DRIVER RESPOND TO PRE-COLLISION SCENARIO AT INTERSECTION IN AUTONOMOUS VEHICLE

N.H. Mokhtar[1], H. Takada[2] and Y. Matsuura[2]

[1]Faculty of Mechanical and Manufacturing Engineering Technology,
Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

[2]Yokohama National University,
79-1 Tokiwadai, Hodogaya, Yokohama,
Kanagawa, 240-8501, Japan.

Corresponding Author's Email: [1]nurhazwani@utem.edu.my

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ABSTRACT: Research on automation system development is attracting a lot of attention from researchers, automotive industry manufacturers and leading technology brands. This study focus is on SAE level 3, the vehicle steering, accelerator pedal and brake pedal are controlled autonomously. The decrement in controlling vehicle and driving task has the possibility to reduce the road crash resulted in an essential change in driver role from active to passive. The effect of role change leads to decrement of situation awareness and reduce driver abilities to control manual vehicle at the right time and manner. Therefore, research on recognition times in complex and actual situations are critical. The primary purpose was to analyze the driver's ability to recognize pedestrian, bicycle and vehicle pre-collision at intersection in the automated vehicle. The road conditions were complicated and imitated a real driving scenario. The statistical tools used for analysis were the F-test, t-test and ANOVA method. This finding shows that the subject can instantaneously recognize unintended acceleration at a low velocity and relative velocity in a pre-collision scenario with pedestrian. The implication of these results is in developing an automated vehicle system related to driver recognition. These findings provide insights that can be useful in developing autonomous vehicles.

KEYWORDS: *Driver Behavior; Autonomous Vehicle; Human Factor; Intersection Road; Pre-Collision*

1.0 INTRODUCTION

Autonomous vehicles have the aspect of safety critical control such as steering control, braking and accelerating without direct input from the driver. Recently, researches related to autonomous vehicle developments are attracting a lot of attention from researchers and the manufacturers. In 2014, Society of Automotive Engineers (SAE) had issued and defined automated driving levels in new SAE International Standard J3016. SAE identified 6 levels of driving automation from no automation to full automation. Most of the open literatures are related to SAE level 2 consist of adaptive cruise control, lane keeping and other technologies. Most researchers are interested in study related to vehicle trajectory prediction in adaptive control [1], the transition from automated to manual [2].

However, in this study, the focus is on SAE level 3. The vehicle steering, accelerator pedal and brake pedal are controlled autonomously. Moreover, drivers are able to take control when desired. Nevertheless, the decrement in controlling vehicle and driving task has the possibility to reduce the road crash number, reduce injury severity and also resulted in the essential changes in driver role from active to passive [3-5]. The effect of role change leads to decrement of situation awareness and have been shown to reduce driver abilities to control manual vehicle at the right time and manner [6-12].

Human behavioral pattern in an automated vehicle is defined as how the driver behaves in an automated vehicle and how the driver reacts when switching to manual driving. Perception, recognition, prediction, decision, response selection and task execution are the stages of information processing. The essential elements to understand the cognitive process when humans are driving are situation awareness and mental workload. Endsley [6] categorized situation awareness into three levels. Level 1 is perception which the driver's ability to identify a factor that could be relevant to safety. For instance, the stimuli in a situation that attracts driver's attention may be important or not. Level 2 is recognition, the driver's ability to recognize the traffic situation by recalling knowledge from semantic memory. Level 3 is the driver's prediction, based on knowledge stored in memory and judgment of the current situation [6]. Mental workload is defined as the specification of the amount of information processing capacity used for the task performance [13].

In a study by Hoeger et al. [13], the result showed the mental workload is low in automated driving mode. The workload is low because the driving task is easier since drivers only monitor the system because the reduced workload, situation awareness declines. The driver takes a longer time to react to situations [14]. Furthermore, this finding is consistent with those of other researchers that the situation awareness decreases as automation takes over the driving task (low mental workload) [5, 15-19]. In a study by Verberne [20], when the system reveals its intentions, drivers tend to trust the system and lose situation awareness instantaneously. Stanton and Young [21] added the system feedback, for instance, what the system is doing and why, also increases driver trust. Without the driver confidence in the automated system, stress and mental workload will also increase [21]. Hence, the lack of certainty and overconfidence might decrease safety because, in both conditions, the driver took a longer time to react. The main purpose of this study is to analyze the driver respond in term of recognition time to pre-collision scenario at intersection road.

2.0 METHODOLOGY

The study was conducted in the driving simulation as shown in Figure 1 [22]. The driving simulator consists of three liquid crystal displays (LCD) on the left, right, and in front of the driver seat. Two speakers are on the right and left of the driver seat. The simulation software used was UC-WIN/Road ver. 10.1.2 developed by FORUM 8. The software equipped with an excellent virtual reality creation and editing function for road alignments, cross section, terrain, building, traffic setup, model setup and others. The drivers were provided with the visual and sound cues in order to fully immerse into the driving task. Realistic road, engine and wind sound are played synchronized with the display over a sound system.

Figure 1: Driving simulator

Six healthy subjects with normal vision participated in this study. The average age was 22.2 years while the average driving experience was 4.2 years. The participants were students of Yokohama National University, Japan. The participants had agreed to participate in this experiment and were provided with informed consent prior to participation. The simulated drive started in daylight at a traffic signal of an urban environment with a straight road, intersection road and curved road. The road had four lane and two lanes for each direction as shown in Figure 2. There was light traffic density in both the oncoming direction and passing direction. The distance between the vehicles was 300 m and the rate of increase in the number of vehicles was 30 vehicles per hour. The roads used in this study were a combination of straight, curved and intersection roads. The main road contains the two ways and lane road with the total length is 8500 m.

There are two main variables in this experiment, independent and dependent. The independent variables were unintended acceleration, type of collision, and distance to intersection. The study design assigned participant in all of the following condition for each participant. In others words the participant experienced the pre-collision scenario event twelve time in total. The dependent variables for the analysis was driver recognition time, from pre-collision event occur to push transfer button. The types of pre-collision scenarios at intersections were pre-collision with a pedestrian, bicycle, and vehicle, as shown in Figure 2. Initially, the subject vehicle was in autonomous mode at 60 km/h. As the vehicle approaching the crosswalk or intersection at distance 55 m or 110 m, unintended acceleration occurs. After a while, a pre-collision scenario with a pedestrian, bicycle, or a vehicle will appear suddenly. The velocities of the pedestrian, bicycle and vehicle were constant at 5 km/h, 15 km/h and 60 km/h. When the participants recognize the scenario, the participant pushes the button and the driving modes changes from autonomous to manual driving mode. The experiment procedure started with briefing session. In the briefing session, the outline of the experiment, instructions, rules and regulations were explained. The participants were asked to take a 5-min test drive to become familiar with the driving simulator. Next, the subjects drove the driving simulator in full automation mode from end to start position on the main road. After resting for a few minutes, the subjects continued to drive in full manual mode. Finally, the main experiment was conducted. All subjects participate in 12 experiments consist of three types of collision, two types of unintended acceleration and two type of distance from crosswalk or intersection. The experiments were conducted within 6 weeks, two experiments continuously in one week and the experiments were held in the morning for half of the participants while others half were in the evening. During the first week, all subjects took longer time due to briefing and pre-experiment (perception time) session. At the end of each session, the subjects were asked to fill out a questionnaire relating to their perception of the task.

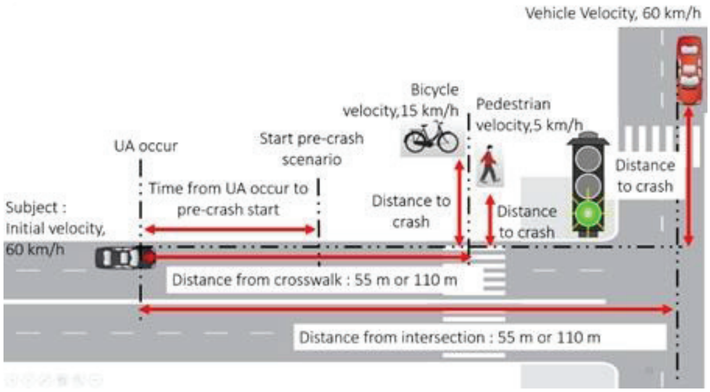

Figure 2: Pre-collision scenario summary

3.0 RESULT AND DISCUSSION

Figure 3 shows the recognition times at intersection roads when unintended acceleration occurs at distances of 55 m and 110 m from the crosswalk or intersection for a pre-collision scenario with a bicycle, pedestrian, and vehicle. The recognition time is the time taken by a subject to recognize unintended acceleration. The x-axis represents the pre-collision scenario and the unintended acceleration condition, while the y-axis represents the recognition time in seconds.

Figure 3 also indicates that the recognition time at 55 m is less than 5 s. Subjects tend to recognize unintended acceleration faster at 55 m because the time to crash at 55 m was less than that at 110 m. At 55 m, the time to crash for acceleration was 3.07 s and that for deceleration was 3.46 s. Based on Figure 3, the lowest recognition time was obtained for a pre-collision scenario with a pedestrian in acceleration cases under each condition. In this section, the aim is to determine the effect of pre-collision type to recognition time by using one-way ANOVA and Post-hoc Tukey method. There were three types of pre-collision scenarios, vehicle, bicycle and pedestrian. The ANOVA test compared average RTs between pre-collision scenario with the vehicle, bicycle, and pedestrian. For further analysis, if the ANOVA results were significantly different, the analysis proceeded to post hoc Tukey method.

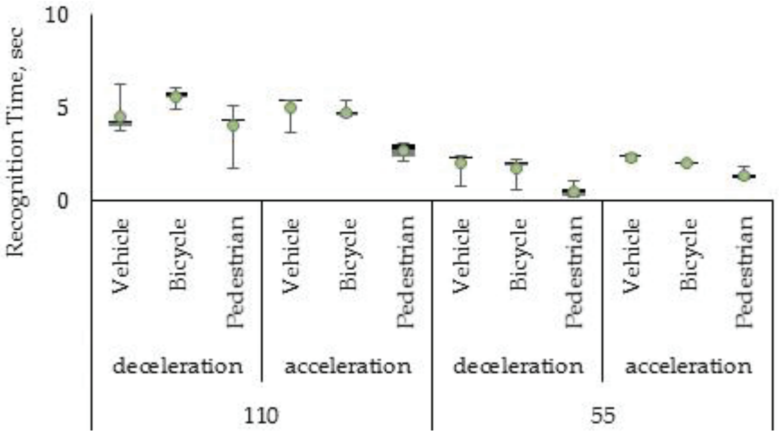

Figure 3: Recognition time result

The ANOVA and post-hoc Tukey results at 55 m are shown in Table 1. The ANOVA results were average recognition times at 55 m in acceleration and deceleration cases were significantly difference. The post hoc Tukey method shows the average recognition times were significant different between type of crash except between vehicle and bicycle at 55 m and deceleration cases. Furthermore, in deceleration cases, at 55 m, average recognition time pre-collision with the pedestrian was the lowest. At 110 m and in acceleration cases, the ANOVA results show that averages RT at the pre-collision scenario with the vehicle, bicycle, and pedestrian at 55 m and 110 m were significant difference as shown in Table 1. The result from post-hoc Tukey method show averages recognition times were not significant different only at comparison between vehicle and pedestrian at deceleration cases and between vehicle and bicycle at acceleration.

The ability of a subject to recognize and segregate one`s own motion and the surrounding motion of other vehicles, bicycles, and pedestrians is critical for driving safety. The driving tasks depend on precise and accurate motion perception are controlling speed, overtake judgment, responding to leading vehicle, sudden brake, and detecting pedestrian. In this study, the subjects were more alert in recognizing a pedestrian than a bicycle. The experimental observation indicated that the subjects were more focused and were keen on pedestrian safety. Furthermore, the subjects recognize unintended acceleration earliest in the pre-collision scenario with a pedestrian. A pedestrian was visible to a subject from a long distance. The relative velocity of the pedestrian (60 km/h) was the lowest as compared to bicycle (62 km/h) and vehicle (85 km/h). This finding shows that the subject can instantaneously recognize unintended acceleration at a low velocity and relative velocity in a pre-collision scenario (pedestrian). On the contrary, the subjects took a longer time to recognize unintended acceleration at a higher velocity and relative velocity in a pre-collision scenario (vehicle).

Table 1: ANOVA and post-hoc Tukey result for 55 m

Unintended Acceleration	ANOVA					Post Hoc Tukey		
		50 m		110 m			50 m	110 m
Deceleration	V,B,P	F (2,13) = 11.46, p=0.0014	SD	F (2, 14) = 4.88, p=0.0247	SD	V-B	NSD	SD
						V-P	SD	NSD
						B-P	SD	SD
Acceleration	V,B,P	F (2,12) = 35.89, p=8.6E-06	SD	F (2, 14) = 36.06, p=3.0E-06	SD	V-B	SD	NSD
						V-P	SD	SD
						B-P	SD	SD

SD: Significant Difference, NSD: Not Significantly Difference, V: Vehicle, B:Bicycle, P: Pedestrian

4.0 CONCLUSION

The ability of a subject to recognize and segregate one`s own motion and the surrounding motion of other vehicles, bicycles, and pedestrians is critical for driving safety. The driving tasks that depend on precise and accurate motion perception are controlling speed, overtake judgment, responding to leading vehicle, sudden brake, and detecting pedestrian. Furthermore, the subjects recognize unintended acceleration earliest in the pre-collision scenario with a pedestrian. A pedestrian was visible to a subject from a long distance. For acceleration cases and at distance of 55 m, the time to crash for pedestrian, bicycle, and vehicle was 3.07 s and the results showed that the recognition time at the conditions was the lowest. This finding shows that the subject can instantaneously recognize unintended acceleration at a low velocity and relative velocity in a pre-collision scenario (pedestrian). On the contrary, the subjects took a longer time to recognize unintended acceleration at a higher velocity and relative velocity in a pre-collision scenario (vehicle).

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