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Driver Behaviour in Pre-Crash Scenarios Involving Pedestrian and Motorcycle

Muhamad Aiman Affandi Mat Zaki[1], Nur Hazwani Mokhtar[1,*], Muhammad Zahir Hassan[1], Ahmad Abdullah Muhamad[1], Noor Faradila Paiman[2], Zulhaidi Mohd Jawi[2], Matsuura Yoshifusa[3]

[1] Fakulti Teknologi dan Kejuruteraan Mekanikal, Universiti Teknikal Malaysia Melaka, 76100, Durian Tunggal, Melaka, Malaysia
[2] Malaysian Institute of Road Safety Research, 43000 Kajang, Selangor, Malaysia
[3] Yokohama National University, 79-1 Tokiwadai, Hodogaya, Yokohama, Kanagawa 240-8501, Japan

ABSTRACT

Driving simulators are extensively utilized for research, especially in investigating road safety in Malaysia. The increasing number of road accidents in Malaysia and the limitations of conducting road tests due to safety concerns and legal restrictions highlight the need for an effective tool to study and improve driver behaviour in critical situations. Although driving simulators have evolved significantly, their equivalence to real-world driving experiences remains a complex and multifaceted issue. This study aims to design and develop a driving simulator to examine driver behaviour, including reaction time, braking time, and mental workload assessed by the NASA Task Load Index (TLX). Additionally, it seeks to gather insights from market surveys to enhance the simulator's effectiveness. The research primarily focuses on pre-crash scenarios using the UC Win Road Software. Key findings provide insights into society's preferences and specifications for driving simulators, alongside data on driving behaviour measured through virtual reality, encompassing recognition time and braking time. Furthermore, the study evaluates participants' workload via the NASA TLX questionnaire. The results indicate a notable correlation between driver behaviour and the speed of oncoming objects. Moreover, the study reveals that there is no significant connection between the workload before and after the experiment based on the NASA TLX questionnaire. In conclusion, this research establishes driving simulators as valuable tools for effectively measuring driver behaviour regarding reaction time and braking time.

Keywords:
Driving behaviour; Reaction time; Pre-crash; Recognition time

1. Introduction

Over the last 40 years, advances in technology have enabled higher-quality computer processing and graphics, as well as more sophisticated and precise control devices [1]. Most simulators are now dynamic, with the driver's actions causing changes in the driving environment. Current simulators can include elements like controllable traffic, various road users (vehicles, motorcycles, bicycles, pedestrians), and interactive modifiable features like billboards and railway-level crossings. These

* *Corresponding author.*
E-mail address: nurhazwani@utem.edu.my

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elements can be programmed to modulate in response to the driver's actions or as a pattern that the driver must respond to traffic simulation modelling integration into the driving simulator [2]. However, driving simulators provide safe and realistic results as real-world driving is expensive and high cost. Driving simulators have been used extensively in research on intelligent vehicle control, road traffic facilities, and intelligent transportation systems up until now. The driving simulator evolved into a useful tool for studying human efficiency, civil engineering, traffic engineering, psychology, and other related fields [1].

In Malaysia, the number of road accidents has increased over the last ten years. Meanwhile, the number of fatalities has been steadily decreasing since peaking at 7,152 in 2016 and reaching its lowest point of 6,167 in 2019. The identification of various risk factors, including road conditions, is required for the development of effective strategies to reduce such fatal accidents. Road tests may be impossible in some countries due to liability concerns. Road tests are frequently allowed only after a first simulation of potentially dangerous situations. In many countries, for example, it is illegal to conduct a roadside investigation into the effects of alcohol or drugs on driving performance.

Apart from considering safety concerns and costs, enhancing the comparison between driving simulators and real-world driving requires factoring in several additional aspects. Simulator fidelity, while important, represents only one aspect of the equation when evaluating the equivalence of simulators to real-world driving experiences. Another critical consideration is the operational definition of "real-world" driving, which can significantly impact the outcome of the comparison. In the existing literature, various methodologies have been utilized to assess driving behaviour and performance. These methodologies include self-reported driving behaviour [13], allied health assessments [4], and on-road drives in instrumented vehicles [5]. These approaches offer valuable insights into different aspects of driving performance and behaviour but might not capture the full complexity of real-world driving situations.

The study has two main objectives. The first objective is to design and develop various driving scenarios, encompassing different road conditions and surroundings, using the UC-Win software. These scenarios will provide a controlled and realistic environment for studying driver responses during critical situations involving pedestrians and motorcycles. The second objective focuses on analysing driver behaviour, with a specific focus on reaction time and braking time, within the various simulated scenarios, including the pre-crash scenario. This analysis will expose how drivers respond to potential hazards and aid in understanding their decision-making processes. Lastly, the study aims to compare driver workload before and after the experiment. This comparison will help assess the impact of the driving simulator experience on drivers' cognitive and physical workload, providing valuable insights into the simulator's effectiveness in influencing driving behaviour.

2. Literature review

2.1 Pedestrian and Motorcycle Crashes in the Recent Years

Over 400,000 pedestrians are killed in vehicle crashes annually. Crash causation varies across developed and developing countries but, overall, pedestrians are more at risk in urban rather than rural areas. One study showed that 70% of crashes occur in an urban environment. Largely, pedestrian injuries occur at intersections or junctions with 2 lanes of travel and speed limits of 25 mph or under. Several studies show many pedestrian-involved injury crashes occurring on the roadway but not in a crosswalk. For instance, a case study from Atlanta found that 37% of pedestrian crashes occurred when the pedestrian was crossing recklessly.

Motorcycle riders, being a vulnerable group of road users, are usually over-represented in accident and fatality statistics in many countries, including Southeast Asia. Approximately, 1.3 million people lose their lives due to road traffic accidents, with motorcyclists accounting for about 28% of all road traffic deaths globally. Compared to other motorized road users, motorcyclists typically face higher risks of injury and death due to the lack of protective features in the event of a collision. In the UK, motorcycle riders have around fifty times (121 vs. 2.26) the death rate in road traffic accidents, compared to car drivers, per mile travelled, based on averaging data over recent years (years 2012 to 2016) (effect on age).

Studying driver behaviour during pre-crash scenarios involving pedestrians and motorcycles is important due to the alarming global statistics and risk factors outlined above. With over 400,000 pedestrian fatalities and approximately 1.3 million road traffic deaths annually, a substantial portion of which involves motorcyclists, it becomes evident that these vulnerable road users face significantly higher risks. Moreover, the prevalence of accidents in urban settings, at intersections, and on roadways highlights the urgent need to understand the intricacies of driver behaviour in such scenarios. By exploring into pre-crash scenarios, this study can identify contributing factors, assess the role of driver decision-making, and develop targeted strategies for accident prevention and road safety, ultimately saving lives and reducing the devastating impact of these accidents.

2.2 Static, 2DOF, 3DOF and 6DOF Driving Simulator

There are static and motion types of driving simulators such as 2DOF (Degree of Freedom), 3DOF, and 6DOF which are more realistic to real-world driving. The degree of freedom of this simulator describes how something moves with a set of fixed parameters. To put it another way, it categorizes how something moves. In total, there are 6 degrees of freedom, and as said above, each of these essentially represents a different type of movement such as elevation, strafing, surging, yawing, pitching, and rolling [7].

First, the tyres will rise and fall over the undulating surface when driving on an uneven surface. The elevation is represented by this vertical displacement. Second, strafing is movement on the horizontal axis (left or right, or 'laterally'). Fourth, yawing (oversteer) where the rear axle slides, simulating traction loss at the rear, which consequently changes the direction of motion of the car. Fifth, the pitching (tilting forward and backward) nose of the car dips down and the rear of the car lifts, as the weight of the car is transferred over the front axle. Lastly, rolling which involves the car pivoting on one side. Also, consider body roll in a car. In the context of a motion platform, it will tilt from side to side to simulate roll.

2.3 Studies Involving Driving Simulator

In recent years, a large body of research has used simulator-based experiments to examine driving behaviour in critical situations [21-23]. For example, Karimi *et al.,* [21], focus on passing behaviour at passing zones on two-lane roads and aims to validate and extend the use of driving simulators in the safety analysis. This study uses a 3D model, and its environmental characteristics were realized from the real segment which had previously been surveyed with drones to collect videos and derive data on real passing manoeuvres. Besides, Yuan *et al.,* [22] studied the safety effects of weaving length, traffic conditions, and driver characteristics on drivers' mandatory lane change behaviour based on a driving simulator study. Manchon *et al.,* [23] studied how the initial level of trust in automated driving impacts drivers' behaviour and early trust construction. This study compared the declared levels of trust, gaze behaviour and Non-Driving-Related Activities (NDRA) engagement [24].

2.4 Related Research

2.4.1 Validation of vehicle driving simulator from the perspective of velocity and trajectory-based driving behaviour under curve conditions

Researchers aimed to validate a driving simulator in a complex environment using experimental scenarios involving curved road conditions of various radius. The researcher examined the accuracy and reliability of the simulator's vehicle speed and employed the cosine similarity method to analyse the lateral deviation of the vehicle's trajectory quantitatively and qualitatively. A data-driven approach was also utilized, considering factors like longitudinal and lateral displacement, vehicle speed, and steering wheel angle. The results indicated that this method effectively addressed challenges that are difficult to replicate in real-world complex scenes. The study involved 27 drivers with diverse characteristics, and the experimental section consisted of a nineteen-kilometre two-way highway with different road types, including straight sections and various curved road sections. Overall, the research demonstrated the simulator's high reliability in speed simulation, particularly on straight-road segments, providing valuable insights for simulator standardization [11].

2.4.2 Validation of a driving simulator for research into human factors issues of automated vehicles

In a study conducted at Monash University's Accident Research Centre, researchers evaluated the University Accident Research Centre's automation driving simulator for investigating human factors associated with automated driving. The research involved twenty participants (11 males and 9 females) with an age range from 21 to 64 years. Participants rated their willingness to resume control of an automated vehicle and their perception of safety during on-road and simulator drives. The study confirmed the behavioural validity of the simulator through statistical analysis of the ratings, demonstrating its effectiveness in replicating on-road driving conditions.

Both on-road and simulator drives followed predetermined routes with similar characteristics, including road length and conditions. Importantly, the experiment did not involve any safety-critical events, ensuring the safety of participants. The research, approved by Monash University's Human Research Ethics Committee, recruited participants with full driver's licenses and a minimum annual driving distance of 6,000 kilometres. Participants were compensated for their time, and the entire experiment lasted between 90 and 105 minutes. The study found no significant statistical differences between the on-road and simulator environments in terms of traffic density and situation complexity [20].

2.4.3 Building and validation of a low-cost driving simulator

This study introduces the design and production of a low-cost driving simulator device aimed at achieving results comparable to high-cost advanced simulation systems. The purpose of this simulator is multifaceted, encompassing its use in laboratory studies to gain insights into driver and vehicle behaviour, improve road infrastructure design, and serve as a training tool for drivers. In a 30-minute experiment involving 51 participants of various genders and ages, the simulator's validity was assessed through a questionnaire comprising nine questions. Impressively, every participant (100%) was impressed by the device's design, ease of use, and the realism of the driving simulation. Over half of the participants rated the experience as excellent (52.9%), while all respondents unanimously found the device to be realistic or very realistic (100%). Remarkably, none of the participants had prior experience with a simulator, making this an exceptional novelty. This pioneering device represents a significant achievement for an Iraqi university and has garnered overwhelmingly positive feedback from its users, underlining its potential for realistic driving simulation and training [13].

3. Methodology

3.1 The NASA Task Load Index (TLX) Questionnaire

In this study, initial engagement involved a group of 30 participants to gather valuable data regarding their opinions on the product to be utilized in the upcoming experiment. The survey was distributed to these participants via Google Forms. The questionnaire encompassed inquiries regarding demographics, driving experience and NASA Task Load Index (TLX). Subsequently, the collected responses underwent systematic exportation to a CSV file and then direct transfer to Excel for comprehensive analysis. The NASA Task Load Index (TLX) Questionnaire was administered both before and after the experiment to assess their perceived workload. This approach was designed to provide valuable insights into how the tasks performed during the experiment might have influenced participants' workload perceptions throughout the study.

3.2 Equipment

This section describes the display equipment, driving simulator, display, and questionnaire used in the study. Samsung Smart TV was utilized as the audio and display system. The Samsung Smart TV serves as the primary visual interface for the driving simulation, presenting a realistic and immersive environment to the participants. The display section of the driving simulator is responsible for rendering various visual elements, including the virtual driving environment, road scenarios, traffic conditions, and other relevant information essential for the participants' driving experience. Its high-resolution screen and advanced display technology ensure clear and detailed visuals, contributing to the overall realism and effectiveness of the simulation.

The study was conducted in the static driving simulator of the UTeM. The driving simulation software FORUM 8's UC-WIN/Road 16 ver.10.1.2, used extensive 3D visual technology and an interactive virtual reality design approach. This software also includes Log Export Plug-in, which allows the user to export simulated data to a.csv file on the computer. The export data include the time, distance, velocity, and position of the user's car, the leading vehicle, as well as the surrounding and other objects in the scenario. The simulator's driver's seat comes from a 1996 Honda Civic Ferio (Figure 2). This seat was selected for its adjustable features, allowing customization of the headrest height, back cushion angle, seat height, and seat-to-steering distance. This adaptability ensures that each participant can personalize the seating arrangement to their individual preferences, optimizing comfort and driving ergonomics during the study. Driving simulator seats on the market are more analogous to gaming chairs and cannot be modified to the driver's preferred posture.

In addition, Thrustmaster TX Racing Wheel Leather Edition (Figure 3) is used in the driving simulator. One of its standout capabilities is its precise force feedback, which provides participants with highly accurate sensations and responses during virtual driving. As the official license promises, Thrustmaster is giving a pair of incredibly accurate racing controllers, which are well-liked by racers for their ability to create unrivalled immersion in the world of racing simulators for PC and Xbox One, in a single, limited-edition bundle. The leather-wrapped wheel rim ensures a comfortable and authentic grip, resembling the feel of a real racing car's steering wheel and minimizing fatigue during extended simulation sessions. Included in the package is a pedal set (Figure 1), which enhances the simulator's realism and provides participants with a more immersive and ergonomic driving setup.

Fig. 1. Accelerator and brake pedal from Thrustmaster

Fig. 2. Driving seat

Fig. 3. TX racing wheel leather edition.

3.3.2 Road dimension

In this experiment, consistent road dimensions were employed for all environments and conditions to ensure uniformity across the study. The road details are illustrated in Figure 4, while the road design is depicted in Figure 5. The road width was standardized at 3.2 meters for each lane, providing sufficient space for vehicles to manoeuvre safely. The sidewalk, running alongside the road, measured 1 meter in length, contributing to pedestrian safety and separation from the traffic flow. Overall, the road extended for 538.4 meters, offering ample space for conducting the driving simulator study.

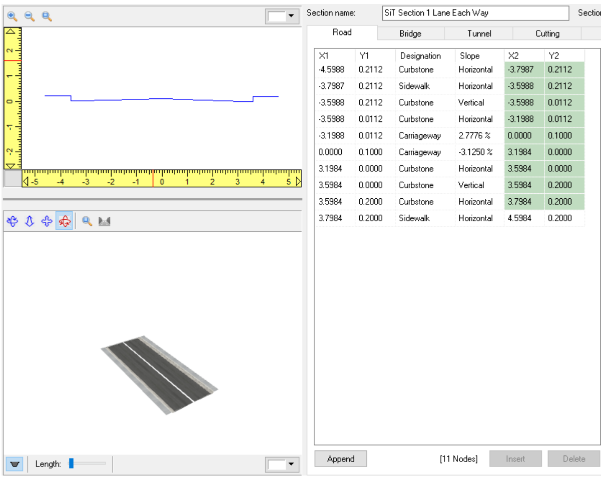

Fig. 4. Road detail information

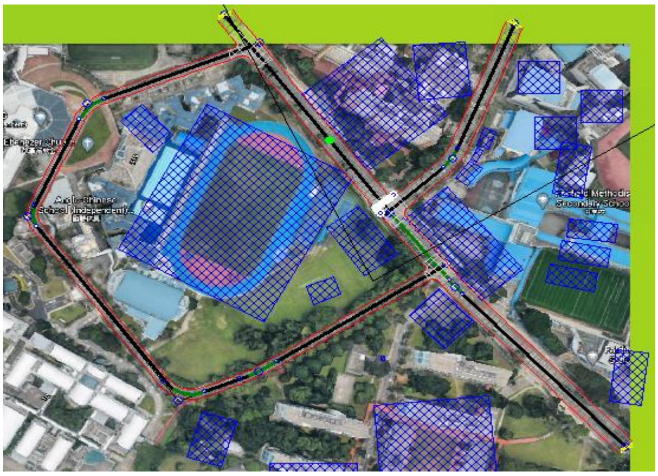

Fig. 5. Road design

3.3 Experimental Design

A sample of 30 participants, consisting of both male and female students, took part in the study. The participants were recruited from the Faculty of Mechanical Engineering and Technology at UTeM (Universiti Teknikal Malaysia Melaka). Regarding the gender distribution, most participants (96.7%) were male, while a minority (3.3%) were female. In terms of age, the participant's age range varied, with most (90%) falling within the age range of 21 to 25 years old, which corresponds to approximately 27 individuals, while the remaining 10% were in the age range of 26 to 30 years old, accounting for approximately 3 individuals. Every participant, irrespective of gender and age, willingly agreed to take part in this experiment.

All 30 participants where at least 1 year's driving experience were recruited for this research. Each participant participates in four studies and one test drive in four different scenarios: a lorry, a pedestrian, a motorcycle, and a bicycle. Before the experiment, all participants were given briefings and pre-experiment (perception time) sessions. The author went over the specifics, guidelines, directives, and rules of the experiment during the briefing session. To familiarize the participants with the driving simulator, participants underwent a brief five-minute test drive, allowing the participant to get a feel for the virtual driving environment. After this practice session, the main experiment commenced following a short interval. During the main experiment, each participant was allocated approximately 20 minutes to complete the tasks. Upon completing their session, participants were given a questionnaire to gather feedback on the experience.

As shown in Figure 6, the scenario will begin with the participants in manual driving mode. In this mode, the participant has control over the driving inputs. After covering a certain distance, the driving simulator switches into full automation mode, taking over the driving tasks. The simulator continues to operate at a constant velocity of 60 km/h for a predetermined distance. At the 150-meter mark from the starting point, a notification appears on the screen, alerting the participants. The participants are then prompted to press button 2 in response to the notification. Upon pressing the button, the participants regain complete control of the virtual car, allowing the participant to brake or accelerate as needed. This segment of the study is designed to gather data on reaction time and braking time in response to the notification. Participants need to complete a questionnaire focusing on the NASA Task Load Index (TLX) at the end of the session. To investigate the driver's behaviours in the pre-crash scenario involving pedestrians and motorcycles, 2 kinds of measurement were collected:

i. reaction time
ii. recognition time.

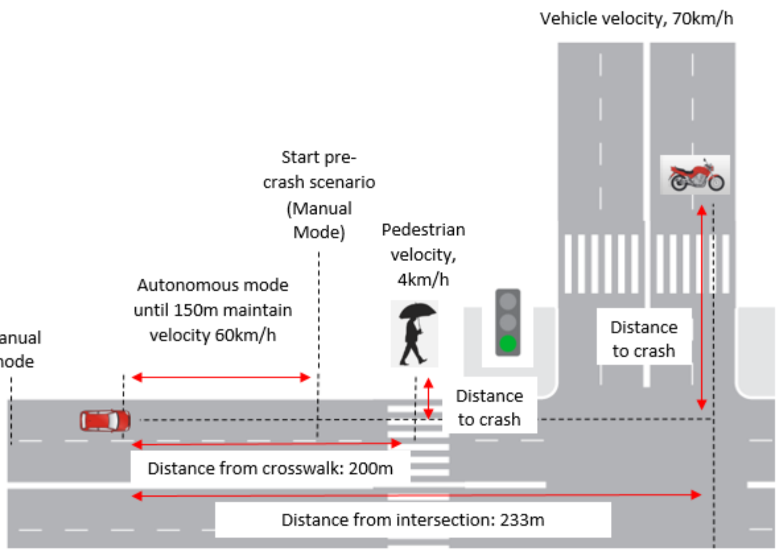

Fig. 6. Driving Scenario

4. Results

4.1 Questionnaire Analysis

This section presents the results and analysis based on the survey questionnaire obtained from 55 participants. The survey questions are being distributed via social media platforms such as

WhatsApp and Facebook. There is a notable gender imbalance, with a majority of 81.82% being male, and the remaining 18.18% being female. Most respondents, a significant 81.82%, fall into the 21 to 30-year age group, followed by 14.55% in the 31-to-40-year age range, and a smaller 3.64% aged 41 to 50 years. In terms of ethnicity, Malays dominate at 83.94%, followed by smaller groups of Indians (5.45%) and Chinese (10.91%), with no respondents falling into the "Others" category. Geographically, most respondents live in urban areas (87.27%), while 12.73% reside in rural regions.

Table 1
Demographic distribution of survey respondents (n=30)

Category	Percentages, %	Category	Percentages, %
Gender		*Race*	
Male	81.82	Malay	83.94
Female	18.18	Indian	5.45
		Chinese	10.91
Age		Others	0
21 – 30	81.82		
31 – 40	14.55	*Residence*	
41 – 50	3.64	Rural	12.73
		Urban	87.27

This section presents the preferences of survey respondents regarding driving simulator products. The data indicates that a significant portion of the participants (72.7%) have prior experience with driving simulator games, suggesting familiarity with the concept and technology. Participants with prior experience in driving simulator games are more likely to prefer having a driving simulator product available in their homes. However, a null hypothesis could be that there is no significant association between participants' prior experience with driving simulator games and their preferences for a driving simulator product. In other words, familiarity with driving simulator games does not influence their inclination to have a driving simulator product available in their homes.

Additionally, most respondents (87.3%) expressed a preference for having the driving simulator product available in their homes, indicating a potential market interest and demand for this type of product for personal use. Nonetheless, a null hypothesis could be that there is no significant relationship between participants' preference for having the driving simulator product available in their homes and their perception of its impact on driving skills. In other words, participants' desires for home use are not connected to their views on how the simulator may affect their driving abilities.

Participants' perception of the product's impact on driving skills reveals a generally positive outlook, with 69.1% agreeing or strongly agreeing that it can improve their driving skills. However, a null hypothesis could be that there is no significant association between participants' perception of the product's impact on driving skills and their views on the affordability of the driving simulator. This implies that participants' beliefs about how the simulator influences their driving abilities are unrelated to their opinions on its price.

In terms of affordability, a considerable portion of participants (65.5%) view the price of the driving simulator (RM3000) as reasonable or affordable, which may have implications for potential market penetration and consumer acceptance. A null hypothesis could be that there is no significant link between participants' views on the price of the driving simulator and their belief in its potential positive impact on driving habits. In essence, participants' judgments of the simulator's affordability are not associated with their perceptions of how it may affect their driving behaviour.

Regarding the simulator's influence on behaviour when driving on the road, 60% of respondents believe it can positively impact their driving habits, suggesting the product's potential to enhance road safety awareness and adherence to traffic rules. Participants are more likely to agree with the integration of driving simulators in formal driver education programs. However, a null hypothesis could be that there is no significant association between participants' belief in the product's potential to positively impact driving habits and their views on replacing traditional driving learning in driving schools with the simulator. This suggests that participants' opinions on the simulator's influence on driving behaviour are not connected to their attitudes towards its integration into formal driver education programs. The data also indicates that a significant majority of participants (47.3%) believe that implementing the driving simulator in schools for road safety study is a viable and beneficial option, emphasizing the product's potential educational value in promoting road safety awareness and responsible driving practices. Participants who view the driving simulator as beneficial in schools are more likely to prefer its use in educational settings. Nonetheless, a null hypothesis could be that there is no significant relationship between participants' belief in the viability and benefit of implementing the driving simulator in schools for road safety study and their preference for home use. This means that participants' perceptions of the simulator's educational value are independent of their desires for home use.

Table 2
Product preference distribution of survey respondents (n=55)

Category	%	Category	%
Do you ever play driving simulator games?		*Do you think driving using a simulator can replace the old-*	
Yes	72.7	*style driving learning in driving school?*	
No	27.3	Strongly Disagree	
		Disagree	10.9
Would you prefer this product available in		Neutral	25.5
your home?		Agree	21.8
Yes	87.3	Strongly Agree	25.5
No	12.7		16.4
		Do you agree by using this driving simulator can reduce the	
Do you think this product can improve		*number of traffic accidents in Malaysia?*	
your driving skill?		Strongly Disagree	
Strongly Disagree	3.6	Disagree	
Disagree	1.8	Neutral	7.3
Neutral	25.5	Agree	20
Agree	40	Strongly Agree	25.5
Strongly Agree	29.1		30.9
		Can this product be implemented in schools for road safety	16.4
Do you think the price for driving		*study?*	
simulator 3000 is affordable?		Strongly Disagree	
Strongly Disagree	5.4	Disagree	
Disagree	16.4	Neutral	3.6
Neutral	38.2	Agree	5.5
Agree	27.3	Strongly Agree	20
Strongly Agree	12.7		41.8
			29.1
Can a driving simulator improve your			
behaviour driving on the road?			
Yes	60		
No	40		

4.2 NASA-TLX Evaluation

The aim of using the NASA Task Load Index (TLX) in the study was to assess the mental and physical effort required by participants during the driving simulation. This assessment aimed to identify areas where participants might have experienced stress, fatigue, or encountered challenges during the simulation. This information is valuable in optimizing driving simulator design, identifying areas of improvement in automation systems, and enhancing driver performance and safety. There was no statistically significant difference in perceived workload between the before and after experiment phases. For a one-tailed test concerning "Mental Demand," the p-value (P(T<=t) one-tail) was found to be 0.426. Given that the absolute value of the t-statistic (0.186) is less than the critical t-value (1.671), and the p-value (0.426) exceeds the significance level ($\alpha = 0.05$), the null hypothesis is sustained. This indicates that there is no statistically significant difference in "Mental Demand" between Variable 1 and Variable 2 in the specified direction. While in a two-tailed test for "Mental Demand," the p-value (P(T<=t) two-tail) was computed as 0.852. As this p-value (0.852) exceeds $\alpha = 0.05$, the null hypothesis is also not rejected. This confirms that there is no statistically significant difference in "Mental Demand" between Variable 1 and Variable 2.

Furthermore, for a one-tailed test on "Physical Demand," the p-value (P(T<=t) one-tail) was determined to be 0.445. Considering that the absolute value of the t-statistic (0.137) is lower than the critical t-value (1.671), and the p-value (0.445) surpasses $\alpha = 0.05$, the null hypothesis is sustained. This indicates that there is no statistically significant difference in "Physical Demand" between Variable 1 and Variable 2 in the specified direction. While in a two-tailed test for "Physical Demand," the p-value (P(T<=t) two-tail) was calculated as 0.890. As the p-value (0.890) exceeds $\alpha = 0.05$, the null hypothesis is also not rejected. This confirms that there is no statistically significant difference in "Physical Demand" between Variable 1 and Variable 2.

Besides, for one-tailed test related to "Temporal Demand," the p-value (P(T<=t) one-tail) was computed as 0.462. Since the absolute value of the t-statistic (0.094) is lower than the critical t-value (1.671), and the p-value (0.462) surpasses $\alpha = 0.05$, the null hypothesis is sustained. This indicates that there is no statistically significant difference in "Temporal Demand" between Variable 1 and Variable 2 in the specified direction. In the meantime, for two-tailed test for "Temporal Demand," the p-value (P(T<=t) two-tail) was found to be 0.924. As this p-value (0.924) exceeds $\alpha = 0.05$, the null hypothesis is also not rejected. This confirms that there is no statistically significant difference in "Temporal Demand" between Variable 1 and Variable 2.

Then for a one-tailed test regarding "Performance," the p-value (P(T<=t) one-tail) was determined to be 0.132. Given that the t-statistic (1.124) is lower than the critical t-value (approximately 1.674), and the p-value (0.132) surpasses $\alpha = 0.05$, the null hypothesis is sustained. This indicates that there is no statistically significant difference in "Performance" between Variable 1 and Variable 2 in the specified direction. In a two-tailed test for "Performance," the p-value (P(T<=t) two-tail) was calculated as 0.265. As the p-value (0.265) exceeds $\alpha = 0.05$, the null hypothesis is also not rejected. This confirms that there is no statistically significant difference in "Performance" between Variable 1 and Variable 2.

After that, for a one-tailed test concerning "Effort," the p-value (P(T<=t) one-tail) was found to be 0.390. Since the absolute value of the t-statistic (0.280) is lower than the critical t-value (approximately 1.671), and the p-value (0.390) surpasses $\alpha = 0.05$, the null hypothesis is sustained. This indicates that there is no statistically significant difference in "Effort" between Variable 1 and Variable 2 in the specified direction. In a two-tailed test for "Effort," the p-value (P(T<=t) two-tail) was computed as 0.780. As the p-value (0.780) exceeds $\alpha = 0.05$, the null hypothesis is also not rejected. This confirms that there is no statistically significant difference in "Effort" between Variable 1 and Variable 2.

Finally, for a one-tailed test related to "Frustration," the p-value (P(T<=t) one-tail) was determined to be 0.156. Given that the t-statistic (1.017) is lower than the critical t-value (approximately 1.673), and the p-value (0.156) surpasses $\alpha = 0.05$, the null hypothesis is sustained. This indicates that there is no statistically significant difference in "Frustration" between Variable 1 and Variable 2 in the specified direction. In a two-tailed test for "Frustration," the p-value (P(T<=t) two-tail) was calculated as 0.313. As this p-value (0.313) exceeds α = 0.05, the null hypothesis is also not rejected. This confirms that there is no statistically significant difference in in "Frustration" between Variable 1 and Variable 2. Consequently, the null hypothesis, indicating no connection between the pre- and post-workload index samples, was accepted. This result provides insight into the participants' overall driving simulation research experiences. Despite potential variations in driving conditions and task complexities, the participants' perceived workload remained relatively consistent before and after the experiment.

Table 3
T- Test Result (n=30)

NASA-TLX	*Variable*	*Mean*	*t Critical one-tail*	*t Critical two-tail*	*P(T<=t)*		*Significance*
t-Test on mental Demand	1	4.33	1.671	2.001	*one-tail*	0.426	Insignificant
	2	4.46	-	-	*two-tail*	0.852	Insignificant
t-Test for physical demand	1	4.26	1.671	2.001	*one-tail*	0.445	Insignificant
	2	4.16	-	-	*two-tail*	0.890	Insignificant
t-Test on temporal demand	1	4.3	1.671	2.001	*one-tail*	0.462	Insignificant
	2	4.36	-	-	*two-tail*	0.924	Insignificant
t-Test for performance	1	7.16	1.674	2.005	*one-tail*	0.132	Insignificant
	2	7.76	-	-	*two-tail*	0.265	Insignificant
t-test on effort	1	5.43	1.671	2.001	*one-tail*	0.390	Insignificant
	2	5.63	-	-	*two-tail*	0.780	Insignificant
t-test for frustration	1	4.26	1.673	2.004	*one-tail*	0.156	Insignificant
	2	3.66	-	-	*two-tail*	0.313	Insignificant

4.3 Reaction Time and Braking Time

Figure 7 to Figure 9 below illustrate the reaction times of 30 participants in the experiment, differentiated by three colours representing different time intervals. Blue represents reaction times of 5 seconds, orange represents 10 seconds, and green represents 15 seconds. The raw data exhibits a range of participant reaction times, with the slowest recorded at 2.01 seconds and the fastest at 0.01 seconds.

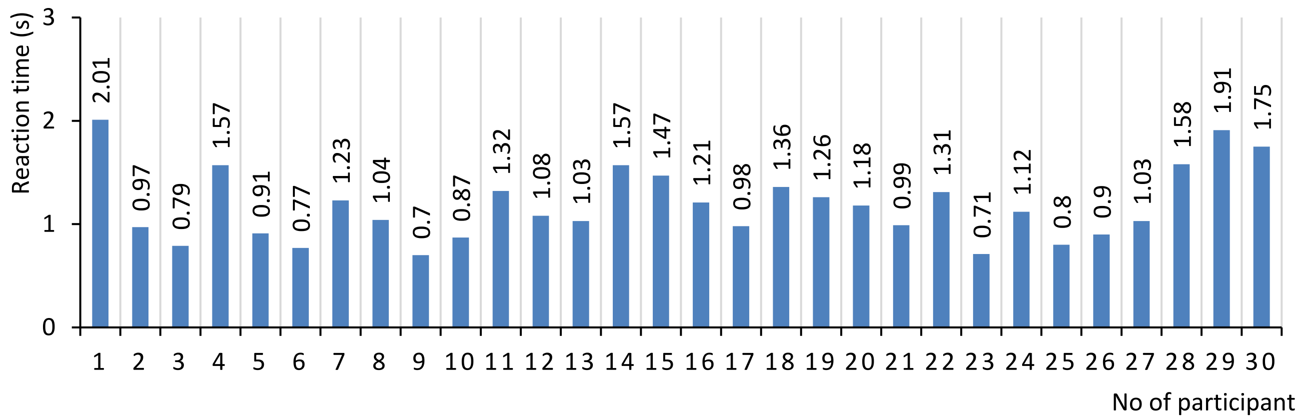

Fig. 7. Participant reaction time graph (5s)

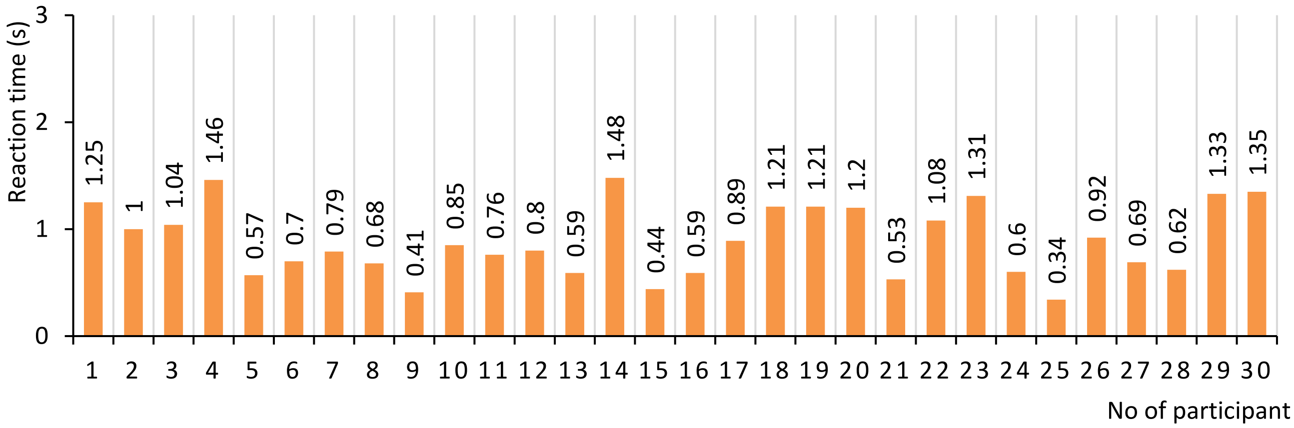

Fig. 8. Participant reaction time graph (10s)

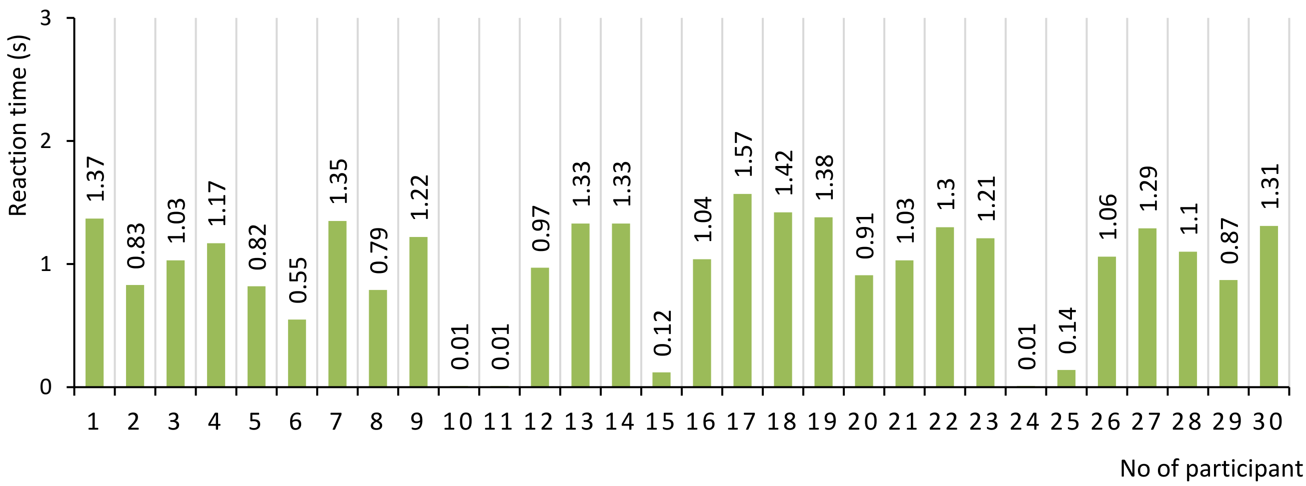

Fig. 9. Participant reaction time graph (10s)

In Figure 10 and Figure 11, the reaction times of 30 participants were recorded for scenarios involving a pedestrian and a motorcycle respectively. The reaction times for the pedestrian scenario are represented by the blue colour, while the reaction times for the motorcycle scenario are indicated by the orange colour. For instance, participant 28 exhibited a lower reaction time in response to the pedestrian scenario compared to the motorcycle scenario. The results suggest that factors such as a lack of surrounding awareness towards the motorcycle, which was approaching at high speed, may have contributed to abnormally high driver reaction times in certain cases.

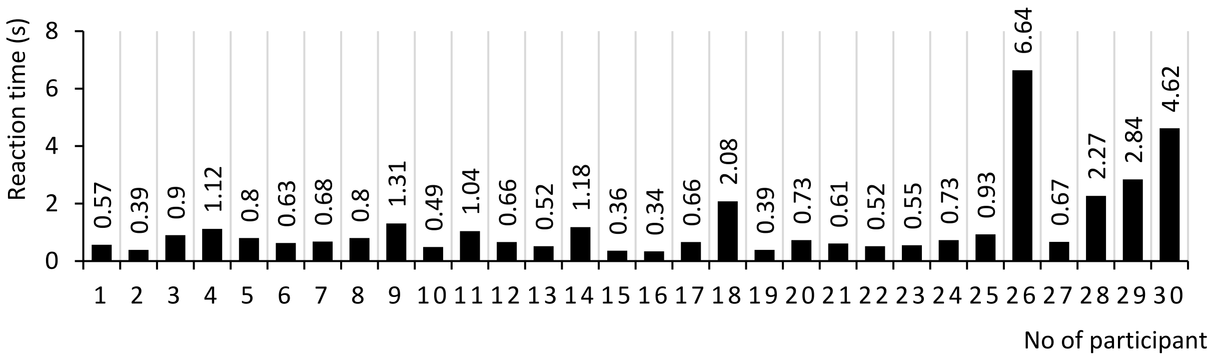

Fig. 10. Graph reaction time for pedestrian scenario

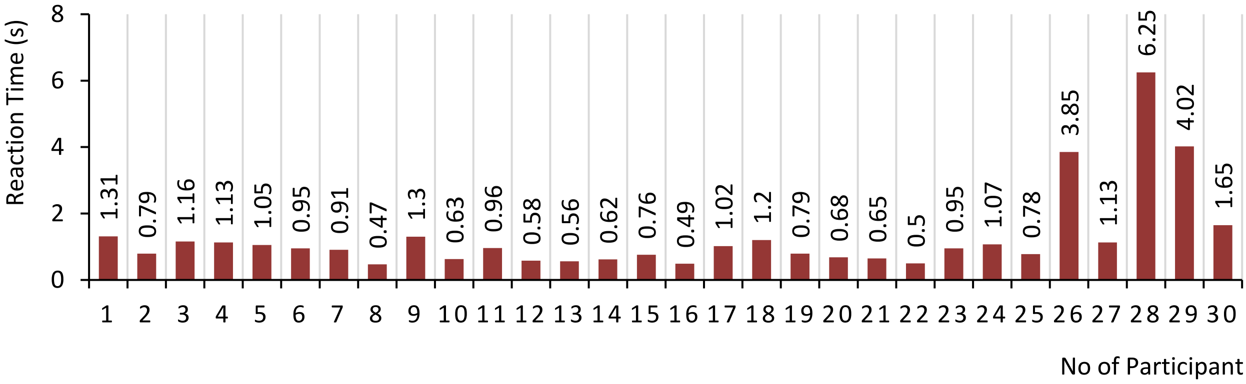

Fig. 11. Graph reaction time for motorcycle scenario

Besides, in Figure 12 and Figure 13, the braking times of 30 participants were recorded for scenarios involving a pedestrian and a motorcycle. The blue colour represents the braking times for the pedestrian scenario, while the orange colour represents the braking times for the motorcycle scenario. The raw data indicates that more participants had higher braking times in the motorcycle scenario, while the pedestrian scenario showed lower braking times.

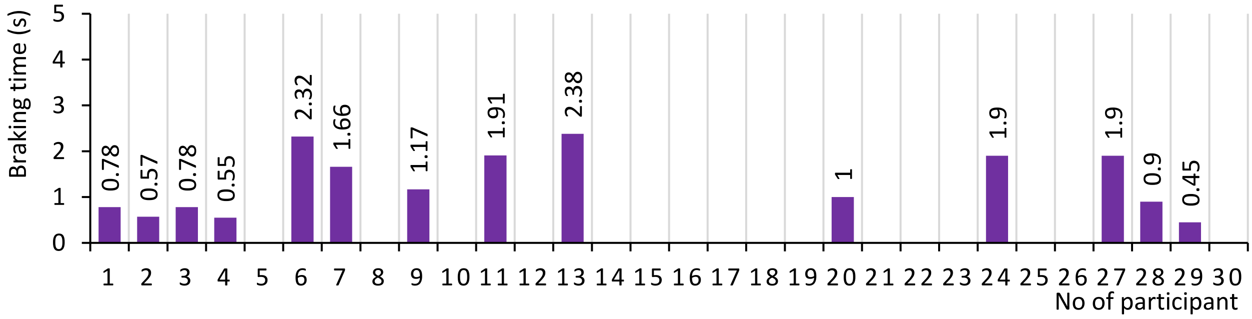

Fig. 12. Graph braking time for Pedestrian Scenario

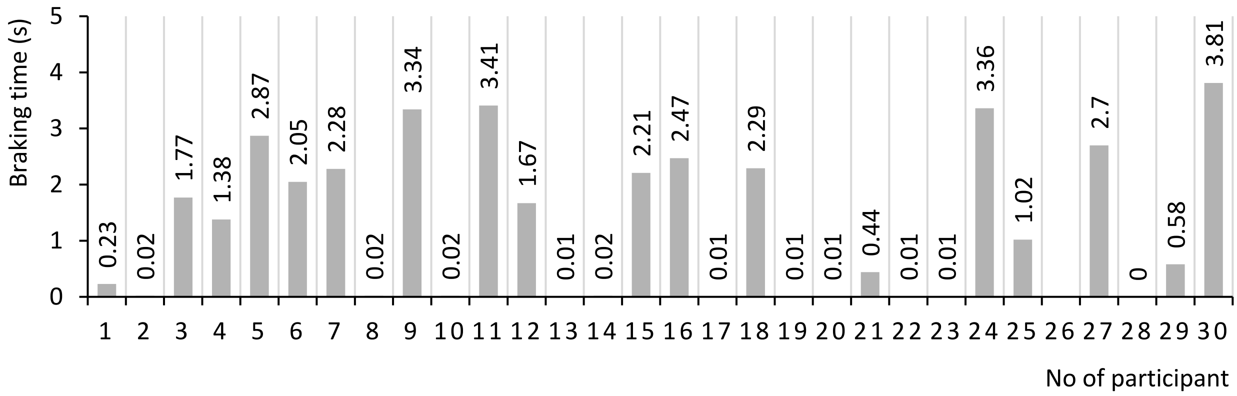

Fig. 13. Graph Braking Time for Motorcycle Scenario

The Box Plot graph displays in Figure 14 below shows the reaction times (RT) of 30 participants who took part in the experiment. The analysis focused on the variable of notification time, set at 5s, 10s, and 15s. Participants were required to brake upon receiving each notification to measure their recognition time. The results indicate that for the 5s notification, the minimum RT was 0.7s, the maximum was 2.01s, and the median was 1.1s. For the 10s notification, the minimum RT was 0.34s, the maximum was 1.48s, and the median was 0.83s. Lastly, for the 15s scenario, the minimum RT was 0.01s, the maximum was 1.57s, and the median was 1.05s. The findings reveal that the 5s notification had the slowest recognition time, likely due to its short appearance time and being the first occurrence for the participants. On the other hand, the 10s notification had the fastest recognition time, potentially influenced by its longer duration. The time of notification appears to have an impact on the participants' recognition time.

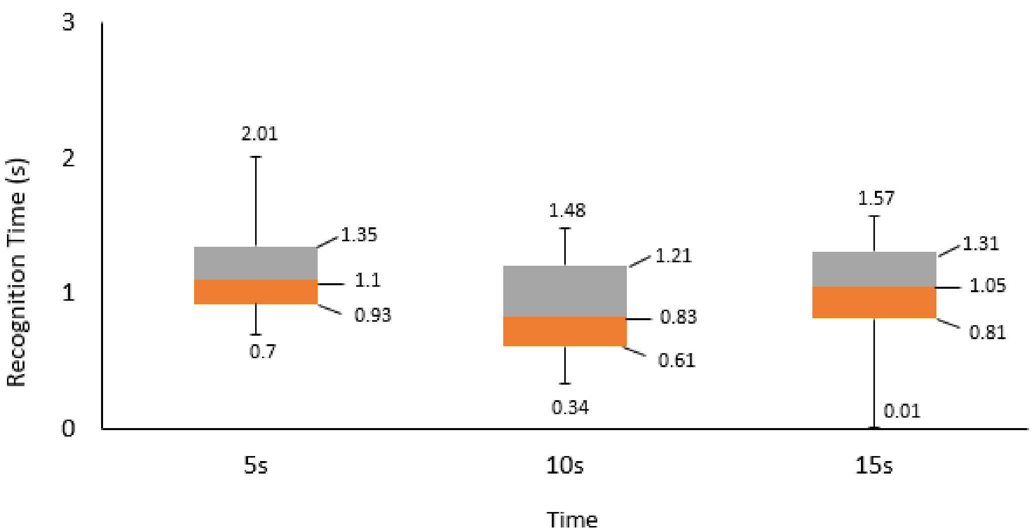

Fig. 14. Box plot reaction time for 30 participants

Based on the data represented in Figure 15, which shows the reaction time and breaking time for motorcycle and pedestrian scenarios, various data points were collected and analysed. The minimum reaction time for the motorcycle scenario was 0.47s, the maximum was 4.02s, and the median was 0.93s. For the pedestrian scenario, the minimum reaction time was 0.34s, the maximum was 2.84s, and the median was 0.68s. The participants' reaction time for the pedestrian scenario was shorter than that for the motorcycle scenario. The manipulated variable that changed in both scenarios was the velocity of the objects (motorcycle and pedestrian). Therefore, it can be concluded that the velocity of the object has an impact on the driver's reaction time, with higher object velocities resulting in longer reaction times by the participants. Furthermore, based on Figure 15 below, the box plot of braking time for motorcycle and pedestrian scenarios, several data points were obtained. The minimum braking time for the motorcycle scenario was 0.02s, the maximum was 3.81s, and the median was 1.02s. For the pedestrian scenario, the minimum braking time was 0.45s, the maximum was 2.38s, and the median was 1.085s. Notably, the participants' braking time for the pedestrian scenario was shorter than that for the motorcycle scenario. Both scenarios involved a manipulated variable, which was the velocity of the objects (motorcycle and pedestrian). Therefore, it can be concluded that the velocity of the object has an impact on the driver's braking time, with higher object velocities resulting in longer braking times by the participants.

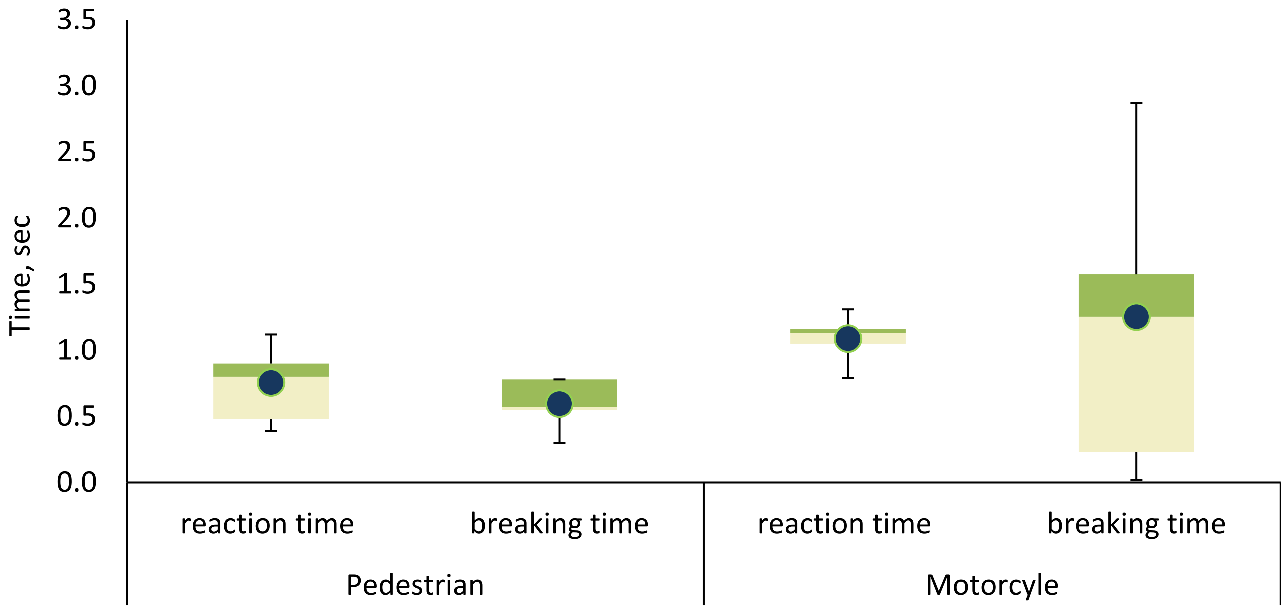

Fig. 15. Box plot reaction time for motorcycle and pedestrian scenario

5. Conclusions

Based on the study's data obtained and analysed from pre-crash scenarios, it was found that driver awareness towards incoming objects or obstacles can be effectively measured by their reaction time and braking time. The participants' data revealed a wide variety of results, reflecting individual differences in how drivers respond to potential hazards.

Furthermore, the study highlighted a crucial finding that the velocity of an oncoming vehicle significantly impacts the driver's reaction time and braking time. When faced with high-speed objects like motorcycles, the driver's reaction and braking times tend to be slower. On the other hand, when the oncoming object is slower, such as a pedestrian, the driver's reaction time and braking time are faster. For instance, in the motorcycle scenario, the recorded reaction times ranged from a minimum of 0.47 seconds to a maximum of 4.02 seconds, with a median of 0.93 seconds. This variation in reaction times corresponds to the object's higher velocity, indicating that speed has a significant impact on driver responses.

On the other hand, when confronted with slower oncoming objects like pedestrians, drivers exhibit notably swifter reactions and shorter braking times. In the pedestrian scenario, the recorded reaction times ranged from a minimum of 0.34 seconds to a maximum of 2.84 seconds, with a median of 0.68 seconds. These data points corroborate the contention that the speed of oncoming objects significantly shapes driver responses. In summary, the study suggests a clear correlation between the speed of the oncoming object and the driver's response behaviour: higher speed results in slower reactions. Consequently, it can be concluded that the velocity of an oncoming object profoundly influences the driver's behaviour, particularly in terms of reaction time and braking time.

Additionally, the study explored the driver's workload before and after the experiment using the NASA Task Load Index (TLX). Interestingly, the results indicated no significant difference in workload before and after the experiment, accepting the null hypothesis based on t-test analysis. This implies that the experiment itself did not substantially impact the driver's overall workload, suggesting that the measured changes in reaction and braking times were primarily influenced by the varying velocity of the oncoming objects.

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