list of preferred feedback modality and presentation mechanisms to enhance drivers' awareness of their surroundings.

Steinberger et al. [22] suggested that the extrinsic rewards (i.e., entry to lottery for cash prize) can motivate people to perform better. However, some others believe that gamification can motivate the players to improve their behavior by virtue of the rewards related to gameplay (e.g., attaining a target score) instead of extrinsic rewards [23].

Gamification is a good evidence-based technique for applying real-life situations to training in the field of driving vehicles. Approaches such as [19] use robotic platform simulators to capture lane-following data from artificial intelligence (AI)-driven and human-operated agents, training convolutional neural networks to transfer work on the physical driving platform. Some of these approaches (e.g., [12,23]) defend green behavior as a justification for choosing the simulators for training.

In the context of driving, gamification may generate "flow" [24] and, consequently, intrinsic motivation and enjoyment by increasing the level of challenge of the otherwise mundane task of driving. Repeated practice offered by the game elements is seen as the major factor of the success of its efficiency [25]. As a result, some studies (e.g., [9]) tend to assess the gamification effectiveness at several points of time, asking the player to repeatedly drive the same track and assessing the driver's performance and behavior each time. Serious games are seen as "as step beyond gamification" [26].

2.2. Serious Games

Serious games are defined as the kind of computer programs that apply gaming tools to safely simulate different real-life scenarios where the main purpose is not to entertain but to train its users on how to apply certain rules in these scenarios [27]. Serious games aim to engage the players in complex and complicated professional problems or to run different emotional challenges without facing the risks associated with doing those tasks in real life [28]. Serious game players feel responsible for reaching the targets of the task by improving their actions, fixing their own errors, and evolving their gameplay within the game content [29]. The feedback coming from serious games can be generated in different formats, such as tables, text, multimedia, pictures, peer feedback, and assessment feedback. This feedback can be used to improve the skills of the users for whom the game was designed [30].

The goals of serious games' applications are usually economic in nature. The review in [31] shows multiple examples of serious games applications related to economics. However, serious games have also been successfully used in education [32], healthcare [33], and tourism [34]. Serious games are also being used in domains that indirectly impact humans. For instance, applications of serious games with environmental objectives raise the human awareness of environment-related issues and the engagement in environmentally friendly practices [35].

The authors of [27] proposed a classification for serious games based on the important features of the game design. These features were activity, modality, interaction style, environment, and the application area. Activity refers to the players' movements that are controlled by the game rules. Modality is the communication channel between the computer and the players of the game (e.g., visual, auditory, and haptic). Interaction style refers to the interface between the game and the user (e.g., a driving simulator). Environment defines the digital game environment relevant to the dimensions of the game (e.g., 2D and 3D). Finally, the application area specifies the various domains of serious games (e.g., driving).

2.3. Driving Simulators

The goal of a driving simulator is to create an illusion of the driving experience. A simulator is always an imitation of reality and, therefore, it is never perfect. The benefit comes from the transfer of what is learned in a simulator to the real world [5]. The knowledge transfer is highly dependent on the fidelity of the simulation. As explained by [36], to accomplish this illusion, the driver input is used to calculate the vehicle dynamics referring to a vehicle model and evaluated by the feedback systems to provide the driver the necessary cues. The scenario controls the terrain so that the vehicle dynamics send the output in the form of audio–visual cues. In immersive simulators, multiple projectors are used to create a seamless image typically projected onto curved screens by warping and blending of the image to surround the driver. In desktop simulators, this is performed by presenting the output typically on a single screen. Some simulators also offer haptic feedback such as steering torque and active seats.

In a driving simulation, a scenario refers to an event that happens in a virtual environment, such as a pedestrian crossing in front of the vehicle or a situation created by the driver maneuvering the vehicle. The environment consists of the terrain, road, signs, buildings, and other objects surrounding the vehicle. Using scenarios, a variety of conditions such as the traffic, weather, and events can be added to the environment. Game engines such as Unity and Unreal Engine have gained momentum in the creation of simulators recently due to their realistic rendering capabilities.

While providing gamification elements on smartphone might distract the driver, driving simulators are characterized as a safe testing environment to test driving performance and behavior, especially in case of novice driving environment, such as when some countries started introducing 2 + 1 roads into the road network [37]. They are also considered tools for collecting data. Data collected by a driving simulator can be used to improve vehicle manufacturing [38] or evaluate users' hazardous driving habits [39]. For example, [40] used a driving simulator to test the relationship between the users' driving performance and their visual attention. Čubranić-Dobrodolac et al. [41] used the driving simulator to investigate the speed perception in different traffic scenarios, while another study used a simulator to assess the speeding behavior as part of a smartwatch campaign [42].

Furthermore, in the context of serious games and gamifications, driving simulators represent an interaction style that allows the players to interact with the game as effective traffic education practices [43] and enhancements in various learning aspects of driving [44]. The software for driving simulators facilitates the design of a range of gamification elements (e.g., feedback, leaderboard, and scores) and feeds them into serious games. For instance, [45] programmed a scoring system and designed feedback in a serious game aimed to educate players about driving impairment caused by alcohol.

The state-of-the-art simulators provide a high level of fidelity and immersive display systems with a large field of view, full vehicle mock-ups, and accurate vehicle dynamics models. Motion simulators use well-developed motion cueing algorithms that account not only for the limitations of the human perceptual system but also for the boundaries of the motion system [36].

3. Related Work

3.1. Difficulties in Driving under Unfamiliar Conditions

Driving in a new environment is a challenging task. Different studies investigate the changes in driving performance and behavior when the driver drives in unfamiliar road sections (e.g., [37]) or when driving from a particular road section to another (e.g., [46]). Drivers should adapt their driving actions, such as speed, lane changing maneuvers, etc.

A changed driving environment can be caused when a driver goes from familiar traffic regulations to unfamiliar traffic ones. Driving under unfamiliar traffic regulations produces some difficulties and challenges. Drivers in such conditions have low situational awareness, which may lead to them making unnecessary, unsafe lane changes [36]. In some complex road sections, namely, roundabouts and intersections, some rules of driving in keep-right traffic and a keep-left traffic systems are opposites. The drivers, as a result, might drive against the traffic [47]. Not only are the regulations different, some vehicle configurations (e.g., turn signal/windshield wiper lever) that are usually used in keep-left traffic regulations are also different to those in vehicles used in keep-right traffic regulations. Drivers might be confused about the correct position of the signal indicator or they might use the windshield wiper lever instead of signal indicator for indicating a turn [47]. None of the studies considered gamification and serious games as methods for correcting such driving performances when driving under unfamiliar traffic regulations.

3.2. The Impact of Gamification and Serious Games on Road Safety

Gamification is a promising avenue for enhancing the driving environment and road safety by adapting certain user driving performances and behaviors either on real or simulated roads. Magaña and Organero [18] proposed a game with a sharable scoring system for accomplishments to motivate eco-driving behavior. Their approach was based on continuously detecting the unwanted practices of the driver (e.g., sharp accelerations and slowdowns) in a real driving environment and providing the score at the end of the journey. Similarly, Avolicino et al. [48] designed a gamification mobile that provides the driver with different gamification elements, such as prizes, scores, feedback, and a ranking when unsustainable behavior is detected in a real driving environment. Paranthaman et al. [12] proposed two gamified approaches to detect bad driving behavior while driving in a real environment and then played immediate feedback for better green and collaborative driving.

Some studies provided gamification elements to prevent risky driving performances or behavior. Bahadoor and Hosein's [17] gamified mobile application assigned scores to safe driving behavior by detecting unsafe practices and encouraging drivers to follow certain corrective behaviors. Shi et al. [20] proposed a serious game that improved erratic and dangerous driving performances and behavior to improve road safety. The game detected some smooth and hazardous driving performances and, accordingly, provided a set of gamification elements, such as auditory feedback while driving and visual feedback, virtual money, and scores when reaching the target destination.

Using a driving simulator, Bier et al. [49] provided verbal intervention as a gamification element to solo drivers in order to reduce the driving speed and the signs of drivers' fatigue. Gounaridou et al. [42] developed a serious game in a virtual city where the players can be a driver. While the player drives in the city, they should follow the traffic rules. In case of traffic violations, the game educated the player about the correct actions via feedback and counted the traffic violations to present them at the end of trail. Fitz-Walter et al. [50] designed a gamified logbook application to motivate inexperienced young drivers to be engaged in more driving events prior to being issued a driving license. For that purpose, the application records the driver's experience while driving. When the application stops recording the journey, it presents feedback and various interactive elements explaining the performance history and rewards the player with virtual coins.

Table 1 compares different gamification studies on driving according to the environment (real or simulated), traffic regulations, the gamification elements provided to drivers, and the driving tasks covered in the study. Some studies developed serious games in real environments, such as [12,17,48], other studies (e.g., [42,49]) depended on a driving simulator when developing a serious game. That might be due to the familiarity of the traffic system that the game was designed for or the target driving tasks the studies focused on.

None of the studies investigated the impact of gamification and serious games on driving under unfamiliar traffic regulations (i.e., driving in keep-left traffic regulations for drivers who only have experience in driving in keep-left traffic regulations). Even when following the traffic rules is covered [42], the study does not consider the familiarity of the traffic regulations and the challenges that arise in such driving conditions. Although study [50] specifically examines inexperienced drivers, the study refers to young drivers who are new to driving. In our study, we focus on drivers who have experience in their home country but are inexperienced driving under the opposite traffic regulations. These studies address neither driving against traffic flow nor the improper use of the signal indicators. These two difficulties are related to driving under unfamiliar traffic regulations. As a result, in the current study, we focus on examining the effectiveness of gamification elements in driving under unfamiliar traffic regulations. In particular, we focus on two difficulties of driving under such driving conditions, namely, driving within the traffic flow and the proper use of signal indicator.

Table 1. A comparison of gamification studies in driving.

Authors	Real/ Simulated Roads	Traffic Regulations	Gamification Elements	Target Driving Performance/Behavior
[12]	Real	Not addressed	Feedback and scores	Green driving behavior
[17]	Real	Not addressed	Scores	Unsafe behavior
[18]	Real	Not addressed	Scores	Eco-driving performance
[49]	Simulation	Not addressed	Verbal intervention	Driving speed and the signs of drivers' fatigue
[42]	Simulation	Not addressed	Feedback	Following the traffic rules
[20]	Real	Not addressed	Feedback	Hazardous driving performances
[48]	Real	Not addressed	Prizes, scores, feedback, and ranking	Unsustainable behavior
[50]	Real	Not addressed	Feedback, interactive elements, and virtual coins	Undertake a wider range of practice

4. The Implementation of the Driving Simulation

To demonstrate the influence of serious games on road safety when driving under unfamiliar traffic regulations, we designed a driving game in a simulated environment. The player drives a simulated vehicle in a simulated keep-left traffic regulatory environment. The driving track starts from the starting point and ends at the ending point, requiring the player to follow a certain direction (see Figure 1a). For this purpose, we chose the driving simulator FORUM8 (see Figure 1b). The simulator device is a fixed-based cockpit that represents vehicles built for right-hand drivers. It has a steering wheel, a driving seat with a seatbelt, an accelerator, a brake pedal, and signal and wiper indicators. Three 42-inch monitors are attached to the cockpit. The total horizontal field of view (FOV) was 150 degrees, while the vertical FOVC was set at 30 degrees. The simulator was supported by a software package called UC-win/Road. It was used to model the traffic systems (e.g., roads, rules, vehicles, and road users) and capture data in an Excel log file and video log file. UC-win/Road was also used to implement driving scenarios which dealt with captured data (e.g., road data, vehicle data, navigation) to create driving events and, accordingly, produce a set of feedback, as discussed later in Sections 4.2 and 4.3.

4.1. Driving Environment

The driving environment of this study simulated the environment proposed by [51], where the lane-change behavior for drivers from keep-right countries was investigated when driving in a keep-left country. Thus, we started modelling the driving environment by selecting a random area on a keep-left country (Australia) using a map (see Figure 1c). Then, UC-win/Road automatically applied the traffic regulations of the selected country to the selected area. Next, we modelled the driving track which included four dual-lane roads. Due to the different terrain in the chosen geographic area, we made some vertical adjustments to make the roads cross each other at three intersections and three roundabouts. The total length of the roads that the participants would drive through (from the start to the end point) was 2 km.

Then, we added road textures, including sets of marking lines on the roads and roundabouts, in addition to sets of pavement arrows. Those arrows indicated the correct directions to follow while driving around roundabouts and through intersections. We also added signs to the roadside (e.g., speed limit and roundabout and intersection ahead signs). Following that, we simulated the actual environment of the road by adding sidewalks, trees, buildings, etc. Finally, we added the driver's vehicle, which was a sedan. The characteristics of the selected vehicle are simulated by UC-win/Road. For example, sedans are short and maneuverable. The driver controlled this vehicle using FORUM8 cockpit steering, acceleration, and braking.

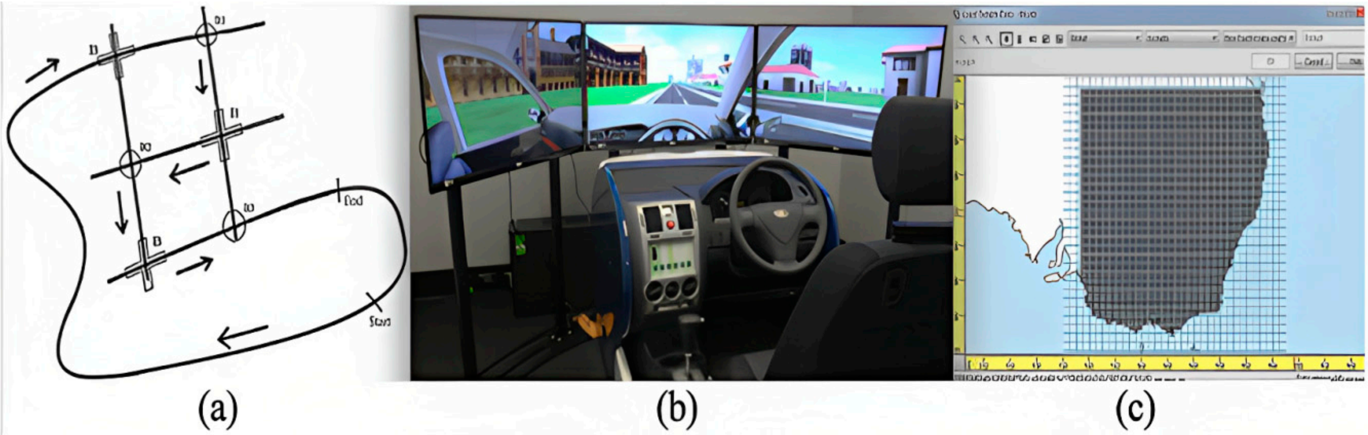

Figure 1. (**a**) the driving track, (**b**) FORUM8, and (**c**) Terrain data for NSW, Australia.

4.2. Events

In general, each driving scenario contains a set of events. Each event is a result of an interaction among the main components of the traffic systems (i.e., vehicles and users of road, and environment). Each interaction is associated with either time or location or time and location together. UC-win/Road applies the time- and location-based method to produce any event. In our game, we started recording the log files when the driver crossed the start point and stopped recording the log files when the driver crossed the end point. Both points are shown in Figure 1a.

As our game required the player to follow a particular direction, we programmed some location-based events that triggered when the player mistakenly strayed from the required direction. Each time the player missed the required direction, the scenario would return the player to the last location on road that had the correct direction. Other events were programmed as well to produce the gamification elements, as will be explained in the section below.

4.3. Feedback

The visual feedback of this study was designed in accordance with the suggestions provided in [21] (see Figure 2). Bitmap (BMP) images were used to present the feedback, as this format is supported by UC-win/Road. They were stored in the software directory to retrieve them in the scenario.

Figure 2. Examples of designed feedback.

In our game, feedback was presented to players in accordance with some events. For instance, six waypoints were added. Each one was 45 m away from a roundabout or intersection, which is the typical distance to present the feedback [52]. Waypoints worked as navigation points placed on road information for the vehicle information to trigger a certain event.

The size, position, and opacity of the image were configured. The target feedback was displayed in a head-up display (HUD) on the driver's actual field of view. FORUM8 showed a 3D model of the front side of the cockpit of the vehicle used in the scene because the feedback would cover a significant portion of the actual driver's field of view if it was displayed in a HUD in the vehicle used in the scene.

5. Materials and Methods

5.1. Recruitment

The gender of the participants in this study was not considered. The criteria for selecting participants were (1) unfamiliar with Australian traffic regulations, (2) between 20 and 35 years of age, and (3) had a driver's license from a country that uses keep-right traffic regulations. In addition, the participants would not receive money, drinks, vouchers, etc. They were motivated to participate as they would experience driving in a keep-left traffic system in a safe environment.

Although the study did not consider gender in recruitment, the study involved 14 male volunteers who fulfilled the required criteria. All of them had no motion sickness during the experiment. The age range was 20–35 years (M = 23.86, SD = 3.07). All participants had experience driving in an environment with keep-right traffic regulations (M = 6.57 years, SD = 3.68) and they drove, on average, 18.14 h/week (SD = 8.83). All participants had no driving license issued from a keep-left country and had no experience driving in keep-left traffic regulations.

5.2. Apparatus and Procedure

In our experiment, we applied FORUM8 as described in Section 4.1. We contacted possible participants directly and invited them to take part in the study verbally. We sent them a summary explanation of our experiment including its location in the Driving Simulator Lab at Macquarie University. We then arranged experiment times for those who were willing to participate in this experiment. When the participants arrived at the lab for their appointments, one of our researchers provided them with a consent form to sign after checking their driver's license for validity and that it was from a right-hand driving country. Each participant was then assigned a unique code for identification. Demographic information, including age, gender, and driving experience data, was collected. No health data was collected. The participants were free to wear glasses or lenses if they had any vision impairment.

The experiment had two driving scenarios—"Scenario 1" (no feedback offered—control scenario) and "Scenario 2" (using gamification element—experimental scenario) (see Figure 3). Both scenarios used the same driving track shown in Figure 1a. Each participant drove one round in each scenario. Participants in both scenarios were required to safely drive from the start point to the end point of the driving track. The experimental scenario was different in terms of applying events that produced the gamification elements. Ten minutes after completing the whole session (both scenarios together), the participant received the performance report, which represented the frequency of driving against the traffic flow and the improper use of the signal indicator. The performance reports were not included as a part of the game. Thus, they did not affect the driving performance. However, the report could be useful for the participants to evaluate their performance when driving under unfamiliar traffic regulations. These reports in this study were primarily useful for researchers, as we will explain in the following section.

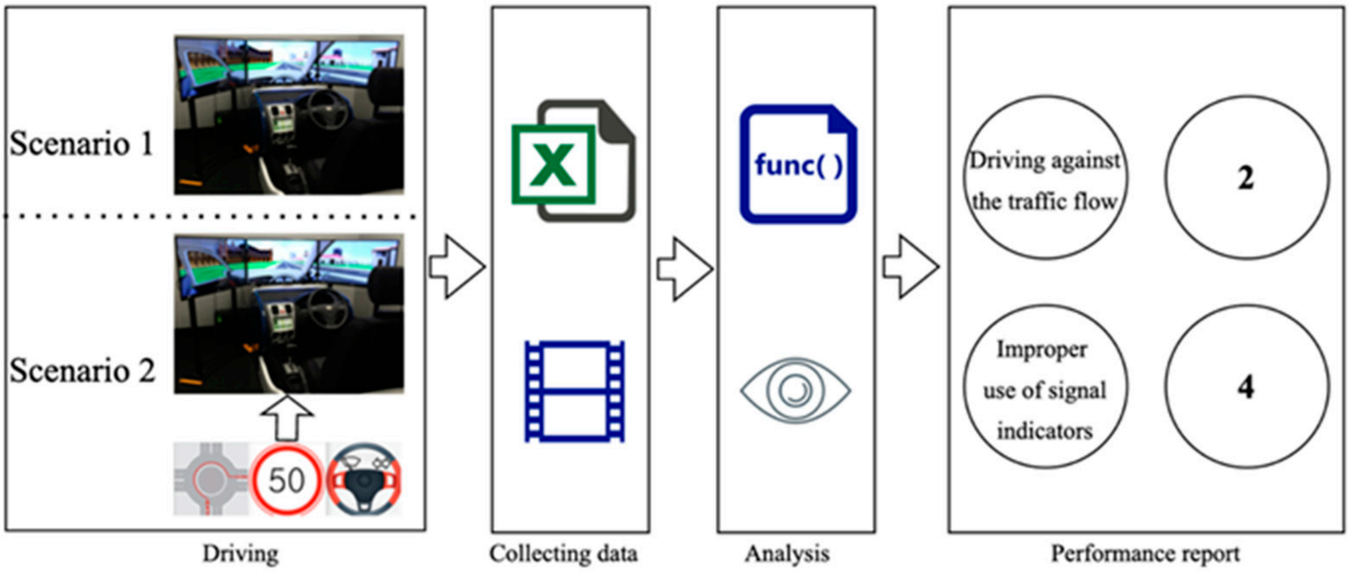

Figure 3. The procedure of conducted experiment.

The researcher randomly split the participants into two groups of the same size (seven participants for each group). Both scenarios were run randomly for every member of the two groups. We randomized the order of the two trials to reduce the effects of the learning. The first group started with Scenario 1, and the second group started with Scenario 2. When the participants finished the first driving scenario, they had a one-hour break before starting the second driving scenario.

5.3. Data Collection and Data Analysis

Data on driving performance and behavior were collected from the log files (CSV and video) generated by the simulator for each scenario. We observed the driving error "improper use of signal indicators" for each driving scenario using a developed macro and the driving error "driving against the traffic flow" by observing the video file. These two errors are related to driving under unfamiliar traffic regulations [1]. A performance report was then created and presented for each participant for each scenario.

We calculated the differences in the number of each target error. We ran the Wil-coxon signed-rank test to compare the number of driving errors in the first scenario versus the second scenario. This statistic test is proper to compare two paired samples whose data are not normally distributed [53].

6. Results

In this study, we focused on two types of errors: (1) driving against the traffic flow, and (2) improper use of the signal indicator. In general, there was a decrement in the frequency of driving against the traffic flow with 13 occurrences when driving without a gamification element (i.e., feedback) and 1 when driving with it. Similarly, the frequency of the improper use of the signal indicator decreased from 15 when driving without feedback to 6 when driving with it (see Figure 4). The difference in the number of each driving error without and with a gamification element was not normally distributed (see Table 2). Therefore, we ran a non-parametric test (Wilcoxon signed-rank test) to compare the driving errors without and with feedback.

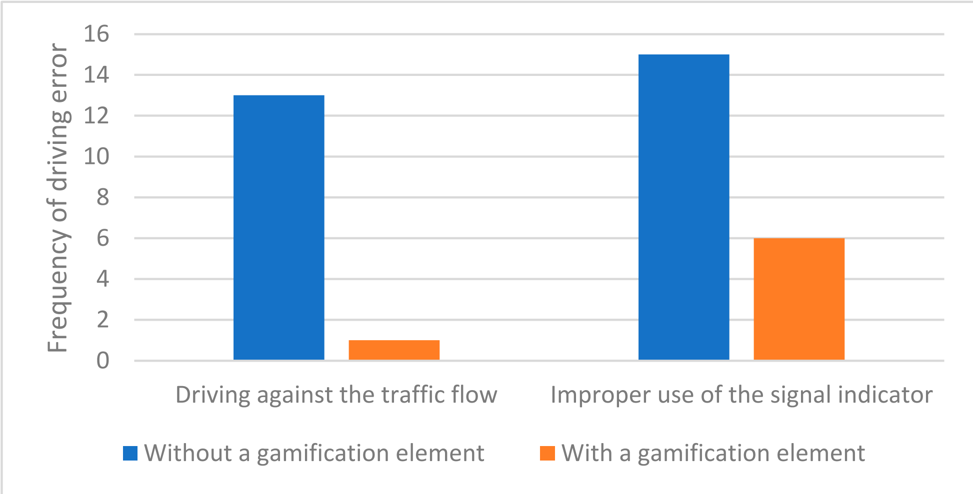

Figure 4. The frequency of driving against the traffic flow and improper use of the signal indicator with and without a gamification element.

Table 2. Results of normality tests for the difference in number of each driving error.

Error	W	*p*
Driving against the traffic flow	0.74	<0.001
Improper use of signal indicator	0.73	<0.001

A Wilcoxon signed-rank test showed that feedback in serious games significantly reduced the frequency of driving against the traffic flow (Mdn = 0.00) compared to driving without feedback (Mdn = 0.00), W = 21.00, $p = 0.035$ (see Table 3). A Wilcoxon signed-rank test showed that feedback in serious games significantly reduced the frequency of the improper use of the signal indicator (Mdn = 0.00) compared to driving without feedback (Mdn = 1.00), W = 21.00, $p = 0.031$.

Table 3. Wilcoxon signed-rank statistics for comparing the number of errors (driving against the traffic flow and improper use of the signal indicator) when driving without and with a gamification element.

Measure 1	Measure 2	W	*p*
Driving against the traffic flow without a gamification element	Driving against the traffic flow with a gamification element	21.00	0.035
Improper use of the signal indicator without a gamification element	Improper use of the signal indicator with a gamification element	21.00	0.031

7. Discussion

Providing the correct traffic flow as feedback to players improved the players' behavior in relation to driving against the traffic flow under unfamiliar traffic regulations. Adapting this behavior might help to reduce head-on collisions, which are one of the most common and serious accidents drivers who are not familiar with the traffic regulations are involved in [1]. Hence, the proposed serious game with a gamification element (i.e., feedback) could be used to improve road safety.

This result justifies the necessity of using the driving simulator when designing unfamiliar roads for drivers, e.g., [37], or when exploring, evaluating, or adapting some driving performances or behaviors (e.g., speeding [41,42]). Speeding and driving against the traffic flow are examples of risky driving performance. The simulator does not put the driver's life in danger. However, that conflicts with some studies (e.g., [12]) that tend to provide gamification elements on the driver's smartphone while driving in real environment.

Providing feedback in our serious game also resulted in the players adapting their behavior with the signal indicator usage, either by encouraging the players to use the signal indicator or by helping them recognize the correct indicator. This result is aligned with the result of [18], which found that gamification manages to correct driving behavior.

Using the proper signal indicator helps other users of roads (e.g., pedestrians and drivers) know the direction in which the driver is intending to move. However, some players were familiar with the vehicle controls used in an environment with keep-right traffic regulations, where the signal indicator is located on the opposite side to that of vehicles used in an environment with keep-left traffic regulations. Such players might take time to look at the symbols on the indicators to recognize the signal indicator. Keeping their eyes off the road might cause the players to ignore important events on the road and thus cause an accident. Thus, the proposed serious game and feedback could be used to improve road safety. However, similar to eco-driving, using a signal indicator might be corrected using serious games on real life such as the designed gamification in [48].

In general, the result of our study indicates the usefulness of providing feedback as a gamification element in terms of adjusting the driving performance and behavior. That might be due to the high preference rate of using feedback as a gamification element among young drivers. In particular, visual feedback was the most preferred feedback modality for driving under unfamiliar traffic regulation [21]. Providing visual feedback to drivers also helped drivers in [12] to correct their driving behavior and performance and thus improve road safety.

8. Conclusions and Limitations

In conclusion, this paper has contributed to understanding the usefulness and the effect of serious games and gamification on a decrement in the driving errors produced when driving in an environment with unfamiliar traffic regulations. Driving against the traffic flow and the improper use of the signal indicator are examples of driving errors that drivers might make regularly when driving under unfamiliar traffic regulations. Gamification is a promising avenue for enhancing user engagement and adapting the user performance in non-game tasks.

Using a driving simulator, we designed a serious game with two scenarios. The first scenario was not supported by gamification, while the second scenario was supported by a gamification element, i.e., feedback. Fourteen players who were not familiar with keep-left traffic regulations participated in this study. The results show that it is possible to improve road safety in cases where the drivers drive under unfamiliar traffic regulations. Indeed, the findings have indicated that serious games and gamification decrease the instances of driving against the traffic flow as well as the cases of improperly using the signal indicator. That also indicates the importance of designing the serious game in a simulation environment prior to transferring the drivers to drive in real environment or using the simulation as a preparation stage for providing gamification elements on real environment.

This paper focused on driving under very focused driving conditions (keep-left traffic regulations for drivers who were only familiar with keep-right traffic regulations). Additionally, the target age group was between 20 to 35. As the experiment was conducted in Australia (a keep-left country), it was very difficult to find participants who fulfilled the experimental conditions (14 participants who fulfilled the inclusion criteria). However, the study indicated that gamification elements were effective to improve the driving performance for participants to safely drive in unfamiliar traffic regulations, although the participants were not familiar with such driving conditions. We plan to collect data from a larger group of participants with a greater diversity in gender and age group. That will enrich our understanding of the user needs toward designing a serious game that will help drivers to safely drive under unfamiliar traffic regulations.

Additionally, the current study has only tested the influence of one gamification element (e.g., feedback) in one round. For future research, we plan to apply other gamification elements and evaluate them in more than one round in order to improve our understanding of the influence of gamification in improving road safety when driving under unfamiliar traffic regulations.

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