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# Modelling and Evaluation of Driving Simulator for Driving Education in Malaysia

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**Abstract.** Driving simulator has been widely used as one of driver training tools because it provides a safe environment which does not expose drivers to hazards. However, Malaysia has yet to adopt the driving simulator in the driving course. In this paper, a cost effective and modular driving simulator prototype integrated is designed and developed based on the Malaysian Ministry of Transport's Standardised License Test. Seven modules which correspond to five practical syllabus circuit tracks and two on-the-road theories are created using a real time development tool named "Unity" and integrated with some off-the-shelf hardware namely a steering wheel, gear shifter and pedals. The justification of the simulator is confirmed by conducting a unique experimental procedure on it participated by 26 individuals. They are divided into two groups each of which follows two different training methodology before taking part in the simulator test mode. One group is provided with only printed materials and another group is allowed to practise in the simulator. Experimental results show that the transfer of skills is far better among the participants of the group who are allowed to practise the simulator before taking part in the automated test of the simulator.

**Keywords:** Driving Simulator, Driving Education, Immersive Learning

# 1. Introduction

Digital learning has come a far way, with the recent popularity of immersive learning, potentials of many aspects in learning can be explored. Advantages of immersive learning are engaging visuals that allows learners to be immersed in a simulated environment that enhances learning by three ways: allowing multiple perspectives on a subject to be explored, situated learning and transfer (Dede, 2009). As the learning activities are conducted in simulated environment, safety concerns are minimal.

Simulators have long been used in several industries such as pilot training and racing driving training. These simulators are built to allow the users to learn, practice and train the specific skill-sets. Kandhai (2011) and his team did an analysis on Immersive Driving Simulation for Driving Education. They reported positive results on the realism and immersion of the virtual environment with users reporting favourable learning experiences in their early testing (Kandhai et al., 2011). Chan (2010) and his group argued that in the case of hazard anticipation, speed management and attention maintenance, driving simulators can be effective tools for evaluating novice drivers (Chan et al., 2010). Burkhardt et al. (2016) mentioned in his paper, the simulators have been demonstrated to help learning and training purposes in road safety and driving education in a lesser extent. These technologies however have not received as much attention in the training and learning purposes of the simulators in driving schools ((Burkhardt et al, 2016). As summarised in Oztel et al. findings, driving simulator is able to educate and instill traffic rules to novice drivers (Oztel, I.and Oz, C., 2015). Not only that, a work done by Tiu et. al proved that these sims can help minorly disabled people as well (Tiu et al., 2020).

Driving education is mainly involved with technical skill and understanding the road infrastructure is challenging for new drivers (Abdul Hannan et. al, 2023). There, the use of driving simulator will reduce the number of practical lessons and increase confidence level of students before the real-road practice. To the best of our knowledge, no studies have been made with regards to taking the simulation approach to educate and prepare would-be drivers in the Malaysian driving license examinations. In this paper, we designed and developed the first driving simulator prototype that conforms to the Malaysian Ministry of Transport's Standardised License Test. We developed our prototype using Unity engine and integrated off-the-shelf hardware. We then conducted an experiment to do a case study the learning effectiveness between conventional method (printed materials) and simulator method in Malaysia movement.

# 2. Literature Review

We review previous work in literature that focuses on driver's education using simulators and some of the current available solutions. In addition, they have done driving training related studies regarding using simulators as a tool.

Fisher et al. and Kandhai et al. have similarities. Fisher and teams (Fisher et al., 2006) work trains hazard perception with Kandhai et al.'s compares faults made by users as to perceived faults (Kandhai et al., 2011). These two papers' result show that hazard perception can be trained by simulators as Kandhai et al.'s paper proved users commit more faults than perceived while suggesting that it can be improved with simulator training. Underwood et al. and Uhr et al. uses more complex simulators in their studies. Underwood et al. evaluate a driving simulator by comparing hazard detection while driving on roads, while watching short film clips recorded from a vehicle moving through traffic and driving through a simulated city in a fully instrumented fixed-base simulator (Underwood et al., 2011). Uhr et al. conducted experiment conducted with 50 experience truck drivers to perform a specific driving manoeuvre using an advanced driving simulator and a real system. Results shows that there is a positive transfer of training from driving simulator into the real system (Uhr et al., 2003).

Backlund et al. constructed a simulator with off-the-shelf hardware and runs on open-source software in 2010. The authors showed a game-based simulation can be used to enhance some aspects of learning in a traffic safety context and can be used to enhance some aspects of learning in driving education (Backlund et al., 2010). Nieto and Alesón-Carbonell (2012) also suggested that a balanced mix of entertainment, specific instructional content and perceived educational value can create a great learning experience in serious games (Nieto and Alesón-Carbonell, 2012). Erhel and Jamet (2013) noted that their experiments show that in terms of motivation and learning process, learning instructions can help deepened the learning and entertainment instructions with feedback is beneficial, concluding that serious game environment can promote learning and motivation if it includes features that prompt learners to actively process the educational content (Erhel and Jamet, 2013).

The team of Mazer (2015) examined the effectiveness of driving simulator retraining on clients with neurological impairment and factors associated with treatment effectiveness. Their results showed with preliminary on the potential clinical usefulness of driving simulator training and suggested that clients with moderate impairment had the potential to benefit (Mazer et al., 2015). Hirsch and Bellavance (2016) executed a pilot project on validating transfer of skills learned from a high-fidelity driving simulator. The authors used a realistic truck simulator with truck drivers (Hirsch and Bellavance, 2016). The authors also have encouraging evidence that showed few hours of driving simulator training is associated with reduced infractions in the first 2 years of unsupervised driving after licensing (Hirsch and Bellavance, 2017).

Based on our review article (Cheng et al., 2022) and another work by Moon et. al (Moon et. al, 2022), we found gaps within the studies relating to driving education. This motivated us to explore the possible use of combining three main areas of driving simulation: Artificial Intelligence (AI) & Computational Intelligence (CI), and Virtual Reality (VR), to improve learning effectiveness in driving education. We close the gap by designing and developing the driving simulator to closely mimic real vehicle driving mechanics with integration of a steering wheel, gear shifter and pedals as shown in Fig. 1. The driving simulator was built based on Malaysian Standardised License Test to visualise the theories and practical parts of the syllabus which is the novelty of this work.

Fig. 1: The driving simulator prototype with a steering wheel rig.

## 3. Methodology

As mentioned earlier the virtual environment of the proposed driving simulator prototype has been developed by “Unity” which is a real time development tool. This specified tool is chosen due to its ease of use and modularity (Unity, 2023).

The first phase in the development process was researching the Malaysian Driving Education syllabus. There are seven modules or tracks according to the syllabus of Malaysian driver's education, which are designed and programmed accordingly in the simulator. The modules are S-circuit, Z-circuit, three-point turn circuit, hill climb circuit, the parallel parking circuit, the yield junction circuit and the stop sign circuit as shown in Fig. 2. Each module is programmed with some conditions, as described below.

**S-circuit:** The simulator version of the S-circuit is shown in Fig. 2(a). Once the user reaches the end of the track, a module completion condition will be triggered. On the other hand, if the user cannot reach the end successfully it will be considered a module failure condition.

**Z-circuit:** The simulator version of this circuit is shown in Fig. 2(b). The completion and failure conditions of this module are the same as S-circuit.

**Three-point turn circuit:** Fig. 2(c) represents the simulator version of this circuit. The completion condition is the same as previous circuits with a small difference that the completion condition will only trigger from the front of the car. The failure condition is the same as the previous one.

**Hill climb circuit:** The simulator version is shown in Fig. 2(d). The completion and failure conditions are the same as other modules with an added condition that the user will be forced to stop at a designated spot on top of the hill climb before reaching the end of the track.

**The parallel parking circuit:** The simulator version is shown in Fig. 2(e). The completion and failure conditions are the same. In addition, a condition checker is modelled here to check whether the car has been in the spot correctly. When the car is parked correctly, a 6 second timer will start and trigger a module completion condition. There will be traffic lights at the parking place to indicate the user whether the car is parked correctly or not.

**The yield junction circuit:** Fig. 2(f) represents the simulator version of this circuit. This module will let the user understand the order of cars allowed to cross the junction with two AI cars acting as traffic. The user has to wait until these two cars pass first in order to cross the junction as they are situated at the last order of the junction. This circuit has no extra conditions other than the AI cars, ignoring the cars will result in a crash where it will automatically fail the module. To complete the module, the user simply has to cross the junction to reach the end of the road.

**The stop sign circuit:** The simulator version of this circuit is shown in Fig. 2(g). Built upon the same foundations as Module 6 with the junction being modified into a cross junction. The user will have to stop at the stop sign and allow the other cars to pass first before moving forward. Disobeying the rule will result in failing the module.

The prototype uses a standardised car controller which has been modified in this research to use the desired controller inputs. The default car model was then replaced with a model that is visually appealing and realistic. After designing all the simulator versions of the modules, to achieve a high level of skill transfer from the simulator, two modes have been programmed as shown in Fig. 3. The modes are practice mode and test mode. The practice mode is only for practising the modules without any time constraint so that the learner can practise them properly. Specifically, they can practise the modules by repeating them multiple times without any failure condition. The test mode comes with a timer. If the timer of a module runs out it will automatically trigger the failure condition. These modes can be accessed in the Main Menu. The purpose of building this function is to allow the experiment to be conducted autonomously.

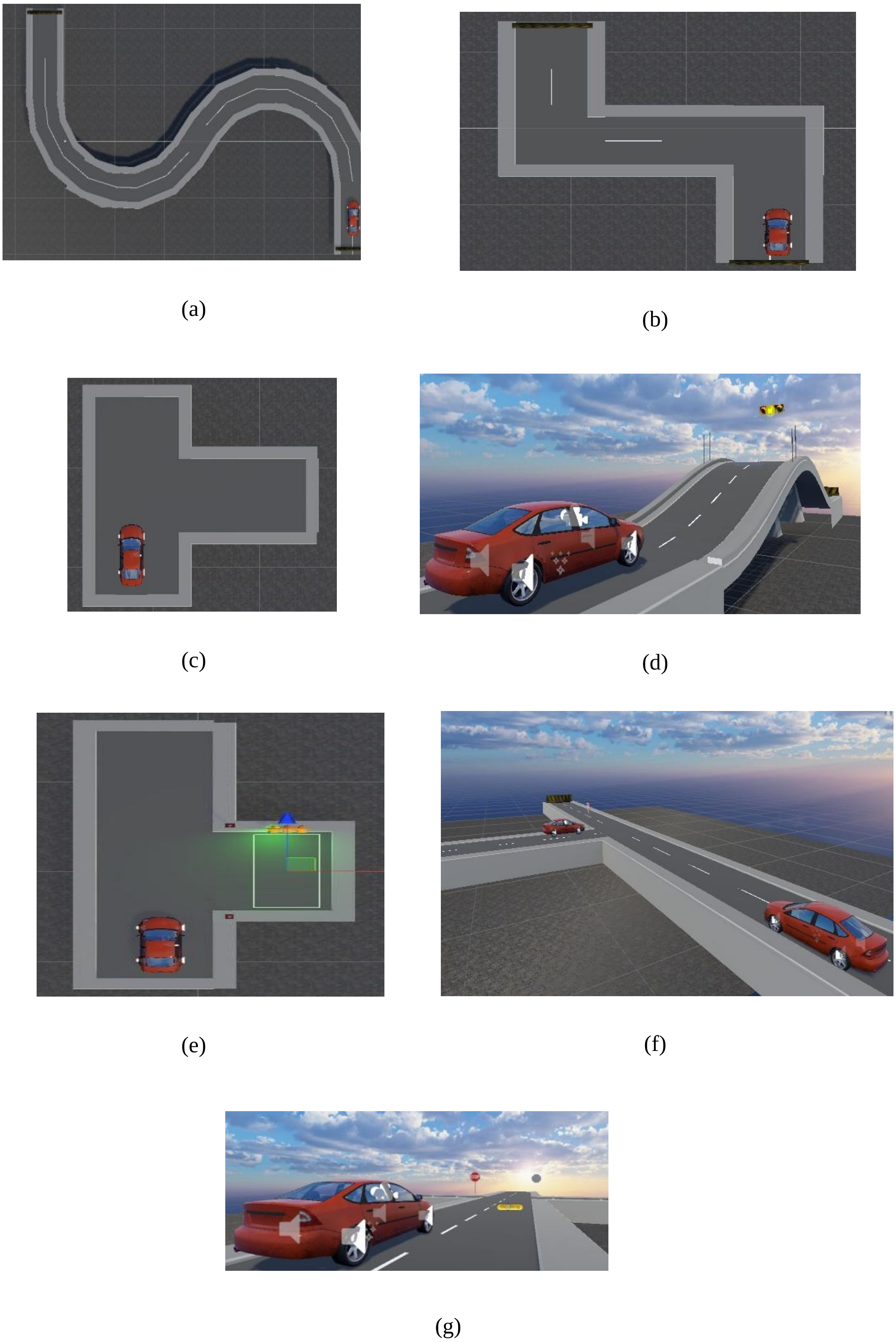


Fig. 2: (a) Module 1: S-circuit in simulator. (b) Module 2: Z-circuit in simulator. (c) Module 3: Three-point turn circuit in simulator. (d) Module 4: Hill climb circuit in simulator. (e) Module 5: The parallel parking circuit with designated parking space highlighted. (f) Module 6: The yield junction circuit. (g) Module 7: Stop sign circuit.

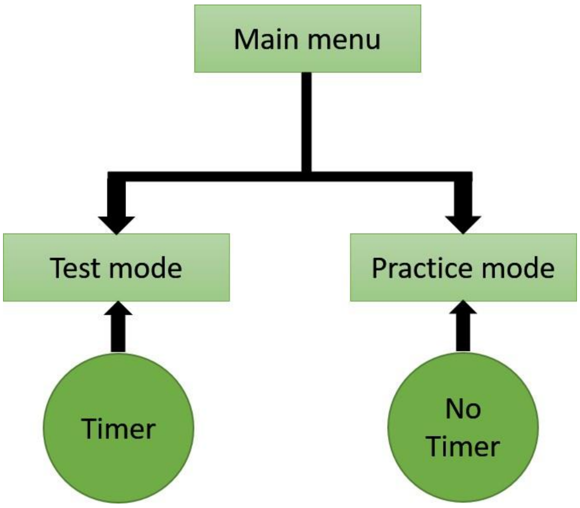


Fig. 3: Different modes of the simulator

**Experiment:** The experiment was conducted with 26 participants age ranging from 15 to 17, with no licence prior to the experiment. Two groups are formed (13 participants in each group):

- Conventional group
- Experimental group

Both groups were given 5 minutes for masking preparation before taking part in the automated test. The conventional group prepare themselves by reading printed materials and the experimental group utilise the practice mode of the simulator to take preparation. The structural diagram of the experiment is shown in Fig. 4.

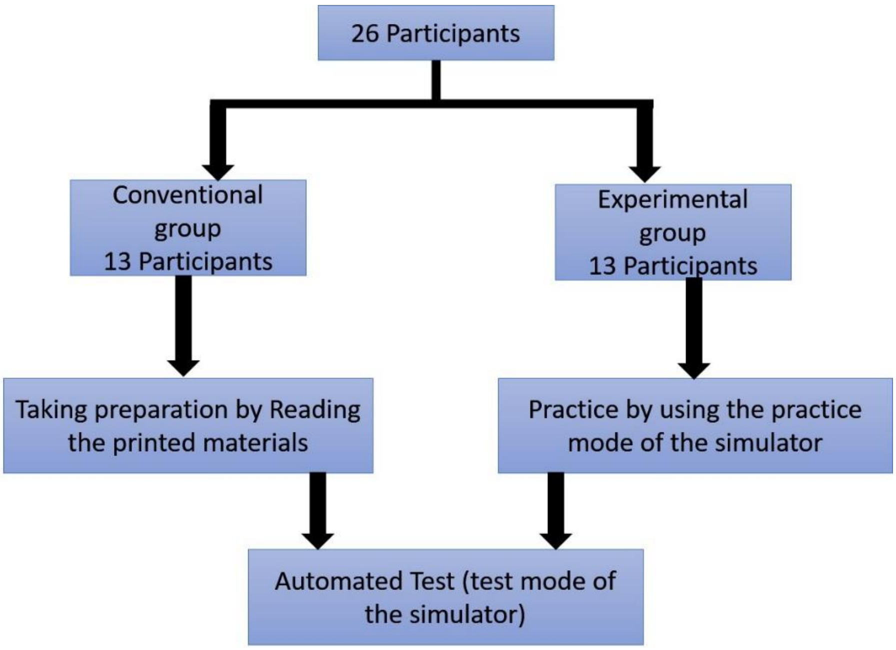


Fig. 4: Structural diagram of the experiment

The test is evaluated with 3 major attempts conclusively, 3 minor attempts for each circuit, and a time limit. The participant needs to pass the test within the 3 major attempts and time limit of each circuit. Each attempt will be deducted once an automated failure is triggered while skipping the current module. Minor attempts are deducted by either resetting or restarting a module without causing an automated failure. After 3 minor attempts have been used, it will be counted as a failure, deducting the major attempts, and skipping the current module.

All of these resulted in a simulator prototype with the aforementioned functions and an experiment conducted to test the system. The results of the experiment are then collected. These results consist of each student's no of fails for each module, the amount of time used for completing each module and no. of attempts used on passing the test.

## 4. Results and Discussion

One of the main aims of this research work is to prove that the transfer of skills is better from the practice mode to the test mode than from the printed materials to the test mode of the simulator. For this purpose, it is important to know how much time each group has spent in accomplishing each module and how efficiently each group completes a module which can be known from the Number of fails for each module parameter. The amount of time used of each module was averaged out and the number of failures of each module are recorded in Table 1 for conventional group and in Table 2 for experimental group.

The overall observation of the data reveals the fact that the conventional group for all modules except module 5 took longer time to complete the modules and failed more times than the experimental group in completing the modules.

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Table 1: Average time used (seconds) and failures of each module from conventional group

| Module | Average Time Used (seconds) | Number of Fails for Each Module |
|---|---|---|
| 1 | 51.6 | 3 |
| 2 | 25.1 | 0 |
| 3 | 62.1 | 5 |
| 4 | 47.2 | 1 |
| 5 | 94.5 | 9 |
| 6 | 54.1 | 0 |
| 7 | 19.4 | 0 |

The overall observation of the data reveals the fact that the conventional group for all modules except module 5 took longer time to complete the modules and failed more times than the experimental group in completing the modules.

From the tables it is also evident that for some modules the conventional group takes more time in completing them as well as fails more frequently than the experimental group in completing them. The reasons are briefly described here.

Since Module 1, which is a S-circuit, requires mechanical skills and familiarities to the steering and good throttle and brake control of the car, the experimental group had an advantage by familiarising themselves with the steering and pedals using the driving simulator, demonstrating that the transfer of skill may be higher than conventional methods. Although the participants from the conventional group praised the detailed printed guide, they lack the familiarity with the simulator.

Table 2: Average time used and failures of each module from experimental group

| Module | Average Time Used (seconds) | Number of Fails for Each Module |
|---|---|---|
| 1 | 34.5 | 2 |
| 2 | 21.2 | 0 |
| 3 | 46.4 | 3 |
| 4 | 16.2 | 0 |
| 5 | 96.6 | 4 |
| 6 | 20.3 | 0 |
| 7 | 21.9 | 0 |

On the other hand, Module 2 requires similar mechanical movements to Module 1. There were no failures among the 2 groups but the experimental group completed the circuit with an average time of 4 seconds less than the conventional group. Showing potential in improving learning effectiveness with hands-on experience.

In case of Module 3 the user needs to reverse the car in order to perform a three-point turn. There are 5 fails from the conventional group and 3 fails from the experimental group. The experimental group uses less time at 46.4 seconds than the conventional group at 62.1 seconds. There is also an observation made where conventional groups are more careful and follow the printed guide very closely to complete the module, probable explanations would be unfamiliarity with driving techniques.

For Module 4, there are no failures in the experimental group and 1 fail in the conventional group. Average time used is 16.2 seconds for the experimental group and 47.2 seconds for the conventional group. A sizable difference between the 2 groups, this could result from the familiarity to the throttle pedal and brake pedal. As observed, participants in the conventional group have a harder time applying the correct amount of throttle input and brake input to place the car at the designated position. So far, these results tell us that early exposure to gain familiarity is crucial in improving learning effectiveness for driving education.

The rated most difficult module by the participants is Module 5, as it requires you to park into the designated spot by reversing. The conventional group has 9 fails and 4 fails in the experimental group. The average time used in the conventional group is at 94.5 seconds and 96.6 seconds for the experimental group. The observation made is that participants of the experimental group attempt the module more slowly due to the fear of knocking into the poles where the conventional group participants are slightly more reckless in parking the car. From this observation, early exposure using simulators may result in users being more aware of their surroundings by understanding dangers around them.

In Module 6, there are no failures in either group. Average time used for the experimental group is 20.3 seconds and 54.1 seconds for the conventional group. With the time difference, the participants of the experimental group understood the visualised theory of the yielding better than the conventional group's participants.

The last module is similar to Module 6. There are no failures in the conventional group but the same 3 that failed the test. The average time used for the conventional group is at 19.4 seconds, quicker than the experimental group at 21.9 seconds. The observation made is that the participants from the conventional group are quicker on the throttle as the printed guide noted that if there are no cars, the user may move. The experimental group participants were slower due to them listening more carefully to any cars still on the move. This observation suggests the simulator can encourage the learning of passive skills such as listening and patience.

With all the modules concluded and tabled in Table 3, the conventional group has a failure rate of

23.1%, 3 students, while the experimental group has none. It is also worth noting that the percentage of passing the test without failing any individual modules is higher in the experimental group at 38.5%, 5 students, than the conventional group at 15.4%, 2 students. With these results, we can observe the correlation of improvements on the experimental group.

From the above discussion it can be concluded that since the transfer of skills from a mode without a time constraint to a mode with a timer of the same simulator is quite remarkable then the transfer of skills from the simulator to real life will also cross a benchmark. Therefore, if the modern driving schools adopt the driving simulator designed and modelled here, they can train their novice drivers with a great care while minimising the safety risk which lacks the previous developed driving simulators.

## 5. Conclusion

A simple, cost effective and modular driving simulator based on Malaysian Standardised Driving Test for driver's education has been designed and developed. An experiment is conducted on two groups of people to compare the learning effectiveness of using the simulator before taking part in the automated test. Both groups were given five minutes to take preparation before the automated test. One group was provided by printed materials and the other group was facilitated by a practice mode of the simulator. It was revealed that the transfer of skills from practice mode to test mode of the simulator is quite better than from printed materials to test mode of the simulator. From this observation it can be confirmed without any further confirmation that the transfer of skills from the simulator to the real-life scenarios will also have a positive outcome when the simulator will be adopted in driving schools to train their novice drivers not only in Malaysia but also throughout the whole world. Future works could add in traffic AIs, Virtual reality and realistic scenarios to enhance learning experiences and learning effectiveness.

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## Ethical Approval

This study adheres the ethical guidelines. The ethical approval number for this project is EA2732021.

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