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Malaysian Driver's Response During Obstacle Avoidance Task Using Driving Simulation Study: A Preliminary Study

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ABSTRACT – *The paper discussed the development of a driving simulator and Malaysian drivers' response during obstacle avoidance tasks using a driving simulation study. It is claimed that the driver reaction time is critical for specialists involved in road accident analysis. This study includes several obstacle avoidance tasks in the driving simulation application developed to measure the drivers' brake response time when confronted with emergency scenarios. A driving simulator that imitates an automatic transmission car is developed. Participants in this study are Malaysian drivers with at least two years of driving experience and a valid driving license. According to the data, older drivers in this study have the quickest brake response time compared to young and middle-aged drivers. Several factors may have influenced their performance while driving the simulator, including their lack of experience and exposure to it, which caused them to drive more cautiously and slowly than other age groups. Meanwhile, young and middle-aged drivers, particularly young drivers, sped through the simulator. The speed and precision with which drivers respond to stimuli affect their reaction time, especially while driving at high speeds. According to the data, male drivers in this study have a faster braking response time than female drivers. It is consistent with prior studies indicating that females react slower than males. The participants also validated the value of the simulation studies in raising their knowledge of defensive driving and becoming more vigilant while driving.*

KEYWORDS: Emergency scenarios, driving behavior, driver reaction time, driving simulator, driving simulation

1. INTRODUCTION

Motor vehicle accidents rank among the leading contributors to mortality, disability, and hospitalization. Road traffic incidents can potentially result in several negative consequences, including property damage, severe injuries, and loss of life. Traffic accidents have increased road safety awareness within current social concerns. In scenarios involving accidents, when the unforeseen existence of an obstruction creates a potential safety risk, the driver's response to the situation, such as engaging in braking maneuvers, often plays a crucial role in determining the eventual outcome of the incident (Droździel et al., 2020).

Droździel et al. (2020) believe that the availability of data related to driver reaction time holds significant importance for professionals engaged in road accident analysis. Driver reaction time in an emergency positively correlates with accident probability (Li et al., 2016). The previously mentioned parameter has a direct influence on the outcome of an accident occurrence, as well as on the overall safety of roadways. Including driver reaction time data is essential in the manuals and training materials applied by court experts, car engineers, and traffic experts (Droździel et al., 2020).

The unexpected aspect of road safety now lies in the behavior produced by drivers. Zhuk et al. (2015) say that the driver's psychophysiological condition affects how accurately they receive and take actions, generally known as their reaction time. Drivers' reaction times depend on how quickly and precisely they apply the brake pedal, turn the steering wheel, and shift gears, especially at high speeds. Experienced drivers typically execute most operations in an automated manner, minimizing the time required for completion. A driver's reaction time variability can be attributed to various factors. The driver's response time increases when dealing with complex traffic conditions or rapid changes (Zhuk et al., 2017).

Recently, there has been a significant surge in the utilization of driving simulators for road-based research. Driving simulators are used to replicate and simulate various driving scenarios. A wide variety of applications can be observed within road safety research, including investigations into driver behavior and studies of vehicle components and technology. The elements above involve various areas of study, such as behavioral research, driving education and training, transportation infrastructure analysis, ergonomics, psychology, and intelligent transportation systems (Iqbal et al., 2020).

The utilization of a driving simulator offers a controlled and replicable setting (Dols et al., 2016; Mohd Siam et al., 2015), thereby enhancing safety (Bruck et al., 2021) and reducing costs compared to conducting experiments on actual roadways (Boda et al., 2018; Bruck et al., 2021; Dols et al., 2016; Mohd Siam et al., 2015). The utilization of driving simulators has been found to offer more precise analysis due to a study that enables data acquisition at a reduced cost, with decreased risk and enhanced control over the factors under investigation, precisely speed (Dols et al., 2016). According to Droździel et al. (2020), this technology allows for adjusting various accident scenarios without compromising safety (Droździel et al., 2020).

2. AIM AND METHODS

This study aims to develop a driving simulator with obstacle avoidance tasks in the driving simulation application. The study seeks to evaluate Malaysian drivers' reactions and behavior when encountering emergency scenarios using a driving simulation study.

2.1 Participants Recruitment

The present study used a driving simulation approach to recruit a sample of Malaysian drivers, both male and female, who have a valid driving license. A minimum of two years of driving experience is necessary. To fulfill the requirements, all samples must be able to drive an automatic transmission car, as the driving simulator simulates an automatic transmission car.

2.2 Driving Simulator Apparatus

The equipment used in this study comprises a personal computer, driving simulator rigs, input/output devices, instrumented pedals, and a display system, as shown in Figure 1.

The driving simulator setup used for this research is seen in Figure 1. The setup includes two webcams for capturing the participants and their foot movements, three interconnected screens for visualizing the driving simulation application, the PXN V10 steering wheel for controlling the simulated vehicle, instrumented pedals with pressure sensors to measure the force exerted by the participants on the pedals, speakers, and a driver seat.

2.2.1 Personal Computer (PC)

A mid-range desktop PC was constructed for the driving simulation study. The microprocessor, also known as the central processing unit (CPU), used in this system is the AMD Ryzen 5 5500, along with 16GB DDR4 RGB Gaming RAM. A GeForce RTX 3060 Ti 8GB DDR6 graphics card facilitates the provision of three video outputs for a multi-monitor system, accomplished through a combination of three DisplayPort connections. Additionally, it enables the connection of a monitoring screen via a single HDMI connection. Also, this PC used a 256GB solid-state drive (SSD) with Non-Volatile Memory Express (NVMe) technology for data storage. The selection of Windows 10 as the operating system was based on its robust driver support and its seamless compatibility with a wide range of gaming and simulation software applications.

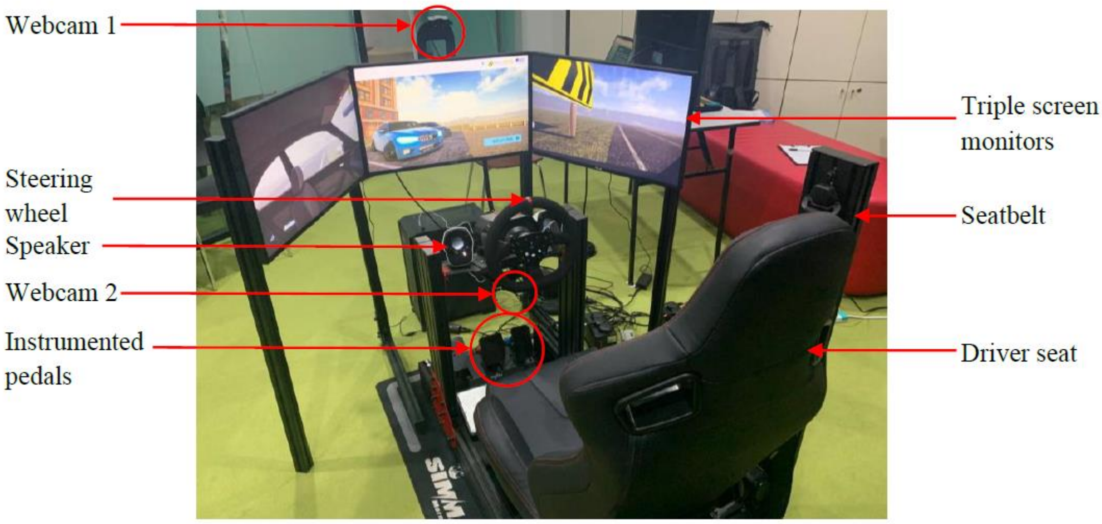

FIGURE 1: Driving simulator setup

2.2.2 Driving Simulator Rigs and Input/Output Devices

The study included a stationary cockpit-style seat with a fixed base. The driving simulator rigs are constructed from powder-coated aluminum profiles. This study provides the steering input through a PXN V10 steering wheel. This particular steering wheel was selected based on its high level of compatibility, as it is designed to be compatible with all gaming consoles (König, 2022). The product has a pre-mounted design to a mounting plate, enabling installation onto our simulation setup. According to the specifications (Shenzhen PXN Electronic Technology Co., 2022), the steering wheel can complete 2.5 cycles of rotation, which aligns with the standard rotation degrees of an actual car steering wheel. The PXN V10 is equipped with a complete three-pedal set but with our modifications to mimic the pedal configuration in automatic transmission cars.

The audio elements of the driving simulation game, including the engine noise and other sounds, are produced and sent via Logitech Z120 Compact Stereo USB-powered speakers. The footage of drivers and their foot movement during the driving simulation is captured using two Fantech Luminous C30 Quad HD USB webcams. The cameras include an integrated microphone, a base allowing full rotation of 360 degrees to facilitate angle adjustments, and a wide field of vision of 106 degrees, enabling a more complete visual coverage (Fantech Malaysia, 2020).

2.2.3 Instrumented Pedals

In a prior study (Ismail et al., 2023), force pressure sensors were placed on the brake and accelerator pedals to determine the foot pressure exerted by the drivers. The force pressure sensor utilized in this study is referred to as velostat. The setup shown in Figure 2 illustrates the velostat and aluminum foil arrangement using the "sandwich" method. The sensor was positioned between two aluminum foils acting as the conductive layers.

2.2.4 Display System

The driving simulator is made up of three screens that display the driving simulation game. The selection of ASUS TUF Gaming VG279QR Full HD 27-inch flat monitors for display combinations. They come with a maximum refresh rate of 165Hz and a reaction time of 1 ms (ASUSTek Computer Inc., 2020). The VESA mounts measuring 100x100mm fixed the displays to the aluminum profile. In addition, a 28-inch Samsung Ultra HD UE590 monitor was used as a control station for monitoring purposes throughout the driving simulation study.

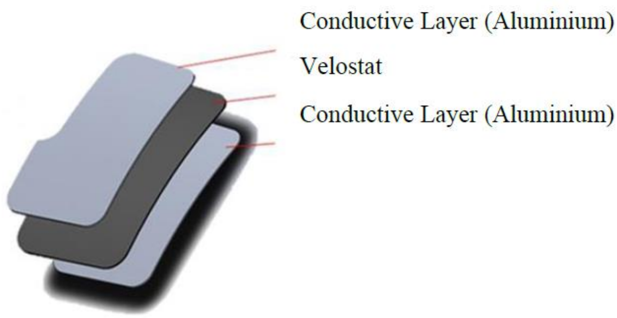

FIGURE 2: Velostat and conductive layers setup using the “sandwich” method (Ismail et al., 2023)

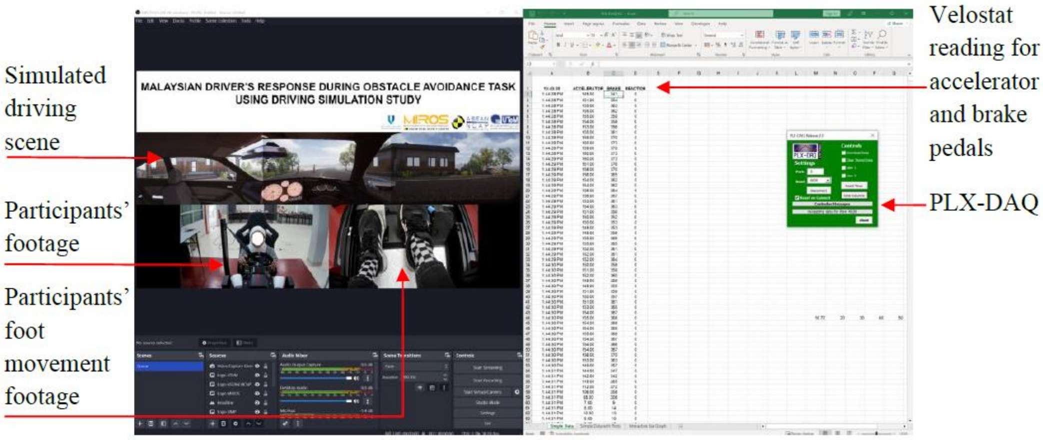

FIGURE 3: Display screen for monitoring purposes

The control station shown in Figure 3 displays and monitors the driving simulation program and presents the data gathered during the driving simulation study. The visibility of the data collection and simulation study is limited to the researchers involved to ensure it is successfully conducted. Open Broadcaster Software (OBS) is used for video recording and displaying many windows simultaneously. It includes the triple-linked monitors for the driving simulation application, participants’ hands-on-the-wheel footage captured by Webcam 1, and their foot movement while driving the simulator captured by Webcam 2. Another side of the monitor is to display the real-time data collected by Arduino into Microsoft Excel using the Parallax microcontroller data acquisition (PLX-DAQ).

2.3 Driving Simulation Software

In summary, the driving simulation in this study was constructed based on the theoretical framework, utilizing the Unity3D game engine and implementing C# programming language. The Unity game design engine offers a wide range of tools that facilitate the efficient and economical production of 3D scenes, enabling users to simulate a driving experience that closely resembles reality (Tsai et al., 2018). According to Abrar and Ali (2016), Unity3D allows the accurate representation of 3D models in the context of road infrastructure projects (Abrar & Ali, 2016).

2.4 Obstacle Avoidance Task

Figure 4 presents an overview of the numerous obstacles implemented in our driving simulation application, specifically designed to assess the response of Malaysian drivers. The obstacles in this study consist of various scenarios, including animals crossing the road, sudden hazards (cars breaking down), traffic lights turning red when driving, random cars driving dangerously, a motorcyclist suddenly coming out of a junction, pedestrians crossing the road, and a parking maneuver.

The surprising events in the driving simulation application are selected and designed based on previous studies by past researchers. Based on actual events reported in the news media, a driver accidentally pressed an accelerator instead of a brake pedal after being frightened by a motorcyclist crossing in front of her vehicle (Isahak, 2020). Another driver also made a pedal error at a traffic light when she wanted to continue driving. She accidentally hit the car in front of her and crashed into a police station nearby (Idris, 2020). In our study, a scenario where animals crossing the road is included as it is inspired by an event where a driver pressed on the accelerator pedal instead of the brake pedal when she was surprised by a cat suddenly crossing in front of her vehicle (Osman, 2019).

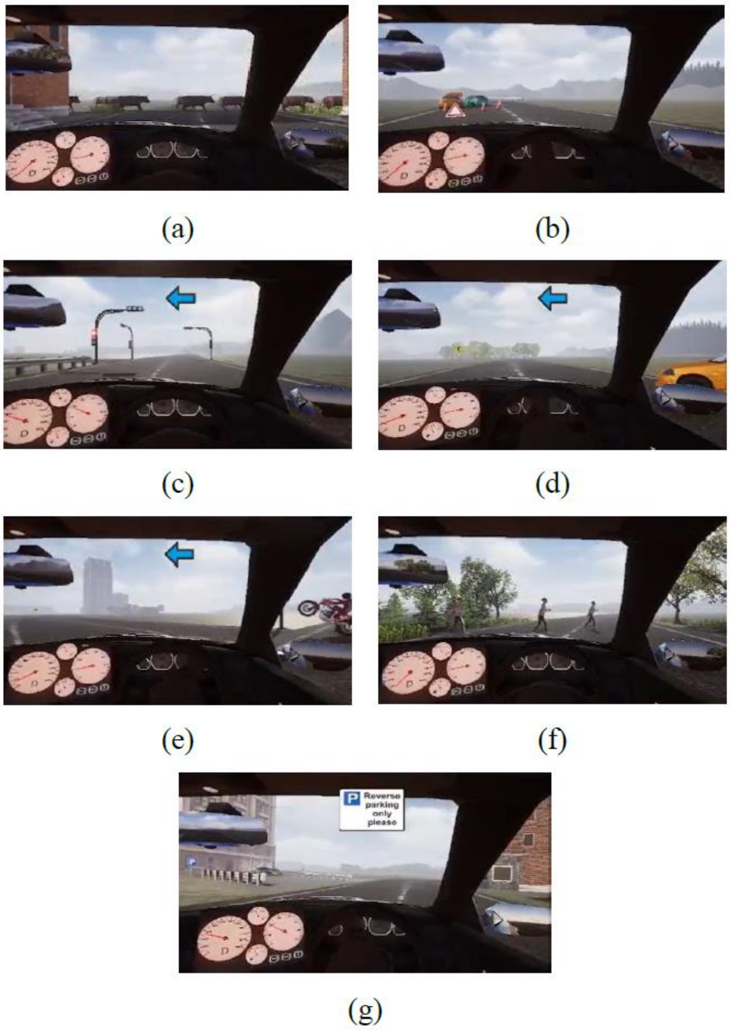

FIGURE 4: Obstacle avoidance tasks (a) Animals suddenly crossing; (b) Sudden hazard on the road; (c) Traffic light turns red; (d) Random cars driving dangerously; (e) A motorcyclist comes out of a junction; (f) Pedestrians crossing the road; (g) Parking maneuver

A scenario when pedestrians cross the road (Freund et al., 2008; Mahajan & Velaga, 2020) is also included in this study as an obstacle to observing Malaysian drivers' responses. We found that Malaysian drivers also made pedal errors during parking maneuvers, as reported in news media (Ab Malek, 2020; Md Sani, 2019; Mokhtar, 2020). Hence, we decided to include a parking scenario for the participants to perform in our driving simulation study. Hazards in front (cars breaking down) and random cars driving dangerously on the road are also unexpected, surprising events in our simulation application. In addition, the driving simulation includes road signs such as the curve warning sign, winding road, roundabout, and bump sign.

2.5 Driving Simulation Study Flow

The driving simulation study involves a series of procedures and a defined flow that occurs before, during, and after the study. Figure 5 shows the study starts with the participants arriving at the designated driving simulation location. Upon arrival, participants will receive a unique identification (ID) number corresponding to their order in the sequence. The primary objective of providing ID numbers is to facilitate their recognition, given that their names are undisclosed and anonymous. Subsequently, they will receive brief instructions related to the assessment. An informed consent form is handed out to participants, allowing them to carefully read its contents and sign the form to express their voluntary decision to participate in the study.

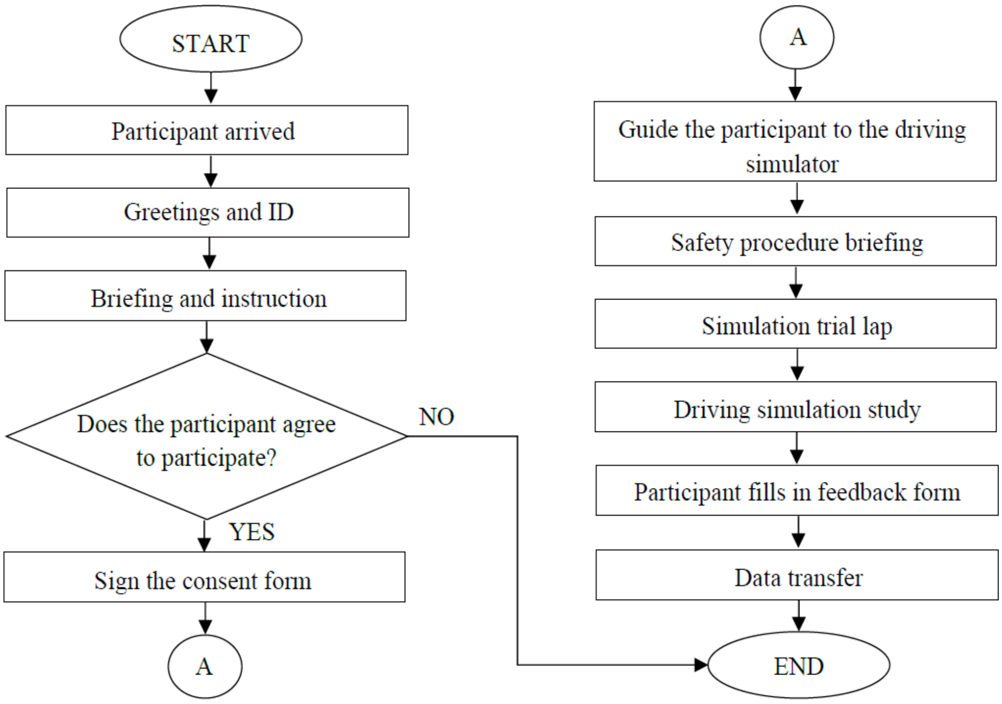

FIGURE 5: Driving simulation study flow

Participants will be directed to the driving simulator, where they will be given a brief explanation of the tasks they must carry out for the experiment, including a safety briefing. Each participant performed a practice drive to become familiar with the driving simulator. Participants in this practice session performed actions such as straight driving, acceleration, deceleration, left/right turns, and other essential driving behaviors. Furthermore, participants were informed that they might leave the experiment at any moment if they experienced motion sickness or other discomfort. Subsequently, the participants will begin an actual driving simulation assessment, covering the objective of obstacle avoidance.

Following the driving simulation test, participants were asked to respond to a post-test questionnaire regarding the driving simulator itself and the driving experience. Participants must respond to the questions sincerely, as there are no objectively right or wrong responses. While completing the online feedback form, the researchers will transfer and save the footage and instrumented pedal data per their respective ID numbers, such as P1 for Participant 1. The driving simulation study procedure will be repeated for subsequent participants.

3. RESULTS AND DISCUSSION

3.1 Participants' Demographic Data

The driving simulation study included 72 Malaysian drivers, 50 males (mean age = 30.22, SD = 12.49) and 22 females (mean age = 26.82, SD = 6.12). All participants had a valid driving license and at least two years of driving experience. They can also drive an automatic transmission car and have fulfilled the requirements for driving simulation participants.

TABLE 1: Participants' demographic data

Independent Variables	Level		No. of Participants (N)	Percentage (%)
Gender	Male		50	69.4
	Female		22	30.6
Age group	Young	19 to 20	6	8.3
		21 to 30	44	61.1
	Middle-aged	31 to 40	10	13.9
		41 to 50	7	9.7
	Older	51 to 60	4	5.6
		61 and older	1	1.4
Driving experience	2 years		11	15.3
	3-10 years		39	54.2
	11-20 years		11	15.3
	21-30 years		7	9.7
	More than 30 years		4	5.6

Table 1 displays the demographic information for the driving simulation study participants. The drivers are divided into three age groups: young, middle-aged, and older. The driving simulation study participants include young drivers aged 19 to 30, who make up 69.4% of the total participants, middle-aged drivers aged 31 to 50 (23.6%), and older drivers aged 51 and above (7%). In other words, most participants are young drivers, and the least are older drivers.

Another characteristic that is considered is the participants' driving experience. Based on the total 72 participants, 15.3% have 2 years and 11 to 20 years of driving experience, respectively. Most participants (54.2%) have between 3 and 10 years of driving experience. However, the number of participants aged 21 to 30 years (9.7%) is higher than the number of participants aged 30 years and older (5.6%).

3.2 Summary of Participants' Feedback on the Driving Simulation

After completing their driving simulation course, participants are requested to provide feedback on the course. The responses of 72 participants have been simplified and are shown in Figure 6.

Figure 6 shows the participants' feedback and thoughts on the driving simulation. After completing the driving simulation course, 77.8% of the 72 participants believed that the simulation accurately showed what it is like to drive in an emergency situation. Since the emergency conditions simulated in the driving situations actually occur and may happen in real life, 77.8% of the participants agree that the driving simulation may assist them in defensive driving to avoid collisions.

The simulated challenges, on the other hand, shocked 76.4% of them when they appeared. However, 16.6% of 72 participants disagreed that the simulated event was virtually equal to actual driving conditions in terms of the realism of the driving simulation. Following their feedback, the driving simulation can be enhanced and developed to be more realistic in real-world situations. More than half of the participants (76.4%) agree that the simulated event can boost attentiveness in specific circumstances in real life.

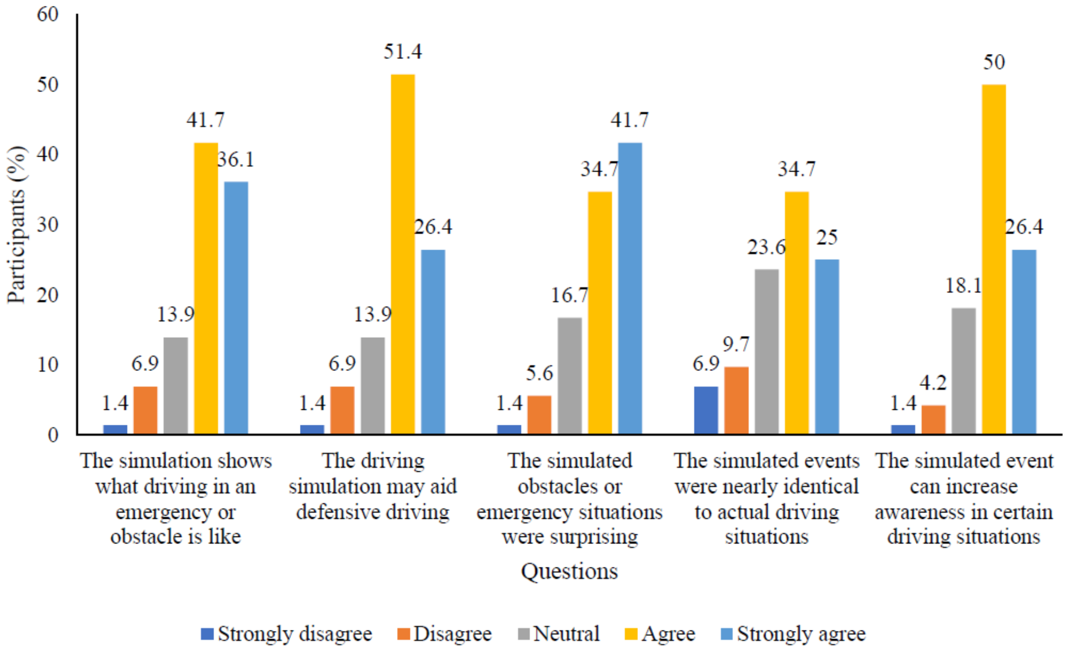

FIGURE 6: Driving simulation feedback by 72 participants

3.3 Participants' Response during Obstacle Avoidance Tasks

The initial sample size for this study consisted of 72 participants. Upon conducting a thorough screening, it was discovered that three of the seven obstacles could not be analyzed due to the participants' responses during the encounter. At the same time, a small number of participants could not complete the test due to experiencing simulation sickness. The drivers were not instructed on how to respond to the hazardous situation. They choose how to react based on their judgment of situations and prior experience.

3.3.1 Random Cars Driving Recklessly Appear and a Motorcyclist Suddenly Comes Out of a Junction

The average brake response could not be calculated after analyzing the participants' data due to the drivers' responses when meeting the simulated obstacles. When confronted with random cars driving carelessly and a biker suddenly appearing in front of the participants, most drivers did not apply brakes, and others merely exerted a very modest amount of force on the brake pedal. According to the footage, most drivers in the driving simulation tried to avoid collisions by turning the steering wheel away, and some pressed the accelerator pedal to speed up the simulated car. As a result of the minimal force applied to the brake pedal when they faced those two obstacles, the average braking response time could not be obtained.

3.3.2 Parking Maneuver

The participants were asked to perform a reverse parking at the end of the driving simulation course. According to the footage, most drivers disregard parking directions in reverse. The pedal errors while performing parking maneuvers were searched using the footage. However, no pedal errors or drivers who mistakenly pressed the wrong pedal were obtained.

3.4 Braking Response Time during Obstacle Avoidance Tasks According to Participants' Age

The braking response time of the participants for four obstacles can be calculated using the data collected. The obstacles include animals crossing the road, a hazard in front, a red traffic light, and pedestrians crossing the street. As a result, for each obstacle, a graph is constructed to represent the participants' average braking response based on their age group. Figure 7 shows a compilation of graphs at four different obstacles.

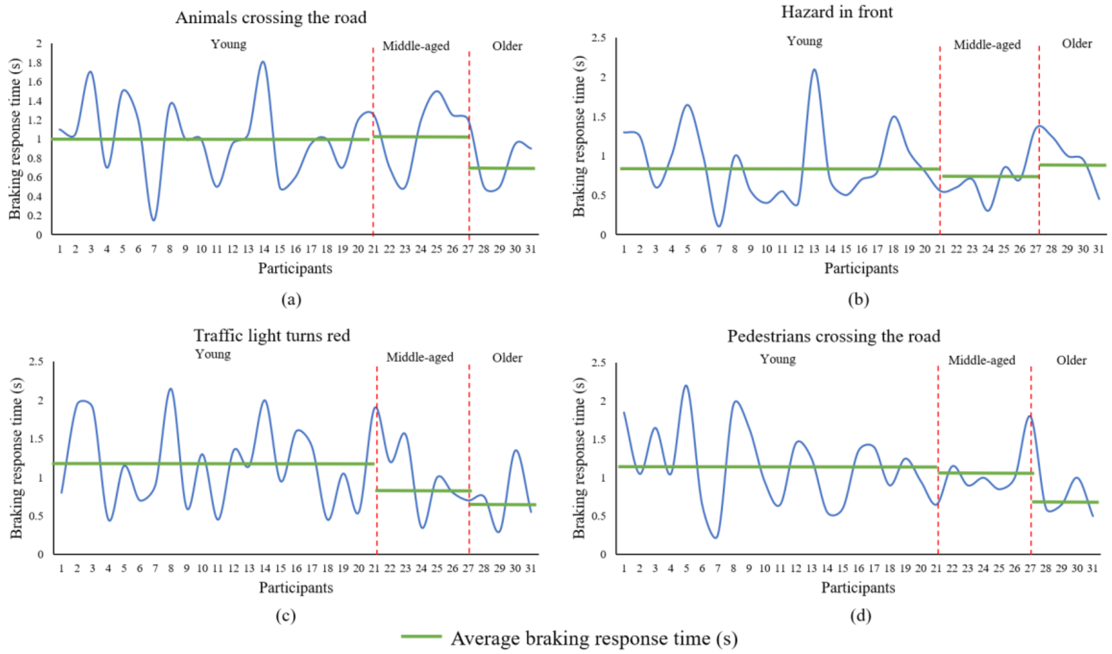

FIGURE 7: Average braking response time according to age groups (a) Animals crossing the road; (b) Hazard in front; (c) Traffic light turns red; (d) Pedestrians crossing the road

Figure 7 shows the brake response time for 31 participants when animals are crossing the road, a hazard in front of them while driving, traffic lights turning red, and pedestrians crossing the street, sorted by age group. The graphs show that older drivers had the quickest braking response time compared to young and middle-aged drivers. When reacting to animals crossing the road, older drivers required an average of 0.71 seconds to apply the highest braking force and 0.74 seconds when the traffic light turned red. With 0.69 s, they also had the quickest brake response time when they saw pedestrians crossing the roadway. However, when there was a hazard in front of them, they took the longest brake response time (0.91 s) compared to middle-aged drivers (0.75 s) and young drivers (0.88 s).

These findings contradict previous studies that claim older adults have a longer average response time than middle-aged and young groups (Hichim et al., 2020; Yan & Jun, 2019; Yuda et al., 2020). In this scenario, it is possible that older drivers were more cautious and aware because they were unfamiliar with the driving simulation. According to the footage, older drivers are more alert and drive slower than younger ones. Furthermore, because of their disproportionate usage of video games, teenagers have more experience with virtual environments (Loeb et al., 2015). As a result, it is possible that some of the gaps between young and older drivers can be related to these impacts.

The footage shows that young drivers in this driving simulation study drove relatively fast and more aggressively than other age groups. According to Feng et al. (2017), younger drivers are more aggressive than older drivers (Feng et al., 2017). On the other hand, the middle-aged group has a somewhat faster rate than the young drivers, but it is still longer than the older group, which has the quickest response time. Based on the footage, middle-aged and older drivers drove slower than young drivers.

3.5 Braking Response Time during Obstacle Avoidance Tasks According to Participants' Gender

The brake response time during obstacle avoidance tasks can be analyzed based on participant gender for four obstacles: animals crossing the road, hazards in front while driving, traffic lights turning red, and pedestrians crossing the street.

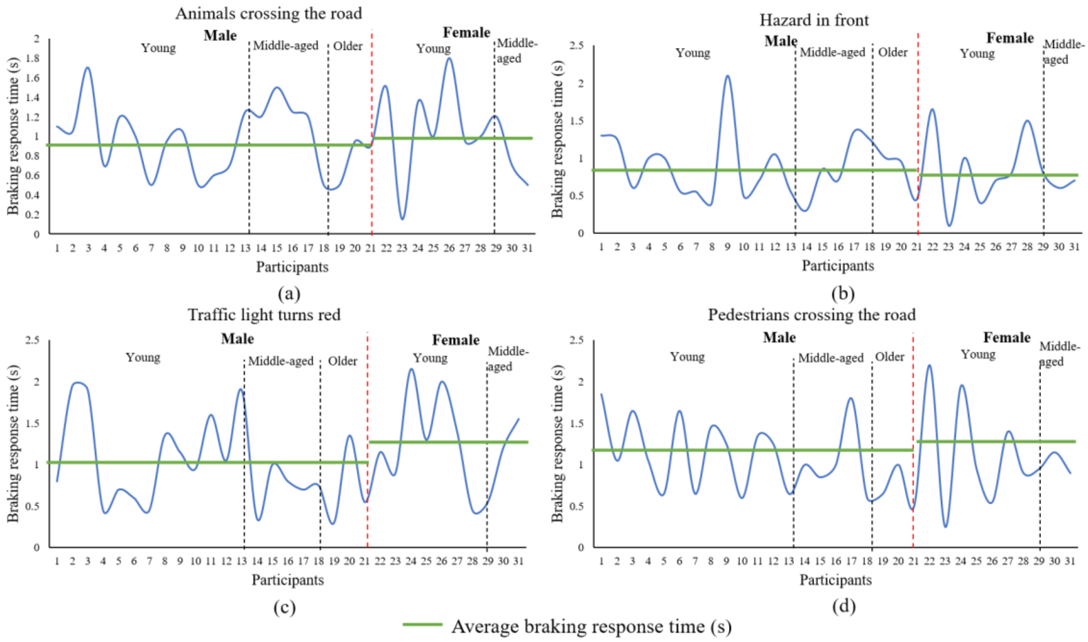

FIGURE 8: Average braking response time according to gender (a) Animals crossing the road; (b) Hazard in front; (c) Traffic light turns red; (d) Pedestrians crossing the road

Figure 8 shows drivers' average braking response time to apply the brakes in reaction to four different types of emergencies, including animals crossing the road, a hazard in front of the driver while driving, traffic lights turning red, and pedestrians crossing the street. According to Azmi and Mustaffa (2022) and Hichim et al. (2020), gender groups are also one of the elements affecting drivers' brake response time (Azmi & Mustaffa, 2022; Hichim et al., 2020). The graphs show that males reacted quicker when applying the brakes than females in every scenario, except when there was a hazard in front of them while driving. On the other hand, the brake response time of females is a little faster than that of males, as in Figure 8(b), coming in at 0.83 s as opposed to 0.88 s for males.

Previous research has shown that males had faster brake response times than females (Azmi & Mustaffa, 2022; Ashok et al., 2016). According to Ashok et al. (2016), males responded more quickly to visual than auditory stimuli. As a result, it is possible to correlate it with the stimuli shown in the driving simulation study. Past studies also state that females' reaction time to a stimulus is significantly longer than that of males (Hichim et al., 2020; Ashok et al., 2016). These current findings are consistent with the past research.

4. CONCLUSION

In conclusion, a driving simulator with obstacle avoidance tasks in a driving simulation application has been successfully constructed. The study also measured the responses and behaviors of Malaysian drivers when confronted with emergency scenarios using the driving simulation application. According to the findings, elderly drivers had the fastest brake response time compared to young and middle-aged drivers. It could be because of their previous experiences and exposure to the driving simulator since they drove slower and more carefully than the other age groups. It demonstrates that speed has a substantial effect on braking response time. The faster the car, the more likely a collision may occur. Another research reveals that the gender of the subjects is highly related to reaction time. Females have a longer reaction time than males, according to the findings. It is consistent with other studies that suggest males had faster reaction times. The participants were also pleased and agreed that the driving simulator and simulation application would help them become better drivers and expose them to defensive driving. In particular, the simulated emergency scenarios can increase their alertness. Despite the study's small sample size and the scenarios investigated, the findings can be applied to future driving behavior and road safety research. However, it is widely held that a larger sample size is always beneficial in producing more accurate results.

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REFERENCES

Ab Malek, R. (2020). *Proton Saga rempuh gerai pasar pagi*. Retrieved from https://www.hmetro.com.my/mutakhir/2020/12/652781/proton-saga-rempuh-gerai-pasar-pagi

Abrar, T., & Ali, H. H. (2016). Integration of Oculus Rift-based virtual reality with unity 3D in a driving simulator. University of Hassselt, Knowledge in Action, Technical Report, June 2016.

Ashok, J., Suganthi, V., & Vijayalakshmi, I. (2016). Effect of gender difference on brake reaction time. Journal of Evidence Based Medicine and Healthcare, 3(16), 583-585.

ASUSTek Computer Inc. (2020). TUF GAMING VG279QR | Monitors | ASUS Global. Retrieved from https://www.asus.com/displays-desktops/monitors/tuf-gaming/tuf-gaming-vg279qr/

Azmi, M. A. I., & Mustaffa, N. (2022). Experimental evaluation of brake response time on motorcycle brake lamp. Journal of Automotive Powertrain and Transportation Technology, 2(1), 608-620.

Boda, C. N., Dozza, M., Bohman, K., Thalya, P., Larsson, A., & Lubbe, N. (2018). Modelling how drivers respond to a bicyclist crossing their path at an intersection: How do test track and driving simulator compare? Accident Analysis and Prevention, 111(October 2017), 238-250.

Bruck, L., Haycock, B., & Emadi, A. (2021). A review of driving simulation technology and applications. IEEE Open Journal of Vehicular Technology, 2(January), 1-16.

Dols, J. F., Molina, J., Camacho, F. J., Marín-Morales, J., Pérez-Zuriaga, A. M., & Garcia, A. (2016). Design and development of driving simulator scenarios for road validation studies. Transportation Research Procedia, 18(June), 289-296.

Droździel, P., Tarkowski, S., Rybicka, I., & Wrona, R. (2020). Drivers 'reaction time research in the conditions in the real traffic. Open Engineering, 10(1), 35-47.

Fantech Malaysia (2020). Fantech Luminous C30 Quad High Def 1440P 2K Quad HD USB web camera webcam with built-in microphone for PC/MAC/LAPTOP. Retrieved from https://fantechmalaysia.com.my/other?product_id=958

Feng, F., Bao, S., Sayer, J. R., Flannagan, C., Manser, M., & Wunderlich, R. (2017). Can vehicle longitudinal jerk be used to identify aggressive drivers? An examination using naturalistic driving data. Accident Analysis and Prevention, 104(February 2016), 125-136.

Freund, B., Colgrove, L. A. A., Petrakos, D., & McLeod, R. (2008). In my car the brake is on the right: Pedal errors among older drivers. Accident Analysis and Prevention, 40(1), 403-409.

Hichim, M. F., Khusheef, A. S., & Raheemah, S. H. (2020). The effects of driver age and gender on vehicle stopping distance under different speeds. European Transport - Trasporti Europei, 80, 1-11.

Idris, S. R. (2020). *Tertekan pedal minyak, kereta rempuh balai polis*. Retrieved from https://www.bharian.com.my/berita/kes/2020/04/673706/tertekan-pedal-minyak-kereta-rempuh-balai-polis

Iqbal, M., Sari, K., Ade Sekarwati, K., & Kemala Putri, D. (2020). Developing PC-based driving simulator system for driver behavior analysis research. Journal of Physics: Conference Series, 1566(1).

Isahak, Z. (2020). *Tertekan pedal minyak, kereta rempuh kedai runcit*. Retrieved from https://www.sinarharian.com.my/article/95009/edisi/johor/tertekan-pedal-minyak-kereta-rempuh-kedai-runcit

Ismail, N. M. A., Zulkifli, A. H., Baharom, M. Z., Ahmad, Z., Hassan, M. H. A., Karjanto, J., & Mohd Jawi, Z. (2023). The development of a driving simulator for driver's response during obstacle avoidance task.

König, F. (2022). PXN V10 Racing wheel review – Quality wheel at a budget. Retrieved from https://simracereviews.com/reviews/pxn-v10/

Li, X., Yan, X., Wu, J., Radwan, E., & Zhang, Y. (2016). A rear-end collision risk assessment model based on drivers' collision avoidance process under influences of cell phone use and gender - A driving simulator based study. Accident Analysis and Prevention, 97, 1-18.

Loeb, H. S., Kandadai, V., McDonald, C. C., & Winston, F. K. (2015). Emergency braking in adults versus novice teen drivers response to simulated sudden driving events. Transportation Research Record, 2516, 8-14.

Mahajan, K., & Velaga, N. R. (2020). Effects of partial sleep deprivation on braking response of drivers in hazard scenarios. Accident Analysis and Prevention, 142(July).

Md Sani, M. S. (2019). *Alamak, tertekan minyak pulak*. Harian Metro. Retrieved from https://www.hmetro.com.my/utama/2019/02/418548/alamak-tertekan-minyak-pulak

Mohd Siam, M. F., Md Isa, M. H., Borhan, N., Sukardi, A., & Voon, W. S. (2015). Measurement of driver distraction in Malaysia's traffic environment: A driving simulator study. Journal of Mechanical Engineering and Sciences, 8(July), 1472-1480.

Mokhtar, N. A. (2020). *Gara-gara tertekan pedal minyak, pelajar kolej patah kaki*. Retrieved from https://www.bharian.com.my/berita/kes/2020/09/736113/gara-gara-tertekan-pedal-minyak-pelajar-kolej-patah-kaki

Osman, H. (2019). Wanita tertekan pedal rempuh pagar Lapangan Terbang Antarabangsa Langkawi. Retrieved from https://www.bharian.com.my/berita/kes/2019/08/600238/wanita-tertekan-pedal-rempuh-pagar-lapangan-terbang-antarabangsa-langkawi

Shenzhen PXN Electronic Technology Co., L. (2022). PXN-V10 | PXN racing wheel, game controller, arcade stick for Xbox One, PS4 Switch, PC. Retrieved from https://www.e-pxn.com/products/racing-wheel/pxn-v10

Tsai, P. S., Wu, T. F., Hu, N. T., Tang, J. H., & Chen, J. Y. (2018). Virtual reality to implement driving simulation for combining CAN BUS and automotive sensors. Proc. of the 2017 IEEE ICICE 2017, 40-42.

Yan, Z., & Jun, Z. (2019). Simulation research on driver response time and steering stability based on EPS system. ACM International Conference Proceeding Series, 310-314.

Yuda, E., Yoshida, Y., Ueda, N., Kaneko, I., Miura, Y., & Hayano, J. (2020). Effects of aging on foot pedal responses to visual stimuli. Journal of Physiological Anthropology, 39(1), 1-7.

Zhuk, M., Kovalyshyn, V., Royko, Y., & Barvinska, K. (2017). Research on drivers' reaction time in different conditions. Eastern-European Journal of Enterprise Technologies, 2(3-86), 24-31.