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Virtual Reality Driving Simulation for Measuring Driver Behavior and Characteristics

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Abstract

This article provides new insights regarding driver behavior, techniques and adaptability. This study has been done because: 1) driving a vehicle is critical and one of the most common daily tasks; 2) simulators are used for the purpose of training and researching driver behavior and characteristics; 3) the article addresses driver experience by involving new virtual reality technologies. A simulator has been used to assist novice drivers to learn how to drive in a very safe environment, and researching and collecting data for researchers has become easier due to this secure and user-friendly environment. The theoretical framework of this driving simulation has been designed by using the Unity3D game engine (5.4.f3 version) and was programmed with the C# programming language. To make the driving environment more realistic we, in addition, utilized the HTC Vive Virtual reality headset which is powered by Steamvr. We used Unity Game Engine to design our scenarios and maps because by doing this we are able to be more flexible with designing. In this study, we asked 10 people ranging from ages 19 - 37 to participate in this experiment. Four Japanese divers and six non-Japanese drivers engaged in this study, some of which do not have a driver's license in Japan. A few Japanese drivers have a license and car, while others have a license but no car. In order to analyze the results of this experiment we are used MatlabR2016b to analyze the gathered data. The result of this research indicates that individual's behavior and characteristics such as controlling the speed, remaining calm and relaxed when driving, driving at appropriate speeds depending on changes in road structures and etc. can affect their driving performance.

Keywords

Driver, Behavior, Game, Driving, Unity3D, Virtual Reality, Simulation, HTC

1. Introduction

Driving simulators, aside from being research tools, have grown to be an important tool in the area of road safety. They are providing an environment for a driver which is safer because there are not any physical obstacles or harm. This gives the administrator of a simulation the ability to manipulate and apply the situations which are not possible on-road in real time [1]. In recent times, driving simulations have been helping researchers as a useful research tool [2] and they have shown many advantages which can be programmed to easily be like real, on-road driving [3] [4]. This allows researchers to apply and experiment with different factors based on driver response and a considerable amount of different conditions which are quite impossible otherwise [2]. These include investigating driving in conditions such as: the effects of alcohol, drugs and fatigue on driving behavior [5]. As well as, the performance of older drivers [6] or driving performance is in different environmental conditions [7].

A well designed simulator can assess the act of drivers, and also can deliver valuable road safety information. A driving simulator applies an experimental design that is adaptable and easy to repeat. It offers the ability to modify driving scenarios at any time and expose drivers to dangerous situations in a methodical manner. Simulator studies have recognized to be a reliable tool which incorporates with intuitive input, cognitive processing and behavioral output [5]. Inclusively, simulation based driving may not be exactly the same on-road driving behaviors [8]. Therefore, the aim of this study is to compare the driving performance using a Game engine-based driving simulator (Unity3D game engine driving Game) as well as, finding driving violations and driver characteristics such as driving too fast, braking to hard or softly and staying on-road or going off-road. Participants were instructed to drive on a specific map. The simulation was designed in unity3D game engine and programmed by C# language. A questionnaire was also given to participants, asking them about their personal information and their driving experience in Japan, and in their home countries. Participants who contributed in this study were ages 19 to 35 years old including 6 non-Japanese and 4 Japanese drivers. Nine of them were male and one was female.

1.1. Study Scheme

A study was commenced to observe driver adaptively to a 3d Driving Simulation by measuring driver behavioral responses in the simulator.

1.2. Participants in This Study

A convenience sample of drivers ages 19 to 35, some of which held a driver license and some of which did not, in Japan, were asked to assist us in this study. 4 Japanese volunteers who have already received their drivers license and 6 non-Japanese Gifu residents. Three of these students have a driver's license in their home country but not in Japan.

1.3. Data Collection

All participants volunteered to participate in this study, as well as filled out a questionnaire afterwards regarding their experience while driving a 3D simulated driving game. As the participants drove, an instructor was beside them to guide them and help them if they would have some sort of issue during the practice. Some participants were new to the 3D virtual reality world, and could not finish their task due to their dizziness and worsening eyesight irritation during the simulation. The data was saved for later review and study for future work. All the Data was saved individually in a CSV file (Figure 1), with the same conditions using a capture card (AverMedia C875) all throughout all steps of the experiment were recorded.

1.4. Driving Simulator Evaluation

The map and route was developed by Unity3D game engine and programmed by C# programming language. The map is too big so finishing each Lap took drivers approximately 1.5 minutes to finish. The simulator driving took about fifteen minutes on average to complete. Drivers practiced the map and memorized it before the experiment commenced, and an assessor was next to them to teach them about the map and how they could improve their driving skills. The results of each participant were shown to them after finishing their tasks required for data collection.

1.5. Outcome Driving Performance Measures

As Figure 1 illustrates, in this study we measured driver tendencies (head movements), speed control (accelerating and braking), position of the vehicle, control of the vehicle (steering wheel rotation and so on). The specific tasks examined included: adjusting speed when approaching the bridge, turning and passing

Data Orders The Columns are representing

Camera Position
A: Head X
B: Head Y
C: Head Z

camera angle
D: Head Roll
E: Head Pith
F: Head Yaw
Time
G: Delta time

Steering wheel Angle
H: Steering wheel Roll
I: Steering wheel Pitch
J: Steering wheel Yaw

car Position
K: car Position X
L: car Position Y
M: car Position Z

Car Angle
N: Car Roll
O: Car Pitch
P: Car Yaw

Trigger Data
Q: Trigger

A1 fx 306.8803

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	306.8803	1.759032	205.8389	323.66333	170.854279	358.273926	0.02	20.0000057	180.487213	1.28E-07	307.03	0.7999998	205.56	-8.54E-07	180.4872	1.10E-07	0
2	306.8786	1.756563	205.8392	323.630981	170.933853	358.139282	0.02	19.9861546	180.446121	359.880493	307.0302	0.7978976	205.56	359.9862	180.487	359.8877	0
3	306.8663	1.744376	205.8404	323.510559	171.621643	357.425537	0.07074369	19.9425354	180.200302	355.367645	307.0295	0.7876632	205.56	359.9447	180.4873	359.2124	0
4	306.8603	1.739482	205.8234	326.098633	173.896057	1.0911268	0.01568678	19.9364738	180.139694	355.190765	307.0292	0.7848303	205.56	359.9401	180.4875	359.0484	0
5	306.8575	1.736549	205.8232	326.12381	174.039474	0.81621981	0.01325964	19.9339542	180.09227	355.051971	307.0289	0.7824242	205.56	359.9387	180.4877	358.9189	0
6	306.8549	1.733597	205.8231	326.133942	174.113937	0.67549801	0.01441751	19.9355526	180.048248	354.922607	307.0286	0.7798491	205.56	359.9403	180.4879	358.7919	0
7	306.8526	1.730855	205.8228	326.211731	174.230667	0.53141373	0.01369065	19.9393787	180.01059	354.811676	307.0283	0.7775004	205.56	359.9452	180.4881	358.6893	0
8	306.8499	1.726684	205.8224	326.207947	174.373917	0.30912763	0.0227554	19.9531612	179.963226	354.671173	307.0278	0.7738887	205.56	359.9601	180.4882	358.5584	0
9	306.8483	1.72344	205.8219	326.203186	174.427322	0.18766783	0.02249583	19.9752159	179.935425	354.587738	307.0275	0.7708055	205.5601	359.9828	180.4882	358.4817	0
10	306.8478	1.720885	205.821	326.192322	174.443054	0.12526822	0.0223783	20.0042458	179.925751	354.55719	307.0273	0.768316	205.5601	0.01189535	180.488	358.4552	0
11	306.8477	1.719263	205.8202	326.228149	174.476425	0.09739455	0.02209062	20.0379486	179.931458	354.571564	307.0271	0.7664759	205.5601	0.04527458	180.4878	358.4713	0
12	306.8486	1.718062	205.8193	326.294373	174.490433	0.11875345	0.02255766	20.0752373	179.949554	354.622131	307.027	0.7652444	205.5601	0.08190536	180.4876	358.5215	0
13	306.8495	1.717856	205.8186	326.313843	174.427094	0.22016367	0.01919976	20.1070843	179.971313	354.683319	307.027	0.7646853	205.56	0.1133252	180.4875	358.5823	0
14	306.8503	1.718005	205.8183	326.362579	174.388031	0.31338641	0.01372028	20.1294689	179.9897	354.736053	307.027	0.7645634	205.5601	0.1349734	180.4874	358.6324	0
15	306.8511	1.718244	205.818	326.401459	174.352493	0.39119941	0.01247094	20.1487198	180.00705	354.78595	307.0271	0.7646213	205.56	0.1536217	180.4874	358.6797	0
16	306.8517	1.718808	205.8179	326.458984	174.349274	0.44149286	0.01256113	20.1667614	180.024658	354.836884	307.0272	0.7648311	205.56	0.1710406	180.4875	358.7276	0
17	306.8529	1.719621	205.8177	326.545135	174.373489	0.48265728	0.01767883	20.1883049	180.047836	354.905029	307.0273	0.7653546	205.56	0.1926235	180.4876	358.7925	0
18	306.8534	1.720515	205.8183	326.755524	174.633957	0.3982096	0.01316076	20.2022285	180.064209	354.953369	307.0273	0.7658992	205.56	0.2059342	180.4877	358.8369	0
19	306.8542	1.721335	205.8186	326.908752	174.799362	0.40017056	0.01285673	20.2133198	180.078598	354.995789	307.0274	0.7665289	205.56	0.2165259	180.4878	358.8759	0
20	306.855	1.722229	205.8199	327.146881	175.205139	0.37565678	0.01207698	20.2212486	180.090347	355.030487	307.0275	0.7671926	205.56	0.2241281	180.4879	358.9079	0
21	306.8564	1.723709	205.8215	327.329956	175.489777	0.50108641	0.020491	20.2285881	180.105789	355.076233	307.0276	0.768435	205.56	0.2314827	180.488	358.9507	0
22	306.8579	1.725542	205.8238	327.373047	175.568588	0.69534945	0.02220304	20.2287521	180.116486	355.107849	307.0277	0.7698692	205.56	0.2315755	180.4881	358.9801	0
23	306.8591	1.727549	205.8259	327.265076	175.447128	0.82844687	0.02221045	20.2208729	180.121048	355.121277	307.0278	0.7713106	205.56	0.2237626	180.4882	358.9927	0
24	306.8597	1.729013	205.8269	327.18161	175.234406	0.83453423	0.0189062	20.2083664	180.120804	355.120422	307.0279	0.7724878	205.56	0.2115287	180.4882	358.9921	0
25	306.8601	1.729813	205.8275	327.069458	175.139023	0.8448329	0.01335749	20.1968174	180.118546	355.11377	307.0279	0.7732662	205.56	0.2000119	180.4881	358.9861	0
26	306.8606	1.730573	205.828	326.991669	175.087906	0.86758733	0.01262117	20.1840782	180.11528	355.104034	307.028	0.7739525	205.56	0.1873911	180.4881	358.9772	0
27	306.861	1.731238	205.8287	327.007233	175.10379	0.80793047	0.01476523	20.1673222	180.110321	355.089325	307.028	0.7746865	205.56	0.1708512	180.4881	358.964	0
28	306.8612	1.73167	205.8291	327.072662	175.212921	0.73205966	0.01231509	20.15205	180.10556	355.075134	307.0279	0.7752325	205.56	0.1558319	180.4881	358.9511	0
29	306.8614	1.731894	205.8298	327.2677	175.334412	0.70228279	0.0129763	20.1354408	180.10054	355.059753	307.0279	0.7757344	205.56	0.139105	180.488	358.9364	0
30	306.8614	1.731961	205.8305	327.654663	175.460861	0.63562375	0.01296301	20.1179562	180.095016	355.043213	307.0279	0.7761617	205.56	0.1218645	180.488	358.9213	0
31	306.8618	1.731372	205.8325	328.757599	176.075729	0.27892935	0.01354144	20.099432	180.089325	355.026123	307.0278	0.7765299	205.5601	0.103649	180.488	358.9058	0
32	306.8613	1.73039	205.8346	329.659485	176.484543	0.04308655	0.02255408	20.0692768	180.080688	354.999969	307.0278	0.7769672	205.5601	0.07377677	180.488	358.8819	0

Figure 1. A sample of the gathered data in a CSV file.

intersections and keeping right and driving between right lanes. It was also vital to check their level of fatigue while driving which will be discussed in the analyzing section in greater details.

2. The Experiment Setup

The experiment setup in this study is divided into two parts: hardware and software setup. As Figure 2 presents, a high spec desktop computer with an Intel Core i7 CPU 4GHz, a 16GB RAM and a GeForce GTX 8GB graphics card was provided for this study. For some parts of this research we used a normal monitor and for the virtual reality part of this research we used HTC vive Virtual reality headset. There are some external measurement devices which we have not used yet in this current research, but they will be used for future works. A Thrust master T150 steering wheel used for driving in simulation (Figure 3), and a Aver Media C875 recording device was used to record the simulation during the data collection, Figure 2 presents the hardware flowchart and connections in this setup.

Some software and applications are being used in this study in order to design, develop and analyze the data. The simulation is running in Unity3D game engine, a 3D flexible environment which gives us the freedom to design and manipulate the simulation at anytime during the research. The codes are programmed by using C# language inside the Monodevelop IDE. Microsoft Excel and Matlab are being used to record and analyze the gathered data as you can see in the Figure 1.

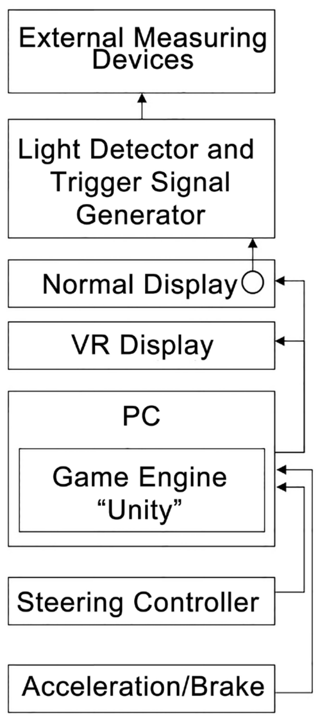

Figure 2. The hardware setup.

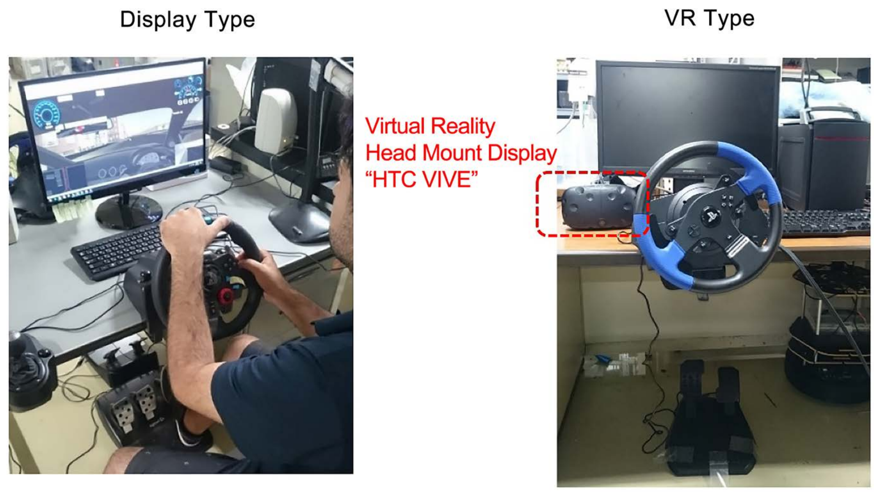

Figure 3. Experiment setup.

3. Data Analysis

The following results belong to a 26 years old Malaysian participant. He has a valid Malaysian driving license but not a Japanese one. He received his driving license 5 years ago. He doesn't own a car and he is not interested in driving cars, however he likes playing computer driving games, which may affect the results of this experiment. He drove cars about one year and he considers himself a cautious driver. We asked him "How difficult was it for you to adjust to the simulation?". He answered that it was neither very easy nor very difficult for him to drive the car in the simulator. Furthermore, he mentioned that around Lap 6th he felt tired of driving. This made him try some different things like drive faster. By pushing the accelerator and going faster he was trying to experiment with the physics of the car and observe the consequences of his actions. In this study the results of his choices have been studied.

The following are his point of views of the simulator:

Pros:

1) The physics for the driving simulation (*i.e.* car handling, momentum, tire friction etc.) are great. It does feel like driving a real car.

2) The application of VR for the simulation gives a more realistic driving perspective as opposed to the conventional method (monitor screen).

Cons:

1) The Simulation track landscape or the world is too simple in his opinion. In a real world car driving scenario, there are many aspects to consider, such as human presence and obstacles.

2) Car steering for the simulation differs from real world car steering.

3) Simulation graphic interface might be too low.

The following figure illustrates the time which this driver took to drive the car in the simulation for each Lap (from Lap 2 to 9). Units are measured in seconds. Overall, the spent time for Laps 5, 6 and 7 is lower than other Laps. The time which was spent for those Laps requires a higher speed for a driver to finish those

Laps. Other figures and charts will relatively show that higher speeds affected the performance of the driver negatively (Figure 4, Figure 5). Figure 4 and Figure 5 illustrate driver could not control the car on the bridge due to the high speed.

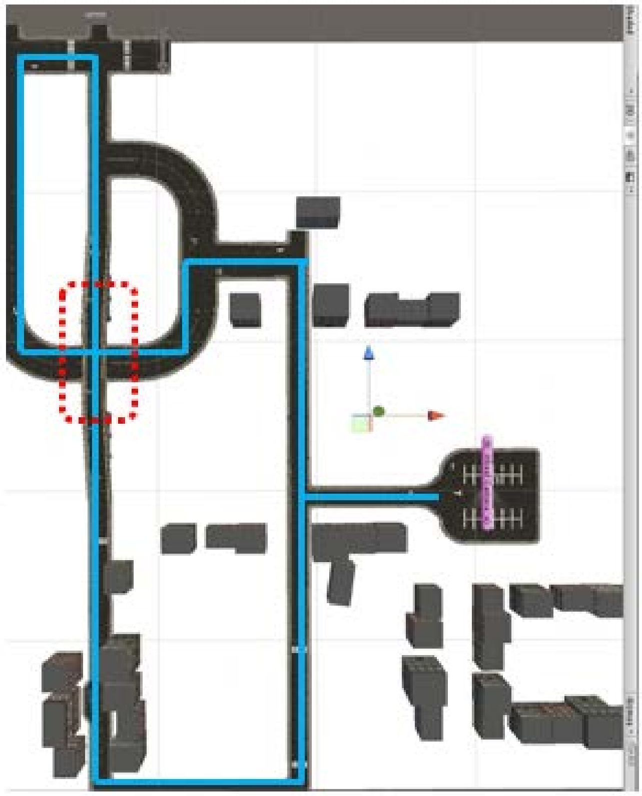

Figure 4. Bird's eye view of the map with the bridge marked.

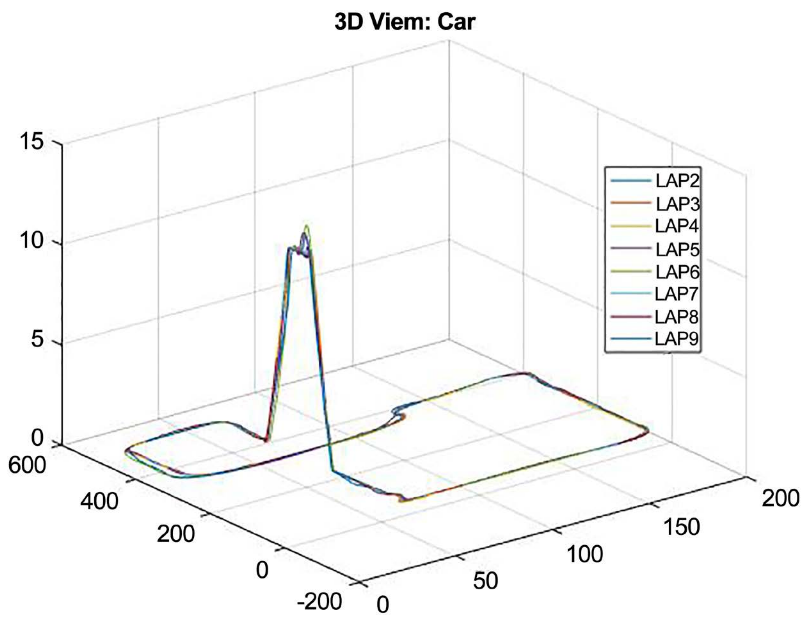

Figure 5. 3D view of car movements.

The following graph shows the 2D view of the driver's performance between Lap 2 to 10. In this graph, Purple, green and light blue are representing Lap 5, 6 and 7 respectively. As we mentioned in the fig x, the driver had a higher speed in those Laps. The average time of all Laps is 77.14 seconds which is higher than the time of 5, 6, and 7th Laps which are 66.96, 66.52 and 72.28 respectively, and besides that, the average time of those three Laps is 66.92 seconds. This 2D view shows that the driver lost his control and he could not drive along the inside of the road. On the displacements of the coordinates of the car in Figure 1, it is obvious that driver was not able to control the car properly. In the beginning of the course, the driver was driving slower compared to other Laps, where he was more careful and adapting to the system. Gradually, the driver decided to experience driving with a higher speed. It was evident that driver felt considerably tired while driving slow as it was uninteresting. After noticing that he was not doing well for almost 3 Laps he decided to drive slowly once more and control the car perfectly.

Figure 6 shows a bird's eye view of the driver performance from Laps 2 to 9. Different colors representing the Laps show that on most Laps the driver was performing the same and was driving within the road and cautiously. The Axis of this graph represents the coordinates of the car in X-axis and Y-axis. Sudden changes in Laps 5th, 6th and 7th are easily seen in this graph, as Figure 7 which represented these changes as well.

Figure 8 details the amount of pressure applied to the brake by the driver. The significant thing about the changes in this graph is: in 3 specific Laps the driver had a higher speed when compared with the other Laps, which resulted in him applying more pressure on the brakes when compared to other Laps. The graphs for Laps 5, 6 and 7 illustrate that the driver was breaking more suddenly, which contrasts the data in the graphs for the rest of the Laps. After the period of time

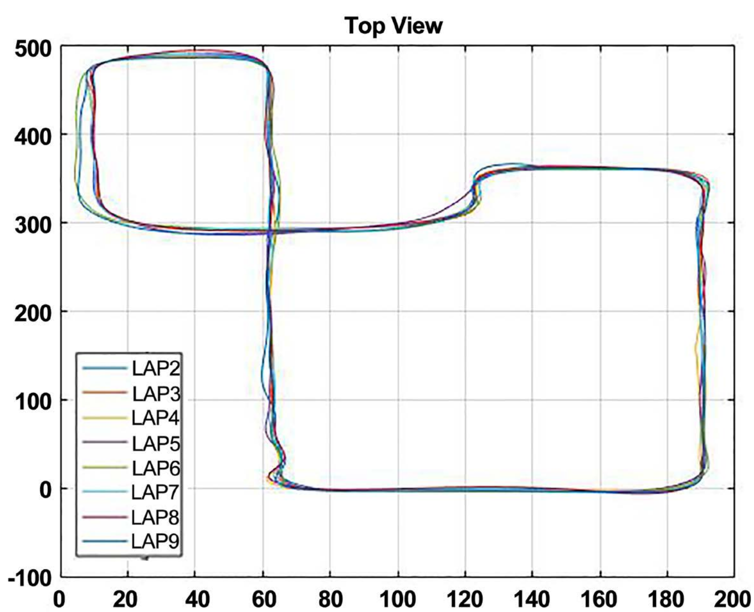

Figure 6. Bird's eye view of the result of the car displacement.

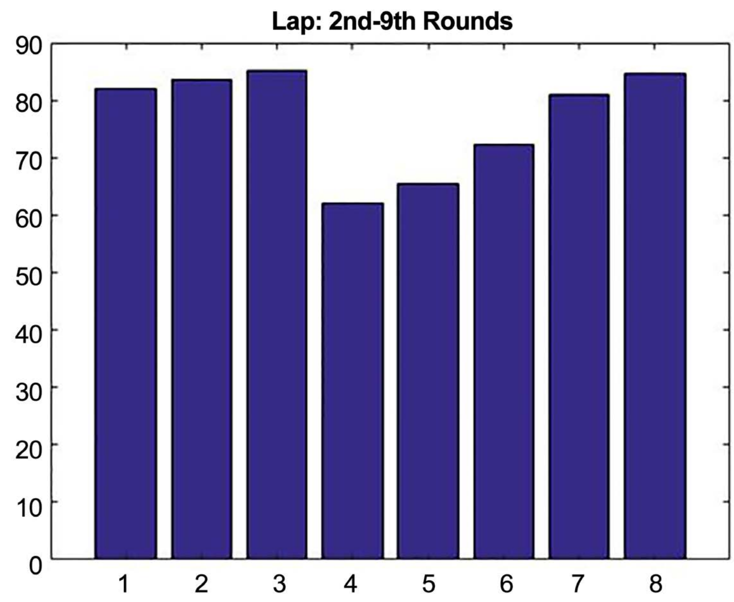

Figure 7. Time of each Lap.

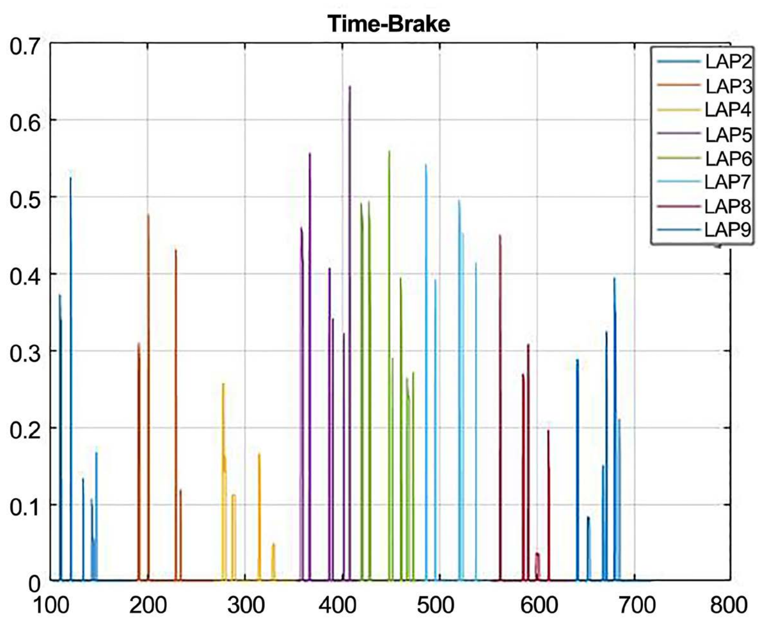

Figure 8. Brake data of each Lap.

taken by Laps 5 - 7, the driver seemed to pay attention more to his driving and behavior and tendencies went back to normal. **Figure 9** presents the acceleration data, similarly, the accelerating results show that the acceleration amount increased beginning at Lap 5 and decreasing after Lap 7. Furthermore, according to Rothengatter and Fuller speed control plays a significant role in driving behaviour because speed influences task conditions and hence the frequency of violations or errors also increases [9] [10]. As **Figure 6** indicates, the driver was not able to control the car and drive on-road due to high speed driving.

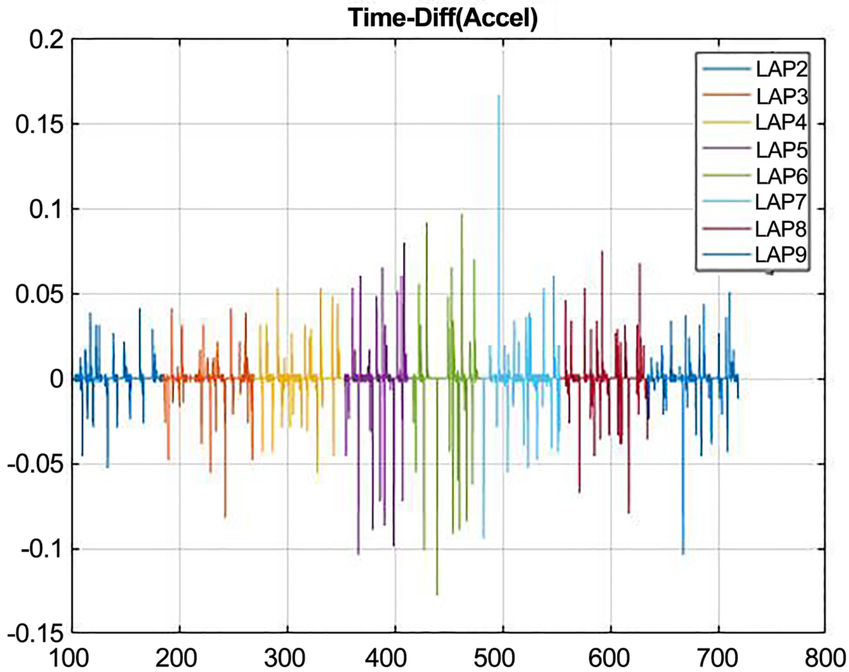

Figure 9. Acceleration data of each Lap.

A similar research shows that participants generally tend to increase their speed as well as the number of violations per time unit [11]. Participants reduced errors during forced-paced driving and increased speed during self-paced driving. Additionally, a positive correspondence is expected between violations and speed of the given tasks [11].

4. Conclusions and Future Work

In conclusion, the data of ten participants was gathered during this experiment, however, in this paper we analyzed one of the participant's performance data (**Figure 1**). The result of the experiment shows just how much driving fast can influence the performance of the driver. The result indicates that controlling the car, speed, tendencies and fatigue are all closely related. We will study more driver behavior and characteristics for future work. We will study and compare the results of the 9 other drivers to be able to understand more about driver difficulties and behavior. Using 3D virtual reality (HTC Vive) was extremely useful in simulating real world driving for the user, and after few Laps drivers adapted to the simulation/Virtual Reality (VR) world. The study result shows that an individual's behavior and characteristics such as maintaining the speed limit, remaining calm and relaxed when driving, driving at appropriate speeds depending on changes in road structures and etc. while driving can affect their performance in a simulated environment as we discussed in the data analysis section. This study was limited by a small sample size and one assessor was observing the participants and instructing them when questions or problems arose. The driving course in this study was limited to one scenario. Furthermore, future research should include more scenarios and different aspects of driver behavior such as mirror checking, speed at intersections, maintaining the speed limit, and obeying street laws can be implemented and analyzed in future studies.

For the future study we want to try to understand driver behavior and the influence of digital Mirror on behavior and performance. By using an eye tracker device (Tobii TX300), we can accurately analyze every instance of where the driver was looking while driving. It's so accurate that we can even observe the order of every glance the eye made and for how long. If a driver looks at objects in the car or at the side-view mirrors or the traffic, it can affect the driver's performance. We can analyze and compare the result with verity of scenarios and different locations of the side-view mirrors.

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