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Use of GPS-Based Action Cameras in a Naturalistic Motorcycle Riding Study

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Abstract – *A pilot study was conducted to test the feasibility of using GPS-based action cameras in a large-scale naturalistic motorcycle riding data collection. A Garmin VIRB XE action camera was used to record riding behaviour data of four consenting participants from their place of residence to their place of work and other locations. Despite some limitations, the present study found that the methodology, data analysis approach and overall implementation plan were suitable for a larger scale study of this kind. Based on the recorded crash-relevant events, this study established a set of minimum required variables for a meaningful analysis of a naturalistic riding data. In addition, issues pertaining to data recording, data analysis and instrumentation were discussed and the potential solutions were suggested. Overall, this study strengthens the idea that a large-scale naturalistic motorcycle riding study can be conducted with lower financial cost, without substantially reducing the advantage of naturalistic data established by the previous large-scale studies.*

Keywords: Naturalistic riding data, action camera, crash-relevant events, motorcycle safety

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1.0 INTRODUCTION

Insufficient details on the events leading to a road crash is an obstacle to a complete understanding of the crash causation factors, especially those related to driving behaviours. The conventional crash report is heavily dependent on the self-report, which is lacking on the precise details of the pre-crash sequence of events. Progress in this area of research is expected to help the transport practitioners and the relevant authorities to come up with effective multidisciplinary approaches to address the human factors in road crashes. In light of this limitation, a video-based naturalistic data collection is an alternative that can provide an extended field of view on the events and situations leading to a conflict or a crash. The pre-crash and crash-relevant events are crucial to determine potential contributing factors. In countries with motorcycles as the major mode of transportation, the need to capture such data is particularly compelling. This is considering the complexity of motorcycle riding and unpredictability of motorcyclists' behaviour within a mixed traffic environment.

A previous study by Dingus et al. (2006) employed a large-scale naturalistic driving data collection method involving 241 participating car drivers with 43,000 hours of recorded driving data, over 2,000,000 vehicle miles (3,218,688 km). Cases of severe drowsiness, impairment, judgment error, risk taking, willingness to engage in secondary tasks, aggressive driving, and traffic violations were among the driving performances issues found by the researchers. One of the most significant outputs of the study was the "event" database to record the occurrences of crash-relevant events experienced by the participants. The database was based on the similar concept of a police crash database, but with a crash contributing factors as the main theme. Although the majority of earlier naturalistic studies used passenger car as the test vehicle, a considerable literature has grown up in recent years around the theme of naturalistic motorcycle riding data collection (e.g., Dozza & Werneke, 2014; Spyropoulou et al., 2010; Ibrahim et al., 2012; Ibrahim et al., 2018; Ibrahim et al., 2014; Ibrahim & Yusoff, 2011; Ibrahim & Sukardi, 2011; Lemonakis et al., 2014; Vlahogianni et al., 2014). The present study describes the experimental methodology and discusses the analysis of crash-relevant events recorded in a pilot study of a large-scale naturalistic motorcycle riding data collection within the Malaysian traffic environment.

The present study utilises the information gathered from the review to develop the experimental methodology and to determine the types of research questions to be addressed, the depth of instrumentation and the parameters to be recorded. The review also provides a reference for data reduction and decoding process. From the review of the motorcycle crash risks in Malaysia, it becomes apparent that the recording and measuring of motorcycle dynamics are of utmost importance. In addition, the recording should be able to capture the characteristics of the road and the riding condition. This consideration is important to determine the type of instrumentation needed for this study. Considering the limitation in the research budget and the scale of the research, a low-cost equipment should be the main priority. Fortunately, recent advances in sensor technology for driving and riding performance monitoring have led to the development of portable video recording devices that utilise Global Positioning System (GPS) to record speeds and track movements. One of such devices presently available in the market is an action camera developed by Garmin Ltd. The availability of the action camera has paved a way for a large-scale naturalistic riding data collection, which was previously being constrained with high implementation cost.

2.0 MATERIALS AND METHODOLOGY

2.1 Instrumentation and Data Recording

A Garmin VIRB XE action camera with GPS speed recording capacity was the main instrument used for data recording in this study (Figure 1). The camera used a rechargeable 980mAh Lithium-polymer battery and was approximately 3.0" (W) x 1.6" (D) x 1.4" (H) (77.0 x 40.6 x 36.8 mm) in size. The camera weighed around 151.7 g. During a high definition image recording (1080 pixels, 30 frames per seconds), the battery lasted for about two hours on a single charge. The waterproof camera was equipped with an image stabilization mechanism. In a naturalistic motorcycle riding study, these two qualities were much needed due to the inherent vibration of a motorcycle and the high possibility of a rainy condition during the recording session. All recorded data were stored in a microSD card.

Figure 1: Garmin VIRB XE action camera used in this study

2.2 Participants Selection

Selection of participants is one of the key considerations in this type of study, especially since the participants would be using their own motorcycle. For example, an inclusion of "types of motorcycle owned" as the main criteria of selection could improve the possibility of studying the impact of motorcycle engine size on speed choice and avoidance manoeuvre. Other selection criteria considered in this study were the distance from participants' residence to their workplace and the routes they would usually use to commute. Four consenting participants were recruited for this study. For the purpose of this pilot study, the length of the recording was purposely varied to determine the most suitable length of data collection session that can capture sufficient crash-relevant events. Table 1 lists the description of the individual dataset for each participant.

2.3 Motorcycle Selection

The selection of motorcycle was carefully considered to represent the typical types of motorcycle used in Malaysia. The types and physical characteristics of the motorcycles were considered during motorcycle selection to determine the feasibility of mounting the Garmin action camera across different motorcycle variants for an optimum video recording. Table 2 lists the four types of motorcycle included in this study.

3.0 RESULTS AND DISCUSSION

3.1 Mounting and Positioning of the Camera

The study found that the mounting and positioning of the camera was an important factor that influenced the depth and usability of the recorded video data. It was learnt that certain motorcycle models such as Honda NC750X might not have a suitable space to mount the camera, which leave the helmet or chest as the options to mount the camera. In addition, certain motorcycle models such as Yamaha FZ150i might not have a suitable space to mount the camera at the centre front, which could affect the field of view. Mounting the camera on top of the helmet resulted in a slightly higher field of view and the forward field of view was occasionally affected when the rider moved his head. However, mounting the camera on a helmet enabled the recording of blind-spot checking behaviour among the participant, which could not be captured through other mounting options. This data is especially important to study the safety of motorcyclists during lane filtering or junction crossing manoeuvres. Figure 2, Figure 3 and Figure 4 display the locations of mounting and the respective footage from the camera.

Table 1: Details of participants' dataset

Participant code	Riding experience	Place of residence	Routes travelled	Motorcycle model	Length of recording	Distance travelled
P-1	30 years	Bukit Damansara	• Sprint Expressway (E23) • North–South Expressway (E2) • Sungai Besi Expressway (E9) • Kajang Silk Highway (E18)	Honda NC750X	31 days	478.7 km
P-2	30 years	Wangsa Maju	• DUKE Highway (E33) • North–South Expressway (E2) • Sungai Besi Expressway (E9) • Kajang Silk Highway (E18)	Honda PCX150	12 days	287.2 km
P-3	15 years	Bangi	• Kajang Silk Highway (E18)	Yamaha 135LC	7 days	80.0 km
P-4	28 years	Seremban	• LEKAS Highway (E21)	Yamaha FZ150i	3 days	327.4 km

Table 2: Types of motorcycles used in the study

No.	Motorcycle model	Engine displacement	Dimensions (L′W′H)	Seat height
1	Honda NC750X	745 cc	2,230 mm x 845 mm x 1,350 mm	830 mm
2	Honda PCX150	149 cc	1,931 mm x 737 mm x 1,103 mm	761mm
3	Yamaha 135LC	134 cc	1,960 mm x 695 mm x 1,065 mm	775 mm
4	Yamaha FZ150i	149.8 cc	2,009 mm x 705 mm x 1035 mm	790 mm

Figure 2: Helmet mounting and sample view of recorded footage

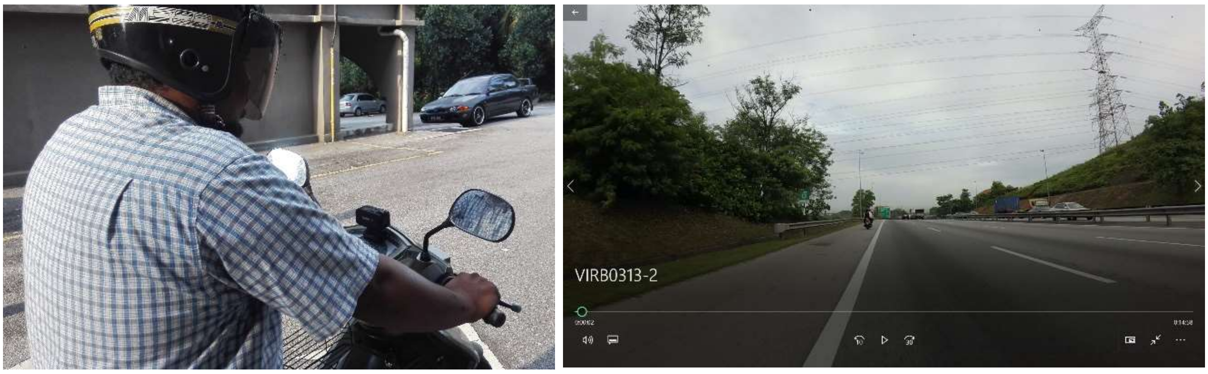

Figure 3: Front panel mounting (option 1) and sample view of recorded footage

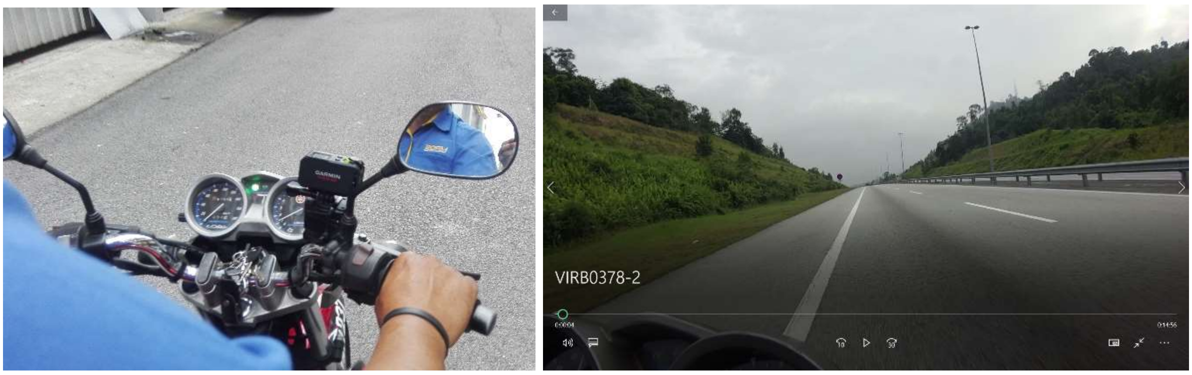

Figure 4: Front panel mounting (option 2) and sample view of recorded footage

3.2 Data Storage and Battery Life Issues

The study found that the action camera was able to record the video with the synchronised sensor and speed data continuously without any major issue. Throughout the 53-days pilot data recording, 355 Gigabyte (GB) of motorcycle riding data with 25 total riding hours and 1173.3 km riding distance were captured. In addition, all GPS data was successfully verified and accounted for each recording file. The recorded footages were not seriously affected by the effect of motorcycle vibration. The current setup was also found to be sufficient to hold the camera firmly at its mounting place. However, major issues were found related to the battery life of the camera and capacity of data storage. Instances of interruption in data recording were encountered in this pilot study due to loss of battery output. On certain data collection trips, participants were also unable to proceed with recording when there was no space for data storage in the SD card. Changing the setting of video recording output from an initial 1080 pixels (30 frames per seconds) to 720 pixels (30 frames per seconds) was found to reduce the size of the video data without substantially affecting the quality of the recorded video. With this setting, the recording required around 9.72 GB of memory space for 45.7 km distance travelled. The change in video recording setting had also improved the battery life. However, the improvement was unsatisfactory, especially for a larger scale study. This issue was solved in this pilot study by connecting the camera to a power bank during the recording. On average, a single data-recording trip lasted for 43 minutes, covering a 45.7 km distance when connected to a fully charged 10,000-mAh power bank. Participants reported no intermittent interruption in recording with the use of the power bank.

3.3 Issues Related to Handling of the Recording Instrument

Similar to the previous naturalistic studies, the safeguarding and maintenance of the recording instrument during the data collection sessions were tasked to the participants. Another task required from the participants was to keep the camera fully charged and to inspect the availability of the camera's memory space for the next recording trip. On average, the battery needed around two hours to be fully charged. This study found that there is a need for a provision of an operating manual to the participants to reduce the likelihood of problems related to the handling of the instrument. For instance, one of the participants reported that he was unable to charge the camera after completing the first recording trip due to unfamiliarity with the device, thus resulting in loss of opportunity for a data collection trip.

3.4 Analysis of Crash-Relevant Events

Observation of a crash-relevant event experienced by the participants was categorized into an actual crash, a near-crash and an incident in the previous naturalistic studies (Dingus et al., 2006; Spyropoulou et al., 2010). The incidents were generally defined as any other crash-relevant conflicts including conflicts that were related to proximity and trajectory crossing. This study used the similar event definition and classification. A crash event was defined as an event that involved any contact with a moving or fixed object at any speed, including falling off the motorcycle and run-off-road crash. A near-crash event was defined as an incident that required a rapid, avoidance manoeuvre by the participant's vehicle or any other vehicle, pedestrian, cyclist, or animal, to avoid a crash. In addition, this study concluded that another dimension of rider factor had to be included in the data coding to capture wilful and unsafe behaviours related to unlawful manoeuvring and crossing, committed by the participants and other road users. The precipitating factors of a crash-relevant event could also be related to animals on the road and infrastructure. The list of variables and parameters in Table 3 were concluded as significant to determine the contributing factors of the near-crash and other crash-relevant events in a naturalistic motorcycle riding study.

Out of all the listed variables, the use of turn signals and brake were the only variables not fully captured using the current camera mounting options. However, a certain modification is possible to capture these variables. One option is to tap the electrical circuit of the signal and brake lamps and connect the respective electrical output to a small light emitting diode (LED) bulb. This LED bulb can be placed on the motorcycle panel within the field of view of the camera. Table 4 lists some examples of crash-relevant events and unsafe riding behaviours captured in this study. It was found that the likelihood of recording crash-relevant event increased with the length of data collection, the distance of travel in a single trip, types of road, a traffic condition and the number of routes travelled in a single trip.

Table 3: List of important variables for explanation of crash and crash-relevant events

No.	Variables	Source of data
1	Use of reflective clothing	Questionnaire/video
2	Travelling speed	GPS data
3	Acceleration/ deceleration	Accelerometer data
4	Use of brake	Not captured
5	Use of turn signals	Not fully captured
6	Purpose of trip	Questionnaire/interview
7	Location of event	GPS data
8	Time of day	Video
9	Road condition (dry or wet)	Video
10	Weather	Video
11	Types of road	Video
12	Number of lanes	Video
13	Avoidance manoeuvre	Video/interview
14	longitudinal headways	Video estimation/interview
15	Demographic/crash exposure data	Questionnaire
16	Travelling distance	GPS data
17	Traffic condition	Video

Table 4: Description of crash-relevant events

No.	Events	Outcome	Avoidance manoeuvre	Frequency of occurrence
1	Other motorists had a trajectory crossing the participants' trajectory	Near-crash	Rapid swerving	5
2	A participant made a late or unsafe merging to a main road	Normal	N/A	4
3	A participant made a U-turn at undesignated places	Normal	N/A	6
4	A participant committed lane filtering or lane splitting	Normal	N/A	8
5	A participant run red-light	Normal	N/A	7
6	A participant tailgating another vehicle	Normal	N/A	1

3.5 The Need for Post-Recording Interview

The analysis of crash-relevant events in this study has led to a conclusion that there is a need for a post-recording interview session with the participants to explain certain precipitating factors of the events and to gauge risk-taking behaviour among motorcyclists. In one of the events, a passenger car made a sudden lane-change manoeuvre and subsequently crossed a participant's trajectory while the participant was travelling at a speed of 101 km/h (Figure 5). No turn signal was observed from the car when the driver made the manoeuvre. Interestingly, the participant was wearing a reflective jacket. A post-recording interview session could help answer certain questions such as whether the participant had anticipated the movement of the car and how does this event affect his or her riding style.

Figure 5: A near-crash event related to unsafe lane change by other motorists

4.0 CONCLUSION

This study set out to determine the feasibility of using a GPS-based action camera to conduct a large-scale naturalistic motorcycle riding study in Malaysia. The feasibility was considered in terms of the suitability of the selected methodology and implementation plan to conduct a larger scale study involving a large group of participants over a longer period of data collection. This study has shown that a larger scale study based on the present study is feasible from both the perspective of experimental methodology and the quality of recorded data. The use of GPS-based action camera has reduced the need for full instrumentation of individual vehicle used in data collection, thus substantially reduced the cost and increase the likelihood of conducting a large-scale study. Although an accurate measurement of certain parameters such as longitudinal and horizontal headways would still require the use of the costly radar-based sensors, alternatives are available for the current setup to estimate the value of the particular parameters. Overall, this study strengthens the idea that a large-scale naturalistic riding study can be conducted with lower financial cost, without substantially reducing the advantage of naturalistic driving or riding data established by the previous large-scale studies. Due to the scale of the required resources and expertise, this study recommends a formation of a research team that includes researchers with expertise in road design, riding behaviours, motorcycle dynamics, and instrumentation to conduct a larger scale study. In addition, a dedicated team of data coders and programmers are also recommended for efficient data coding and analysis.

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