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The Impact of Type of Automation, Scenarios, and Driving Style on Motorcyclist Willingness to Cross a Junction

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Abstract – *This paper discusses whether knowing the automation, appearance, and driving style of an oncoming vehicle (automated and manual) affects a motorcyclist's decision to cross a junction. In a video-based experiment with 54 participants, two vehicles (Perodua Myvi) with different colors are presented as an automated vehicle (grey) and a manually-driven vehicle (white), respectively. A lookalike and rotating LiDAR was developed and placed on the top of one of the vehicles. Both vehicles went through four scenarios involving a junction with two driving styles (assertive and defensive). The participants were asked to indicate whether they would cross the junction with the approaching vehicle (automated and manual) at a distance ranging from 100 m to 25 m. The results showed no significant influence of automation, scenario, and driving style on the motorcyclist's willingness to cross a junction. However, we found that the motorcyclists indicated a higher willingness to cross when the automated vehicle is approaching than when the manually-driven vehicle is at a distance of 50 m and 25 m. We conclude by discussing the limitation and the future study.*

Keywords: Automated vehicle, junction, driving style, motorcyclist

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1.0 INTRODUCTION

In today's age of artificial intelligence, automated vehicles are inevitable. So, the acceptance of automated vehicles is of concern to the researcher. The pillars of adopting automated vehicles are technology and innovation, infrastructure, consumer acceptance, and policy and legislation (Abu Kassim et al., 2019). From the technological point of view, automated vehicles require significant investment to be safely deployed for public usage. Not only that, specific road infrastructures cater to automated vehicles are needed to adopt this technology.

On the other hand, public acceptance is also vital in adopting automated vehicle technology. Most Malaysians are still reluctant to trust automated vehicles for daily transportation due to their uncommonness to society (Abu Kassim et al., 2019). According to a study in France, participation from the public while testing automated vehicles will help build acceptance and trust (Piao et al., 2016). The government of Malaysia has not yet clearly addressed the arrival of automated vehicles on public roads (Abu Kassim et al., 2019). Policymakers need to make the correct decision to benefit both the technology developers and the general public while ensuring safe deployment simultaneously. Furthermore, safety is the main reason the general public trusts and accepts the automated car (Stanciu et al., 2017; Jing et al., 2020; Lee et al., 2021). To achieve safety, the automated vehicle will be improved by minimizing perception errors, decision errors, decision errors, and action errors (Wang et al., 2020).

When automated vehicles are available on the public road, they will share the road with other road users, creating a mixed traffic scenario (Rothenbücher et al., 2016). One group of road users who will be the most affected is vulnerable road users (VRU), including pedestrians, cyclists, and motorcyclists. Many studies on the interaction between automated vehicles and pedestrians were done by researchers in American and European countries (Rothenbücher et al., 2016; Dey & Terken, 2017; Dey et al., 2017; Lee et al., 2021). In Malaysia mainly, motorcyclists are the critical users of Malaysian traffic. In addition, Malaysia has the highest road fatality risk among the ASEAN countries, and 50% of the accidents involve motorcyclists (Sultan et al., 2016). Surprisingly, there is no study to understand motorcyclists' responses and behavior, especially when encountering a situation where they must share the road with automated vehicles in the coming future.

In this study, exploration was done on the early study of the interaction between the automated vehicle and the motorcyclist in a mixed traffic scenario. The aim is to investigate the effects of vehicle driving style, type of automation, and different scenarios on motorcyclists willingness to cross the junction.

2.0 METHODOLOGY

There are two phases involved. In Phase 1, a ghost driver seat costume was fabricated, and a lookalike LiDAR was developed to enhance the saliency of the vehicle to look like an actual automated vehicle. The vehicle's power management system and the driving system was also developed to be used for the experiment. In Phase 2, the equipment and video recording were set up. A human driver then put on the ghost driver seat costume to drive the car to perform like an automated vehicle in a recording-based study. The whole scenarios were recorded and presented to the participants using the online platform.

2.1 System Architecture

This study used two different vehicles to simulate the scenario of “automated” and “manual” types of automation. A specially developed vehicle called the Automated Vehicle Simulator (AVS) was used to simulate “automated” driving (see Figure 1(a)). This study also implemented the ghost driver approach to evoke the feeling that an automated vehicle was operating on the road without a human driver (see Figure 2(a)) (Rothenbücher et al., 2016; Dey et al., 2019). Hence, a ghost driver seat costume was developed to create an optical illusion as a fully automated vehicle. The seat costume structure was formed in wire mesh and covered with the regular seat cover. The driver manoeuvred the vehicle using the bottom section of the steering wheel to avoid being seen from the windshield. A lookalike LiDAR is also built to enhance the saliency of a fully operating automated vehicle (see Figure 2(b)). LiDAR is heavily associated with a fully automated vehicle, as shown on Uber’s and Google’s version of the vehicle on the mass and social media.

(a) (b)

Figure 1: Snapshot of the vehicle used in this study (a) Ghost driver, (b) Human driver

(a) (b)

Figure 2: (a) A ghost driver used in this study, (b) Lookalike LiDAR (in a circle) on the roof of the instrumented vehicle

The behaviour system is developed to control the driving style of the AVS. Both vehicles driving style were simulated by a human driver whose was guided by a special device called Automatic acceleration and Data controller (AUTOAccD). This device assists the driver to accomplish the selected acceleration based on the specific driving styles, namely assertive (with a constant speed of 34 km/h) and defensive (with a constant speed of 24 km/h). The ghost driver then maintained the speed depending on the specified driving style without sudden accelerating and braking in the driving process. See (Karjanto et al., 2017) for further information on AUTOAccD and pre-defined driving styles).

The other vehicle is used to simulate the non-automated (manual) driving and is an exact model similar to the AVS but with the absence of the ghost driver and a visible lookalike LiDAR (see Figure 1(b)).

2.2 Training and Protocol

There is only one dedicated driver, to maintain consistency, who was trained to operate both vehicles. The challenging task is to drive the AVS while wearing the ghost driver suit. The driver is also trained to maintain a constant speed in the longitudinal direction without jerking, sudden accelerating, or braking. Several pilot tests were performed in the daylight from 9 am to 12 pm to gain a high level of consistency. Once the motorcyclist was ready, a coordinator communicated with the ghost driver to drive according to the planned route. The ghost driver then maintained the speed depending on the specified driving style without sudden accelerating and braking in the driving process.

2.3 Experiment Design

Four scenarios were studied involving a motorcyclist whose intention is turning to the right when approaching a T-junction (see Figure 3).

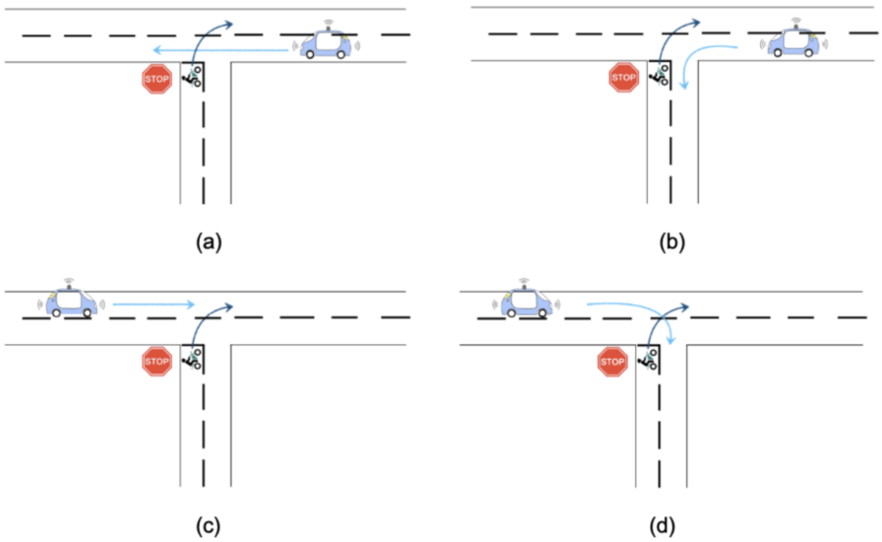

Figure 3: Four scenarios were studied: (a) The vehicle coming from the right and going straight; (b) The vehicle coming from the right and turning to the left; (c) The vehicle coming from the left and going straight; (d) The vehicle coming from the left and turning to the right

The first two scenarios are when the vehicle is coming from the motorcyclist's right, and the vehicle is either going straight or turning to the left. The other two scenarios are when the vehicle is coming from the left side of the motorcyclist and is either going straight or turning to the right. In total, 16 stimuli were created using the video-recording, which are four (4) scenarios times two (2) driving styles times two (2) types of vehicle (see Table 1). The four scenarios (S1 to S4), tested as between-subject. Two driving styles were selected: assertive and defensive (D1 and D2) and tested as a within-subject study. These two driving styles were selected are the most commonly used metric for defining driving style with opposite characteristics (Xu et al., 2015; Basu et al., 2017; Karjanto et al., 2017). In addition, two types of vehicles, automated and manual (A1 and A2, respectively), were also selected as the within-subject study.

Table 1: The combination of scenarios, driving style, and type of vehicle used in this study – The type of vehicle was designed as a between-subject measurement, whereas the scenarios and driving styles are designed within-subject measurement

Scenarios	Driving Style (DS)	Type of Vehicle
S1: Coming from the right and going straight (Right-Straight)	D1: Assertive	A1: Automated A2: Manual
	D2: Defensive	A1: Automated A2: Manual
S2: Coming from the right and turning left (Right-Turn)	D1: Assertive	A1: Automated A2: Manual
	D2: Defensive	A1: Automated A2: Manual
S3: Coming from the left and going straight (Left-Straight)	D1: Assertive	A1: Automated A2: Manual
	D2: Defensive	A1: Automated A2: Manual
S4: Coming from the left and turning right (Left-Turn)	D1: Assertive	A1: Automated A2: Manual
	D2: Defensive	A1: Automated A2: Manual

2.4 The Route, Video Recordings, and Questionnaire

An action camera with a normal view and 4K definition was placed on top of the motorcyclist's helmet to get a motorcyclist point of view. At the start of the video recording, the AVS was parked at the waiting location, not visible to the motorcyclist. The video recordings were done on a T-junction with a stop sign, as shown below (see Figure 4). The location of setup is within the vicinity of Universiti Tun Hussein Onn Malaysia (UTHM), Pagoh Campus. In scenario S1 and S2, the motorcyclist was facing to the right, watching the incoming vehicle coming from the right (D1, D2, A1, A2), while in the scenario S3 and S4, the motorcyclist was facing to the left, watching the incoming vehicle coming from the left (D1, D2, A1, A2).

The recordings were segregated into 16 video footages (four (4) scenarios from two (2) types of automation with two (2) driving styles). The willingness of the motorcyclist to cross into the junction was measured at the four (4) specified points of distance from the motorcyclist, the distances being 100 m, 75 m, 50 m, and 25 m from the motorcyclist. Each of the eight (8) videos of the approaching car was clipped at specific timestamps corresponding to when the vehicle was at these four (4) measuring points, which yielded 64 small video segments (16 x 4) as the stimuli for the experiment. Each video segment stimulus thus showed the approaching car, with the video starts by showing the vehicle approaching from 100 m away. The video segments were between 4 and 13 seconds long, allowing participants to form an opinion of the vehicle's external appearance-related characteristics and driving behaviour. The relative positions of the motorcyclist (camera placement) and the corresponding distances of the four (4) measuring points (see Figure 5). The order of the videos was randomized, and the link was shared with the participants. The question gives the willingness to cross the junction, "Are you willing to cross the junction when the vehicle is at this position (100 m)?". The answers are given on a 5-point Likert scale in which 1 is "Unlikely" to 5, which is "Likely".

(a) (b)

Figure 4: Location of video recordings for this study, located at UTHM Pagoh; side view from the left (a), and (b) front view facing the T-junction

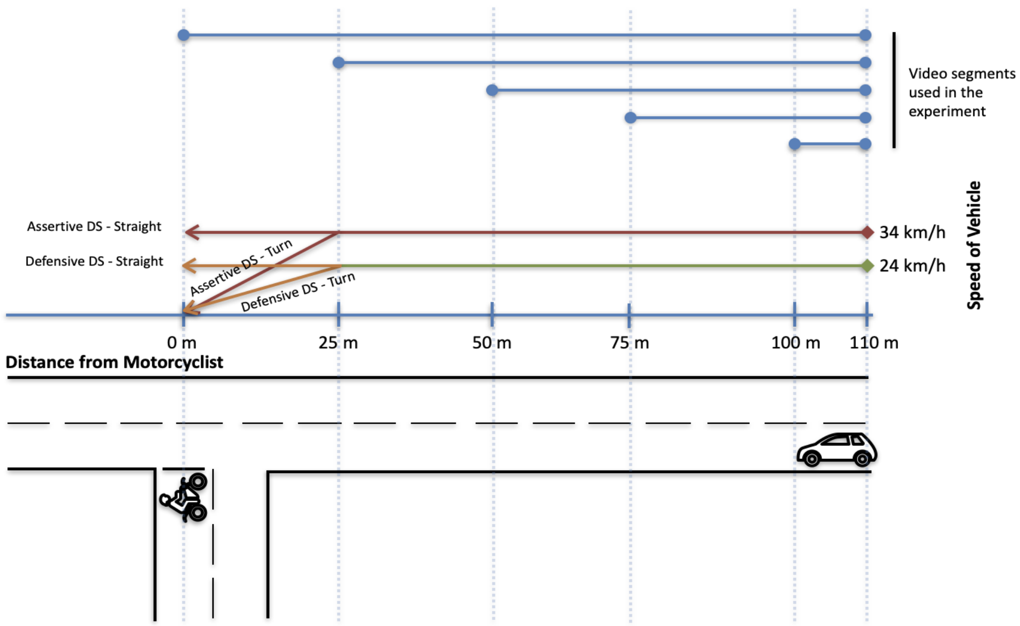

Figure 5: Illustration of the relative position of the motorcyclist and vehicle

2.5 Participant

A total of 54 participants with valid Malaysian motorcycle licenses took part in this between-subjects study. The first group of 27 participants watched the videos of the manual-driven vehicle, while the other 27 participants watched the videos of the automated vehicle. Recruited participants are between 19 and 57 years old (mean = 25.8 standard deviation = 7.4), with 40 males and 14 females. The average duration of motorcycle license ownership is 7.9 years (standard deviation = 7.2). The number of kilometers rides per year is between 1000 to 5000 km (mean = 2481.1, standard deviation = 1299.3). All participants have never encountered or experienced any automated vehicle before.

The willingness of the motorcyclist to cross the junction is the dependent variable in this study. The two within-subjects factors are the driving style (assertive and defensive) and the scenarios (right-turn, right-straight, left-turn, left-straight). The between-subjects factors are the type of automation (automated and manual). Therefore, three-way analyses of variances (Mixed ANOVA) were performed for this study. The dependent variable should be approximately normally distributed checking by using "Shapiro-Wilk Test of Normality". The dependent variable should also be equal between the groups of the between-subjects factor. The homogeneity of variances can be tested using "Levene's Test for Equality of Variances". Lastly, the variance of the differences between groups should be equally tested using "Mauchly's Test of the Sphericity". The assumption must be satisfied. If not, adjustments to the degree of freedom can be made. If the value is $p < 0.05$, then it does not have sphericity.

3.0 RESULTS AND DISCUSSION

The mean scores of the motorcyclist willingness to cross the junction according to the scenario and driving style of the vehicle are shown in Table 2. It is observed that the general pattern of the motorcyclist's willingness to cross into the junction does not change substantially between the two different automation, four different scenarios, or the driving style of the vehicles. In the case of vehicle driving in the assertive driving style, the willingness of the motorcyclist to cross into the junction decrease steadily as the vehicle comes closer, which is an expected response. On the other hand, when the vehicle is driving in the defensive driving style, generally, most of the mean score of willingness is less than the means score of the willingness while in the assertive mode.

Analyses of variances (Mixed ANOVA) were conducted for each distance (100 m, 75 m, 50 m, 25 m), with scenarios and driving style as within-subjects factors, and automation as a between-subjects factor, and the motorcyclist's willingness to cross as the dependent variables, to evaluate the main effects and the two-way interactions and the three-way interaction between the independent's variables. In each case (distance of the vehicle away from motorcyclist), the assumption of sphericity (verified by Mauchly's Sphericity test significance value > 0.05) holds when looking at the F-statistics. Therefore, only main effects are reported for brevity and conciseness, as the interactions were not significant (See Table 3 and 4).

4.0 DISCUSSION

The focus of this study is on the effects of type of automation (automated vs. manual), scenario (left-turn, right-turn, left-straight and right-straight), driving style (assertive vs. defensive), and distance from the motorcyclist (100 m, 75 m, 50 m, and 25 m) on the willingness of the motorcyclists to cross the junction. Based on the results, no evidence was found that whether the automated vehicle or manual vehicle affects the willingness of motorcyclists to cross into the junction.

Perhaps the online videos prepared in the survey questionnaire were not clear enough to recognize automated vehicles' appearance, although they knew it was an automated vehicle before answering the questions. However, when the automated vehicle is driving towards the participants, the automated vehicle body and the LiDAR are grey, making the automated vehicle exhibit much difference compared with the manual-driven vehicle. It is indicated from the result when the automated vehicle has reached 50 m away from motorcyclists, most participants are willing to cross the road. In contrast, the participants' willingness decreased when the manual vehicle was oncoming (see Table 2). There is another factor that affected the observation of the automated vehicle, which is the weather. The sunlight on a sunny day reflects on the front mirror of the vehicle, making it harder for the motorcyclist to detect the presence of the ghost driver. However, previous work found no eye contact between another road user, pedestrians, and automated vehicles (Dey and Terken, 2017). Therefore, the participants were only concerned about when good timing is to cross the road instead of the driver's presence in the vehicle.

Table 2: The Motorcyclist willingness to cross the junction across variations of vehicle driving scenario and automation. 1 = Totally unwilling to cross; 3 = undecided (neutral); 5 = Totally willing to cross. Top: Mean score; Bottom (small italics): Standard deviation

Scenario	**Driving Style**	**Automation**	**Vehicle distance from**			
			100	75m	50m	25m
Right- Straight	Assertive	Automated	4.85 *0.45*	4.556 *0.577*	3.444 *1.188*	2.185 *1.415*
		Manual	4.77 *0.50*	4.185 *1.001*	2.556 *1.220*	1.333 *0.620*
	Defensive	Automated	4.70 *0.54*	4.296 *0.669*	3.333 *1.038*	1.852 *1.099*
		Manual	4.70 *0.72*	4.222 *0.847*	2.704 *1.436*	1.296 *0.542*
Right- Turn	Assertive	Automated	4.74 *0.52*	4.482 *0.580*	2.556 *1.050*	2.111 *1.281*
		Manual	4.81 *0.39*	4.296 *0.775*	2.667 *1.330*	1.778 *1.155*
	Defensive	Automated	4.74 *0.52*	4.370 *0.688*	3.482 *1.051*	1.852 *1.027*
		Manual	4.77 *0.64*	4.296 *0.823*	3.074 *1.299*	1.963 *1.285*
Left- Straight	Assertive	Automated	4.77 *0.50*	4.482 *0.700*	3.370 *1.182*	2.037 *1.372*
		Manual	4.74 *0.52*	4.111 *1.013*	2.778 *1.368*	1.519 *0.802*
	Defensive	Automated	4.74 *0.52*	4.407 *0.636*	3.407 *1.118*	1.852 *1.199*
		Manual	4.81 *0.39*	4.370 *0.792*	2.704 *1.325*	1.370 *0.629*
Left- Turn	Assertive	Automated	4.74 *0.52*	4.519 *0.643*	3.667 *1.074*	2.111 *1.368*
		Manual	4.74 *0.52*	4.296 *0.823*	2.889 *1.281*	1.333 *0.620*
	Defensive	Automated	4.74 *0.52*	4.370 *0.629*	3.482 *1.087*	1.778 *1.121*
		Manual	4.70 *0.66*	4.222 *0.847*	2.741 *1.403*	1.296 *0.609*

Table 3: The main effect of the scenario and driving style on motorcyclist willingness to cross the road – scenario vs. driving style vs. automation

Vehicle Distance (m)	F (3, 156)	Significance	Effect Size (η^2)
100	0.584	0.626	0.110
75	0.668	0.554	0.130
50	1.135	0.330	0.210
25	1.003	0.380	0.190

Table 4: The main effect of the scenario, driving style, and the automation on motorcyclist willingness to cross

Vehicle Distance (m)	F (3, 156)	Significance	Effect Size (η^2)
Scenario vs. Automation			
100	1.259	0.290	0.017
75	0.337	0.740	0.006
50	0.169	0.885	0.003
25	3.545	0.050	0.064
Scenario vs. Driving Style			
100	1.226	0.302	0.023
75	1.463	0.231	0.027
50	1.266	0.288	0.024
25	0.715	0.511	0.014
Driving Style vs. Automation			
100	0.241	0.625	0.005
75	4.517	0.038	0.080
50	2.294	0.136	0.420
25	3.244	0.077	0.059

The results also indicated that the vehicle's driving style (assertive and defensive) does not influence the motorcyclist's willingness to cross the junction. However, most motorcyclists willing to cross the junction at 50 m and above for all driving styles, for both automated or manual vehicle (see Table 2). The defensive driving style was set at 24 km/h, but the assertive driving style was 34 km/h. At the current speed selection, the difference might not be explicit enough when viewing as recording video. In a similar work with pedestrians, Dey et al., 2019 experimented with the 50 km/h as the assertive driving mode before decelerating in front of the pedestrian. Therefore, the selection of speed could be why driving style did not indicate any statistical significance in this study.

4.0 CONCLUSION

This study found no significant change in the willingness of the motorcyclist to cross the junction in front of an automated vehicle instead of a manual vehicle in terms of driving style, type of automation, and the selected scenarios. However, this study found that participants were more willing to cross into the junction in front of the automated or manual vehicle at a distance of 50 m and above.

The limitation of the study is the video-based nature of the experiment as opposed to a real-world field investigation. Participants might have responded that it entailed riskier behaviour than they would in the actual situation due to the lack of immediate danger of physical harm. Future study will involve performing another study with the same methodological approach but instead bringing the motorcyclist to the road and watching the real-time scenarios. Another consideration is to increase the selection of speed for the assertive driving style. The speed of 50 km/h can be used instead of 34 km/h to create an obvious difference between the two driving styles.

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