Effect of Right-Turn Lane on Motorcyclists' Gap Acceptance and Hazard Perception during Intersection Approach

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ABSTRACT

In Malaysia, accidents at junctions accounted for 33.7% of total motorcycle accidents and 19.6% of total motorcycle fatalities. Using a naturalistic data collection approach, this study investigated the effect of right-turn lane on gap acceptance behaviours of motorcyclists during right-turn manoeuvre across oncoming traffic at unsignalised junctions. Twenty experienced motorcyclists with a mean age of 27 years and average riding experience of 10 years were asked to ride an instrumented motorcycle on selected experiment routes which include turning right on three specific junctions. In general, participants are more likely to accept larger gaps and reject smaller gaps at junctions with a right-turn lane as compared to gaps at junctions without a right turning lane suggesting the safety effect of the right-turn lane. Changes in riding performances were also observed in terms of turn signal use and choice of speed when the availability of the right turn lane was considered. Interestingly the results indicate that the participants' hazard perception and responding was better during the right turn at junctions without the right-turn lane compared to junction with the right-turn lane. The findings of this study are beneficial in developing a better understanding of the motorcyclists and road design factors that can contribute to risk of accidents and also in paving the way to more effective design solutions.

1. INTRODUCTION

Motorcycle accidents at intersection are a major safety concern especially in countries with large number of motorcyclists riding in a mixed-traffic environment. In Malaysia, accidents at intersections accounted for 33.7% of total motorcycle crashes and 19.6% of total motorcycle fatalities in 2006-2010 (Royal Malaysian Police, 2012). Majority of these accidents occurred at unsignalised intersections with alarming number of killed or seriously injured motorcyclists as the results. The non-automated control or the non-existence of any type of control means the safety of road users entering or turning at unsignalised intersections is strongly influenced by their driving skills such as gap acceptance decisions and hazard perception. As a vulnerable group in a mixed-traffic environment, safety of motorcyclists at unsignalised intersections is strongly affected by these skills.

Understanding the underlying causes of poor gap acceptance decisions will contribute critical information to traffic safety because the finding can be incorporated into road design and safety considerations. For instance, Zhou (2009) suggested that providing a lane for turning vehicles at unsignalised junctions will minimize the risk of accidents by reducing the pressure from tailing vehicles and the likelihood of making a turn at unsafe gaps. However, this finding might not be entirely true in the case of motorcyclists. Any conclusions on the pattern of riding behaviours of motorcyclists should thoroughly consider the different physical state, flexibility of movement, driving workload and safety risks facing the motorcyclists. The availability of a turning lane might influence the behaviours of motorcyclists differently as compared to car drivers in terms of gap acceptance.

Growing numbers of researches have pointed the need to better understand the behaviours of motorcyclists on the road in order to improve or find new countermeasures to address their safety. This is mainly due to the unique nature of motorcycle riding and the different levels of accident risks facing them as compared to other motorised vehicles. For example, motorcycle riders are subjected not only to visual conspicuity but also cognitive conspicuity of other road users which may resulted in lower probability of being detected (Ragot-Court et al., 2012) due to perceptual constraints (Crundall et al., 2008; Pai, 2011). Different manoeuvring capabilities coupled with unique acceleration and cornering characteristics are also putting them in higher accident risk (Broughton et al., 2009). Having a clear understanding of motorcyclists' behaviours will lead to more accurate and effective design considerations (Pai, 2011; Espie et al., in press).

Despite a grave need for safety initiatives and improvements for motorcycle safety, to date, very few studies (e.g, Minh et al., 2005; Tuan and Shimizu, 2009; Sangole et al., 2011) were so far conducted on motorcyclist gap acceptance behaviours at intersections and its application to safety countermeasures especially in the developing countries. In Malaysia, although a quite substantial number of studies have tried to address the relationship between road design geometry and riding characteristics (e.g., Davoodi et al., 2012; Hussain et al., 2011; Faezi et al., 2011; Law and Radin Umar, 2005), the focus of these studies were mainly on the design of exclusive motorcycle lanes which have different traffic settings than intersections. One of the possible reasons of this lack of studies is the challenge in gathering quality field data that contains information critical to explaining motorcyclists' behaviours on the road.

The search for sustainable safety solutions through safer road design has recognised the need to understand the cognitive aspects of gap acceptance as a decision-making process (Beanland et al., 2013) in addition to studying the statistical probability of accepting or rejecting certain gaps. Field observations or riding simulator study can provide a better understanding of motorcyclists' decisions to accept or reject certain gaps with potential to explore various road design factors that can be heavily influenced by individual preferences. This study explores the effects of right turn lane on gap acceptance and hazard perception of motorcyclist at unsignalized and uncontrolled intersection. Using an instrumented motorcycle to collect riding data in actual traffic setting, this study examines the influence of exclusive right turn lane on the gap acceptance and hazard perception skills of motorcyclists.

2. METHODS

2.1 PARTICIPANTS

Participants were selected from a group of candidates who responded to advertisements and information received through word of mouth. The main criteria of selection were possession of a valid motorcycle license and a minimum one year of riding experience. Twenty experienced motorcyclists with a mean age of 27 years and average riding experience of 10 years were recruited to participate in the experiment. All of the selected participants were local residents or worked in the area where the data collection was conducted and were familiar with the route. Female participants were not included in the experiment due to the lack of suitable candidates.

2.2 INSTRUMENTED MOTORCYCLE

An instrumented motorcycle (see Figure 1) was used to collect participants' riding data. Motorcycle speed and acceleration were captured by a GPS system and an accelerometer installed on the motorcycle. The use of the turn signal and brake pedal were recorded directly using electrical signals captured by the data acquisition system. Video footage of front and rear surroundings was captured by two weather-proof cameras installed on the motorcycle. All equipment apart from the cameras was concealed in a helmet box. A set of questionnaires was given to the participants before the experiment run to capture their demographic data.

Figure 1. The instrumented motorcycle used in the study

2.3 PROCEDURE

The experiment runs were conducted on weekdays at around 10:00 a.m. to 5:00 p.m. with dry weather condition. Before each experiment run, a briefing session was conducted to explain the procedures of the experiment to the participants. The route of the experiment was carefully explained especially the location of the junctions involved. The experiment route selected was a two main carriage way road with 60 km/h speed limit with total distance of 8 km and average trip duration of 25 minutes (Figure 2). During the experiment runs, participants made three right turns at three different unsignalized junctions in which one right turn was made at each junction. After the first turn, participants made a U-turn and returned to the starting point and repeated the trip for the second and third junctions. A right-turn lane was available at one of the three junctions (Junction 3 in Figure 2). Participants were advised to ride the instrumented motorcycle as they would normally ride. Health screening interviews were also conducted to ensure the participants were free from health problems or any influence of alcohol or drugs. Prior to an actual experiment run, participants were given an opportunity to familiarize themselves with the handling and operation of the motorcycle. Participants were then signed an informed consent form before participating in the experiment.

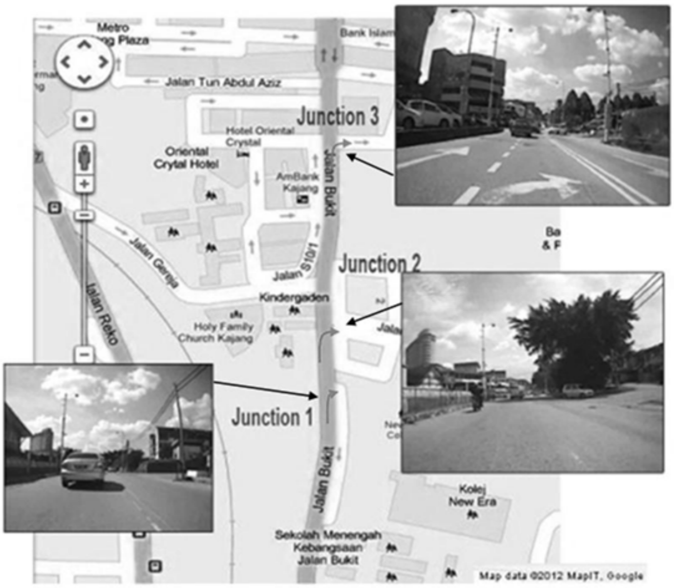

Figure 2. Maps of the selected route and three unsignalized junctions

2.4 DATA ANALYSIS

2.4.1 Dependent measures

Parameters that are related to gap acceptance manoeuvres at junctions are size of gaps accepted (GAP) and rejected (GAP-reject) by participants. A gap is defined as the time interval between two successive vehicles and lag is defined as the time interval between the arrival of a turning vehicle at an intersection and the arrival of the next approaching vehicle (see Figure 3). In one of the oldest studies on gap acceptance analysis, Ashworth (1970) included both lags and gaps in the analysis but treated them as similar and assumed to follow an exponential distribution. In a more recent study, Harwood *et al.* (2000) treated gaps and lags as one similar variable in their gap acceptance model. In this study, it was nearly impossible to capture a full view of the traffic condition at the junction from the turning motorcycle and to control for the availability of gaps between two successive oncoming vehicles. Hence, the gap acceptance analysis of this study treated lags as a similar variable as gaps. Other riding parameters measured in the experiment were turning speeds and the period of signal activation before the turn (SIG). Below are the detail definitions of these dependent measures.

- GAP (in s): the time interval between two successive vehicles, measured from the rear of a lead vehicle to the front of the following vehicle chosen by participants to make the right turn. The gap was calculated by measuring the time interval from the point when the participant started to turn (captured by front camera) to the arrival of the front of the approaching vehicle (captured by rear camera)
- GAP-reject (in s): the time interval (GAP) rejected by participants.
- Speed (in km/h): the speed at which participants make the right turn, as recorded by the GPS installed on the instrumented motorcycle.
- SIG (in s): the period of turn signal activation, measured from the point of signal activation to the point when participants make the right turn, or stop due to the approach of an oncoming vehicle.

Riding experience, presence of right turn lanes and combination of experience and presence of right turn lanes were used as factors in each analysis of dependent variables. Data recorded at Junction 1 was not used in the analysis due to limited events of gap acceptance observed.

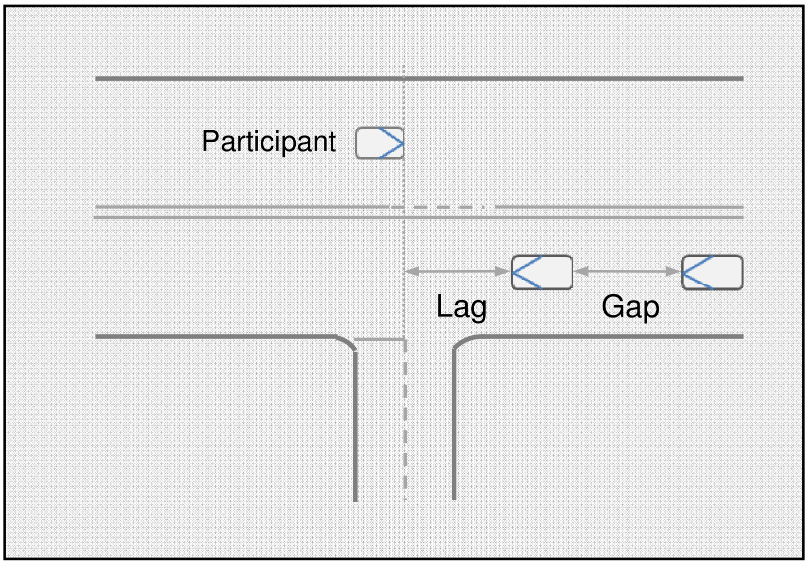

Figure 3. Lag and gap during the right turn event

3. RESULTS

3.1. GAP ACCEPTANCE BEHAVIOURS

Table 1 lists the mean values of accepted and rejected gaps at both types of junctions for each experience group. In general, participants tend to accept larger gaps (M = 6.7 s, S.D. = 3.1 s) at junction with a right-turn lane compared to junction without such lane (M = 5.9 s, S.D. = 2.4 s). Also, compared to junction without the right-turn lane, larger percentage of participants was observed to reject smaller gaps at junction with the right-turn lane. Although the effects of the right-turn lane on gap acceptance and rejection were not found to be significant by ANOVA (see Table 2), these patterns can be observed from the plot of percentage of gap acceptance and rejection at both junctions (see Figure 4). The effect of experience on gap acceptance was also not found to be significant by ANOVA but the value was quite close to significant ($p = 0.09$). In general, it was found that motorcyclists with more than 10 years of riding experience tend to accept smaller gaps at junctions without a turning lane. In contrast, the less experienced group was found to accept smaller gaps at junctions with a right turn lane and accept larger gaps at junctions without a right turn lane. Increasing the sample size and will most likely yield a better results.

Category		Accepted gaps (s)	Rejected gaps (s)
No turn lane	Overall	5.9 (SD = 2.4)	2.3 (SD = 1.0)
	Experience group		
	< 10 years	4.2 (SD = 4.4)	0.6 (SD = 0.9)
	10 years or more	3.3 (SD = 2.4)	0.6 (SD = 1.4)
With turn lane	Overall	6.7 (SD = 3.1)	1.9 (SD = 0.9)
	Experience group		
	< 10 years	3.6 (SD = 4.4)	1.4 (SD = 1.3)
	10 years or more	3.7 (SD = 4.0)	0.3 (SD = 0.7)

Table 1. Mean values of accepted and rejected gaps at both types of junctions for each experience group

Variables	d.f.	F-ratio			
		GAP	GAP-reject	Speed	SIG
Experience group	1	3.006	0.083	0.637	0.487
Availability of right turn lane	1	0.439	0.331	4.810*	5.798*
Experience group x availability of right turn lane	1	0.002	0.331	0.637	1.247
Mean square error	100	7.169	1.076	17.989	8.880

*Significant at the 0.05 level.
Table 2. Analysis of variance (ANOVA) results

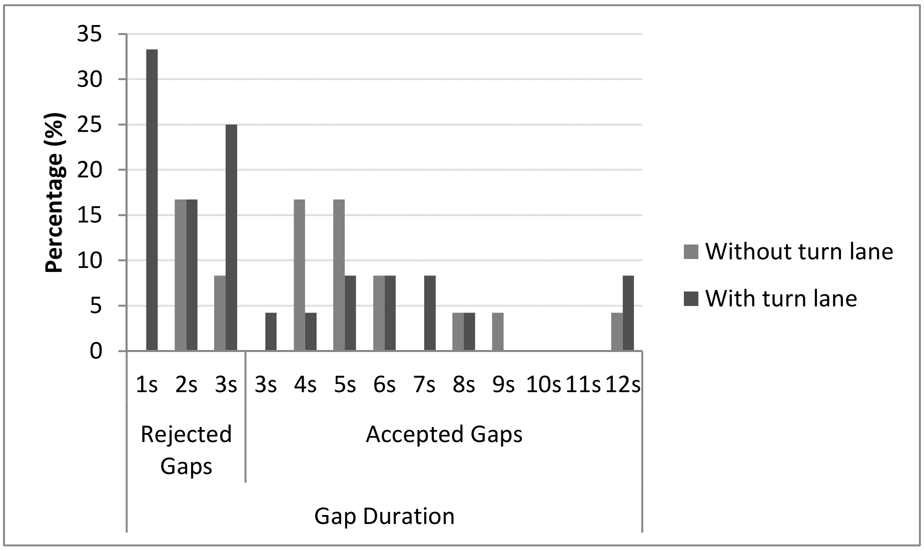

Figure 4. Percentage of gap acceptance/rejection based on the size of available gaps at both types of junctions

3.2. HAZARD PERCEPTION AND TURNING SPEED

The ANOVA results indicate that the availability of a right-turn lane has a significant effect on participants' choice of speed and the use of turn signal during the right turn. They were found to turn at higher speeds (M= 19.3 km/h, S.D. = 5.6 km/h) at junctions with a right-turn lane as compared to junctions without a turning lane (M= 16.3 km/h, S.D. = 1.5 km/h). In terms of turn signal use, they were found to use the signal sooner (M = 8.2 s, S.D. = 3.5 s) at junctions without a right turning lane as compared with junctions with a turning lane (M = 6.8 s, S.D. = 2.3 s). The mean time of signal activation is lower at junctions with a right turn lane for both groups as compared to junctions without a right turn lane. In this study, hazard perception skills of motorcyclists were measured by the use of the turn signal during the right turn. The duration of turn signal activation before the right turn (measured in seconds) was used as an indicator of level of responses from participants towards possible hazards. In motorcycle riding, the situational awareness of a motorcyclist includes being vigilant for obstacles and making predictions based on the information from the traffic situation (Haworth *et al.* 2000). Thus, the sooner the participants activate the signal before turning, the better their hazard perception skills were. Interestingly our results indicate that the participants' hazard perception and responding was better during the right turn at junctions without the right-turn lane compared to junction with the right-turn lane.

4. DISCUSSION

The study investigated the performances of motorcyclists in negotiating a right turn from a major road at unsignalised junctions. The key measures of performances were gap acceptance behaviours and hazard perception. The results indicated that the availability of a right turn lane contributes to certain interesting effect on the gap acceptance behaviour of participants although different patterns of riding behaviours were observed between the more experienced and the less experienced group. In general, participants are more likely to accept larger gaps and reject smaller gaps at junctions with a right-turn lane as compared to those at junctions without a right turning lane. One explanation for this maybe the motorcyclists were less pressured by the waiting traffic and thus were more conservative in accepting available gaps. This behaviour was confirmed by a previous study on car drivers which found out that a driver a more likely to accept smaller gaps in traffic if queuing vehicles are waiting behind them (Tupper 2011). The result of this study could imply a safer condition for right turning motorcyclists at junctions with a right turning lane because they tend to reject unsafe gaps. A previous study by Zhou (2009) demonstrated that intersections with exclusive turning lanes reduce the likelihood of same direction crashes such as rear-end, turning-same direction and side swipe collisions occurring.

The use of the turn signal is one of the actions a driver or motorcyclist can take to react to a perceived hazard which in this case the oncoming traffic and the vehicles from behind the motorcyclists. The use of the turn signal indicates a situational awareness of a motorcyclist and it is one of the possible reactions in a 'threat appraisal'. Threat appraisal is one of four processes listed by Groeger (2000) to play a role in hazard perception. The other three processes are detection of hazard, selection of actions to avert the hazard and the implementation of them. The experiment results show that both groups of motorcyclists are affected by the availability of a right turn lane at junctions in terms of the turn signal use. The mean time of signal activation is lower at junctions with a right turn lane for both groups as compared to junctions without a right turn lane. The study found out that the participants activated their turn signal sooner when approaching a junction without a right turn lane whereas at junctions with a turning lane, they tended to activate the turn signal when approaching the entry of the turn lane or the point where they started to change lanes (entering the right turn lane). They also tend to turn at a higher speed at junctions with a right turn lane. One explanation for this finding is that the presence of the right turn lane increases the safety perception of the motorcyclists during the right turn. For instance, the participants could have assumed that it is not important to turn the signal sooner because the act of entering the turning lane would be a sufficient indicator of their intention. The impact of this behaviour on safety could not be concluded from this study but it warrants a further study in the future because a delay in signal indication can still lead to possible conflicts with any vehicle following from behind.

5. CONCLUSION

In conclusion, this field study has demonstrated the possibility of collecting gap acceptance data of motorcyclists in the field and analysing them with the use of computer software. The results of this study have provided insights on the factors that influence gap acceptance behaviours and hazard perception of motorcyclists at unsignalised junctions. The results indicated the differences in motorcyclists' gap acceptance behaviours at junctions with a right turn lane as compared to those at junctions without a turning lane. Changes in riding performances were also observed in terms of turn signal use and choice of speed when the availability of the right turn lane was considered. The results are beneficial in developing a better understanding of the motorcyclists and road design factors that can contribute to risk of accidents and also in paving the way to more effective design solutions.

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