IATSS Research 42 (2018) 171–179

Contents lists available at ScienceDirect

IATSS Research

Case study

Empirical analysis of hazard perception and driving behaviors among high school and college students on motorcycles in Phnom Penh, Cambodia

Nagahiro Yoshida *, Toshiki Koyanagi

Graduate School of Engineering, Osaka City University, 3-3-138, Sugimoto Sumiyoshi-ku, Osaka-shi 558-8585, Japan

ARTICLE INFO

Article history:
Received 17 July 2018
Received in revised form 18 December 2018
Accepted 19 December 2018
Available online 28 December 2018

Keywords:
Motorcycle
Hazard perception
Traffic behavior
Traffic safety
Traffic education

ABSTRACT

In Cambodia, motorcycle use has spread rapidly in recent years, and serious accidents involving motorcycles have increased. Motorcycle accidents involving young people are particularly common, and there are various issues concerning traffic safety. To understand the situation in Phnom Penh, Cambodia, we conducted a questionnaire survey on driving attitude and behavior of motorcycle users targeted at high school and college students and a video observation survey of motorcycle driving conditions. Based on the survey analysis results, we held a traffic safety workshop (WS) comprising practical skills and classroom learning centered on hazard anticipation. In this study, we conducted a statistical comparative analysis of driving behavior frequency on non-intersection intervals of arterial roads before and after the WS, based on observational results from video cameras mounted on motorcycles. The results showed that the WS effects were associated with a reduction in average travel speeds and changes in driving behavior, such as frequency of lane changing. Different responses to the WS were observed according to attributes, and thus, the relationship between the content of this kind of traffic safety WS and behavioral changes needs to be clarified and a more advanced traffic safety WS program developed.

1. Research background and objectives

In Cambodia, the use of motorcycles has increased rapidly in recent years, and the proportion of accidents involving motorcycles has also increased. According to an OECD report, the number of traffic accident fatalities in 2016 was 1,852 (11.8 per 100,000 people), and 73% of these fatalities were riders of "motorized two-wheelers." [1] Motorcycle accidents have accounted for more 90% of fatalities in the 15–24 age group, and the main causes were identified as excessive speed, drink driving, and dangerous passing. In response to these circumstances, a review of the driving license system for motorcycles is underway, although it was made compulsory to wear a helmet when riding a motorcycle of 49cc or above in 2007, and in 2015, it was made compulsory for motorcycle passengers to wear a helmet, and the law regarding traffic violations was toughened. With regard to road infrastructure, the Asian Highway Network and other arterial roads in Cambodia are being improved, and traffic signals and a control center are being introduced in the capital city, Phnom Penh. Traffic safety education is supported by NGOs and traffic safety is included in the compulsory education curriculum. However, judging from the current situation regarding accident occurrence, both the quantity and quality of this education is insufficient, and knowledge about the necessity of additional traffic safety education and its specific effects is required.

Given the above issues concerning safe motorcycle use by young people, we decided to carry out an International Association of Traffic and Safety Science (IATSS) project comprising three parts described below, to gain specific knowledge about traffic behavior and related traffic safety education. First, we conducted a questionnaire survey on motorcycle driving attitude and behavior targeted at high school and college students in Phnom Penh, and ascertained the actual traffic conditions through an observation survey using video cameras mounted on motorcycles. Next, based on these results, we held a traffic safety workshop (WS) for the participants in the driving behavior survey. The WS consisted of classroom learning and practical skills training. In classroom learning, the situation regarding occurrence of traffic accidents in Cambodia was explained, and hazard anticipation training was carried out using dangerous driving scenarios selected from the results of the video observation of driving behavior. In practical skills training, basic driving training was given. Finally, video observation of driving behavior was carried out for a second time to examine the effects of the traffic safety WS.

In this study, with the aim of clarifying issues relating to fundamental driving behaviors that contribute to motorcycle traffic safety, such as

* Corresponding author.
E-mail addresses: yoshida@eng.osaka-cu.ac.jp (N. Yoshida), koyanagi@plane.civil.eng.osaka-cu.ac.jp (T. Koyanagi).
Peer review under responsibility of International Association of Traffic and Safety Sciences.

https://doi.org/10.1016/j.iatssr.2018.12.004
0386-1112/

travel speed, we compare the awareness-related questionnaire results and the behavioral video observation results, and we conduct a comparative analysis of driving behavior before and after the WS. The term “motorcycle” in this study refers to the automatic scooters used in Cambodia and does not include auto rickshaws.

2. Review of past research

Many studies on motorcycle traffic safety examine problems in Asia, including analysis of risk behavior in Thailand [2,3], risk analysis of accidents at intersections in Malaysia [4], and road design related to motorcycles in Asian countries [5], and various issues have been identified, such as helmet use, alcohol, training, daytime running lights, driving licenses, and risk-taking [6].

With regard to driver education, there are numerous studies on hierarchical models of driving behavior [7,8] and their extension [9], as well as specific assessment methods [10]. In research on motorcycle use and the effects of education, there are studies on the relationship between safe driving training and traffic accidents [9], the relationship between education and traffic safety behavior [11], behavioral intention [12], educational content and the license system [13], and educational methods and children's developmental stage [14]. To improve traffic safety performance among young people in particular, dealing with risk-taking behavior [15] and the importance of more advanced driving skills training in addition to the conventional simple skills training have been identified [16].

At the same time, to better understand these driving behaviors, the importance of traffic safety measures based on evidence, such as naturalistic driving observation studies [17] and development of on-board devices [18], has been identified [19].

As described above, there are various study results regarding education of young people on motorcycle traffic safety, but information about the current reality of motorcycle driving behavior in young people and issues relating to traffic safety education in Cambodia is limited. This study focused on hazard perception and driving behaviors among young Cambodians on motorcycles and analyzed challenges pertaining to traffic safety education based on a questionnaire survey and naturalistic driving data. The study also focused on changes in actual driving behavior as a result of traffic safety education, as well as changes in driving behaviors from shared information on traffic accidents, improved ability to perceive hazards [20,21], and the opportunity to participate in a traffic safety WS on basic driving skills training. This is a case study of the psychological characteristics and motorcycle driving behaviors of young Cambodians that also takes results from previous studies into account; this study examined whether conventional knowledge on motorcycle driving among young people in other countries also applies in Cambodia. In terms of assessing driving behaviors, motorcycle driving depends greatly on traffic conditions, which change minute by minute; riders repeatedly change lanes and pass between cars, unlike when driving cars (notably when following), and there is a need for better understanding obtained from on-board videos as naturalistic driving data. By utilizing the fundamental theory of traffic flow associated with traffic density, this study considered the validity of the analysis of driving behavior while also conducting a detailed analysis on changes in driving behaviors, which may be able to provide new knowledge on practical approaches to assessing driving behavior.

3. Research method

3.1. Overview of questionnaire survey on driving attitude/behavior

The results of a survey of 1,079 high school and college students in Phnom Penh in 2015 were used in this study. In the analysis, those who left questions unanswered were excluded, and only data from 557 people with motorcycle driving experience was used. The number of respondents by attribute is shown in Table 1. The questionnaire consisted of eight questions on individual attributes, 22 questions on hazard recognition in one's own driving behavior, and 24 questions on one's own driving attitude. In the 22 questions on hazard recognition in driving behavior, four levels of response to driving items were obtained—from “1. I don't think it's dangerous at all” to “4. I think it's very dangerous”. In the analysis, the responses were tallied by scoring each response for hazard recognition (“1. I don't think it's dangerous at all”: -2, “2. I don't think it's particularly dangerous”: -1, “3. I think it's dangerous”: 1, “4. “I think it is very dangerous”: 2).

3.2. Summary of video observations of actual driving behavior

To confirm the actual situation regarding driving behaviors included in the questionnaire results, video cameras were installed on the motorcycles (50cc–125cc) of students who commute to high school or college within the city of Phnom Penh, and an observation survey was performed. In the survey, the route routinely used by the subject between their home and school was filmed during two separate periods: one from December 2015 to January 2016, and one at the end of July 2017 after the traffic safety WS described below. The subjects were a total of 27 people who responded to an appeal for cooperation in the survey through a local college. Four of these 27 people were common samples before and after the WS. In the analysis, driving behavior was compared by separating it into behavior when the subject had not attended the traffic safety WS (before WS) and behavior when the subject had attended the traffic safety WS (after WS) (Table 2).

VIRB Elite action cameras with GPS functionality were used for the video observations. The measured viewing angle was 123°, which is roughly the same as the angle of view of a human being (120°). Using the video data, in addition to average interval speed in terms of non-intersection intervals of road, the number of times the subject changed lanes, passed a motorcycle, and was passed by a motorcycle were counted as driving behaviors indicating driving conditions, and the number of times the subject exhibited eight driving behaviors in common with the hazard recognition questions in the questionnaire were counted. As a result, data for 1,014 non-intersection intervals totaling 160.5 km was extracted (Table 3). The number of subjects in the video observation survey was small compared to the questionnaire survey, but an analysis of key driving behaviors observed repeatedly under different route/traffic conditions was performed.

3.3. Vehicle density in video analysis

Motorcycle driving behaviors depend heavily on traffic conditions, which change minute by minute; for example, an uncongested road means that speeding is easier. If the details of traffic conditions can be known, driving behaviors and their associated psychological conditions can be analyzed. Therefore, the relationship between traffic density and driving speed was utilized from the perspective of traffic flow theory. Vehicle density was used to describe the traffic conditions ahead of the motorcycle instead of traffic density, which is difficult to measure directly. Vehicle density was used as an explanatory variable in an analysis of driving frequency and speed.

Table 1
Attributes of questionnaire respondents.

Attribute			Sample size
High school student	Male	Driving experience: Less than 1 year	39
		Driving experience: More than 1 year	78
	Female	Driving experience: Less than 1 year	25
		Driving experience: More than 1 year	117
College student	Male	Driving experience: Less than 1 year	43
		Driving experience: More than 1 year	86
	Female	Driving experience: Less than 1 year	39
		Driving experience: More than 1 year	130
Total			557

Table 2
Individual attributes of subjects fitted with cameras.

	Before WS	After WS	Total
Date of observation	December 2015–January 2016	July 2017	
No. of people observed	17	10	27[a]
Gender	8 males/9 females	5 males/5 females	13 males/14 females
Student category	9 high school students/8 college students	5 high school students/5 college students	14 high school students/13 college students
Driving experience	Less than one year: 5 people/more than one year: 12 people	Less than one year: 0 people/more than one year: 10 people	Less than one year: 5 people/more than one year: 22 people
Motorcycle category	50cc: 4 people/90–125cc: 13 people	50cc: 3 people/90–125cc: 7 people	50cc: 7 people/90–125cc: 20 people
No. of observation intervals	584 intervals	430 intervals	1,014 intervals
Observation time period	Morning: 327 intervals/afternoon: 143 intervals/evening: 114 intervals	Morning: 129 intervals/afternoon: 184 intervals/evening: 117 intervals	Morning: 456 intervals/afternoon: 327 intervals/evening: 231 intervals
Weather	Clear: 429 intervals/cloudy: 155 intervals	Clear: 192 intervals/cloudy: 238 intervals	Clear: 621 intervals/cloudy: 393 intervals

[a] Of this total, 4 people participated both before and after the WS

First, for motorcycle travel intervals, non-intersection intervals were taken as the subject of analysis, and the boundary with the intersection was taken as the extension of a straight line from the end of the corner cut-off at the intersection. The width and length of the non-intersection intervals were measured using Google Earth. Measurement errors may occur in the passage times because the interval start and end positions were reliant on visual estimates. As a rough guide, assuming that the error in average interval passage time is ±1 s from the start/end position, the error in average non-intersection interval speed will be approximately −1.23 to 1.41 (km/h).

Next, with regard to vehicle density, vehicle area occupation ratio around the observed vehicle (hereafter, vehicle density) was used. To calculate this, a 9-m range in front of the motorcycle was defined using traffic lane markings, and the number of vehicles seen inside that range, even if only a small part of the vehicle, was counted every five seconds according to the type of vehicle, and the space occupation ratio of total vehicle area was found (Fig. 1). Measured values for each type of vehicle used locally were used for the area parameters (Table 4). Using Eq. (1), the instantaneous vehicle density was averaged over the number of observations within the same non-intersection interval and taken as a representative value for the interval. The coefficients used were a, b, c: number of motorcycles, four-wheeled vehicles, auto rickshaws and others; α, β, γ: area parameters; A: area by which the total vehicle area is divided; n: number of observations within interval.

$$\left(\sum_{K=1}^{n}(\alpha a_{mn}+\beta b_{mn}+\gamma c_{mn})\right)/An \quad (1)$$

Table 3
Summary of video observation results.

Basic video observation data	No. of people observed	27
	Observation time	573 min (average of 24.9 min per person)
	Travel distance (non-intersection intervals)	160.5 km (average of 7.0 km per person)
	No. of non-intersection intervals on arterial/non-arterial roads	594/420 intervals (total 1,014 intervals)
	Average non-intersection interval distance	0.160 km
	Average non-intersection interval passage time	29.6 s
Observed driving behaviors	Driving behaviors indicating driving conditions	Lane changing (no. of times) Passing a motorcycle (no. of times) Being passed by a motorcycle (no. of times)
	Driving behaviors in common with questionnaire	Q2 Driving motorcycle on sidewalk for a few meters (no. of times) Q4 Weaving between cars on a congested road (no. of times) Q6 Passing when cars turning left/right ahead are stopped (no. of times) Q8 Turning directly in front of an oncoming car when turning left at an intersection (no. of times) Q3 Driving in the wrong direction on a one-way road (no. of times) Q5 Driving off sooner than other cars after waiting for a traffic light at an intersection (no. of times) Q10 Not paying attention to doors opening when passing parked cars (no. of times) Q21 Driving closer to the car in front when it seems as though other cars might try to cut in (no. of times)

Excluding 136 intervals for which it was not possible to accurately count all of the vehicles inside the angle of view owing to the effect of camera shaking and road congestion, etc., data for a total of 878 intervals was obtained from the video analysis. The number of observations of instantaneous vehicle density found every five seconds averaged 4.86 per interval, with a standard deviation of ±4.42.

Using the calculated results, when correlation coefficients of average interval speed and average interval vehicle density according to road conditions were compared, excluding the small number of one-way intervals, correlation was highest for "intervals with median strip, and 2 or more lanes in each direction" (Table 5), and the scatter diagram of occupation ratio and speed confirmed that, as average interval vehicle density increases, average interval speed decreases (Figs. 2, . 3). Reasons for different correlation coefficients depending on road conditions include the fact that, in addition to road conditions such as road surface, the situation concerning crossing the centerline, reckless right/left turning, driving in the wrong direction on the road shoulder, etc. also varies

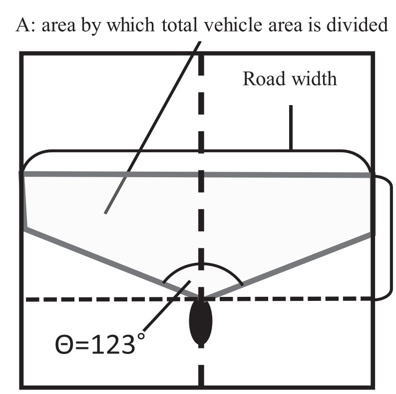

Fig. 1. Nine-meter range in front of motorcycle.

Table 4
Area parameters.

	Sample size (no. of vehicles)	Average vehicle area (m^2)	Standard deviation (m^2)
Motorcycle	6	1.22	0.14
Four-wheeled vehicle (including three SUVs)	6	8.51	0.51
Auto rickshaw	10	4.59	0.17

according to road conditions. The conditions on "intervals with median strip, and 2 or more lanes in each direction" are such that driving behavior is less affected by the road and other people, and a detailed analysis of the 542 "intervals with median strip, and 2 or more lanes in each direction" was conducted.

3.4. Summary of traffic safety WS

The traffic safety WS held at the Royal University of Phnom Penh on July 16, 2017 consisted of two hours of classroom learning and two hours of practical skills training. In classroom learning, after an explanation of the situation regarding traffic accident occurrence in Cambodia, hazard anticipation training was carried out using dangerous driving scenarios selected from the results of the video observation of driving behavior. Observed cases of near-misses were used as the dangerous driving scenarios, for example, entering the blind spot of a four-wheeled vehicle when weaving between cars, and another vehicle suddenly appearing from a blind spot. The training method took the form of stopping the video before the dangerous driving scenario and having the participants anticipate the potential hazards, before explaining the actual dangerous driving scenario. In practical skills training, approximately two hours of basic skills training, such as riding a figure of eight and braking, was given by a motorcycle instructor.

4. Analysis results

4.1. Hazard perception while driving

Table 6 shows aggregate results by question on hazard recognition in driving behavior. The results showed that the level of hazard recognition differs depending on the item, with a difference of approximately one point in the average values between the top items, such as "driving under the influence of alcohol" and "driving at night without switching lights on," and the bottom items, such as "driving while listening to music through headphones" and "riding a motorcycle with more than one person on board." Next, scoring the responses to all of the questions and comparing the average values determined for each individual attribute showed that the hazard recognition level is higher in females and college students, while there is hardly any difference in hazard recognition level between the attributes of possessing and not possessing a driving license (Fig. 4). Furthermore, performing a multiple regression analysis by taking the total score for hazard recognition level as the response variable and individual attributes as explanatory variables

Table 5
Correlation between vehicle density and average speed by traffic lane scenario.

Traffic lane scenario	No. of intervals	Correlation coefficient, R
Interval without median strip, and 1 or 1.5 lanes	165	−0.27
Interval without median strip, and 2 or more lanes	126	−0.37
Interval with median strip, and 1 or 1.5 lanes in each direction	33	−0.48
Interval with median strip, and 2 or more lanes in each direction	542	−0.54
One-way interval	12	−0.65
All intervals	878	−0.43

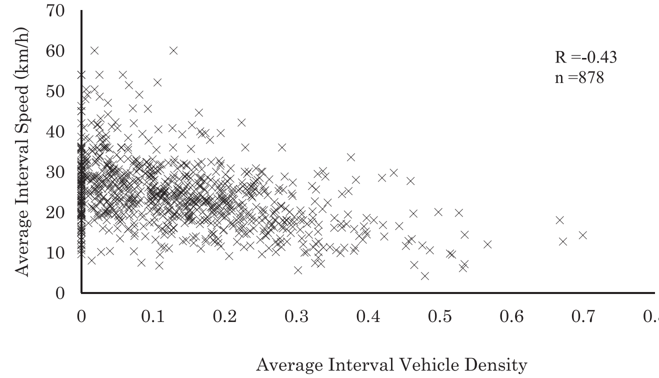

Fig. 2. Relationship between average vehicle density and average speed (all intervals).

confirmed that, although the coefficient of determination is low at 0.05 and there is large variation among individuals, there is a significant difference between gender and student categories (Table 7). These results showed that, in regard to hazard recognition, danger tends to be underestimated more by males than females, and more by high-school students than college students.

A factor analysis was performed using the varimax rotation by maximum likelihood method, with responses to the questions as explanatory variables; we found three axes of factors. The first factor was interpreted as an axis that captured "serious offenses," as it related to serious and dangerous driving behaviors such as "drinking and driving" and "driving at night without a headlight." The second factor was interpreted as an axis that represented "subjectively mild offenses," such as "riding a motorcycle with more than two people at once," "sometimes driving with one hand," and "driving while listening to music with earphones." Such subjectively mild offenses included behaviors that riders did not consider to be risk factors for serious accidents. The third factor was interpreted as an axis describing "rushing," including "accelerating faster than other cars after waiting for a traffic signal at an intersection" and "driving through spaces between cars on a congested road," which reflect being in a hurry while riding. There were no explanatory variables whose commonalities exceeded one axis in the analysis results; thus, these three were selected as factor axes.

A multiple regression analysis using the factor scores as explanatory variables (Table 8) found that the coefficient of determination was 0.998; impact from individual attributes was not observed, which confirmed the idea that these three factors can explain nearly everything. Comparisons among the trio of factors showed that the significance of the factors was "serious offense," "subjectively mild offense," and

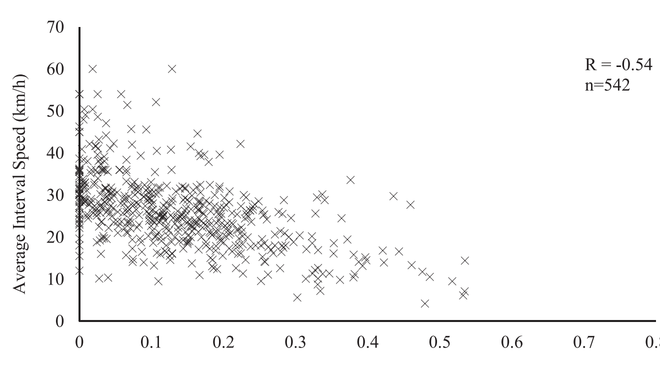

Fig. 3. Relationship between average vehicle density and average speed (intervals with median strip, and 2 lanes in each direction).

Table 6
Aggregate results for hazard recognition score in driving behavior.

Question no.	Questionnaire item	No. of responses	Mean	Standard deviation
Q. 13	Driving under the influence of alcohol.	557	3.69	0.76
Q. 14	Driving at night without switching lights on.	557	3.51	0.88
Q. 8	Turning directly in front of an oncoming car when turning left at an intersection.	557	3.49	0.89
Q. 22	Occasionally driving as fast as you can.	557	3.43	0.88
Q. 21	Driving closer to the car in front when it seems as though other cars might try to cut in.	557	3.41	0.88
Q. 3	Driving in the wrong direction on a one-way road.	557	3.40	0.84
Q. 6	Passing when cars turning left/right ahead are stopped.	557	3.39	0.90
Q. 1	Not wearing a helmet when riding a motorcycle.	557	3.34	0.87
Q. 15	Driving while operating a cell phone.	557	3.27	0.86
Q. 7	Increasing your speed when you think you'll be late for an appointment.	557	3.23	0.87
Q. 9	Not signaling when turning right/left.	557	3.18	0.84
Q. 5	Driving off sooner than other cars after waiting for a traffic light at an intersection.	557	3.10	0.93
Q. 12	Acting first, and frequently putting safety checks aside.	557	3.09	0.89
Q. 10	Not paying attention to sudden opening of doors when passing stationary vehicles.	557	3.04	0.91
Q. 4	Weaving between cars on a congested road.	557	3.01	0.87
Q. 18	Stacking bulky luggage on the rear rack of a motorcycle.	557	2.93	0.85
Q. 20	Driving with damaged mirrors or lights.	557	2.93	0.92
Q. 11	Not reducing speed at places where there are strong crosswinds, such as elevated bridges.	557	2.90	0.95
Q. 2	Driving motorcycle on sidewalk for a few meters.	557	2.82	0.85
Q. 19	Driving with one hand.	557	2.82	0.90
Q. 16	Driving while listening to music through headphones.	557	2.68	0.90
Q. 17	Riding a motorcycle with more than one person on board.	557	2.59	0.86

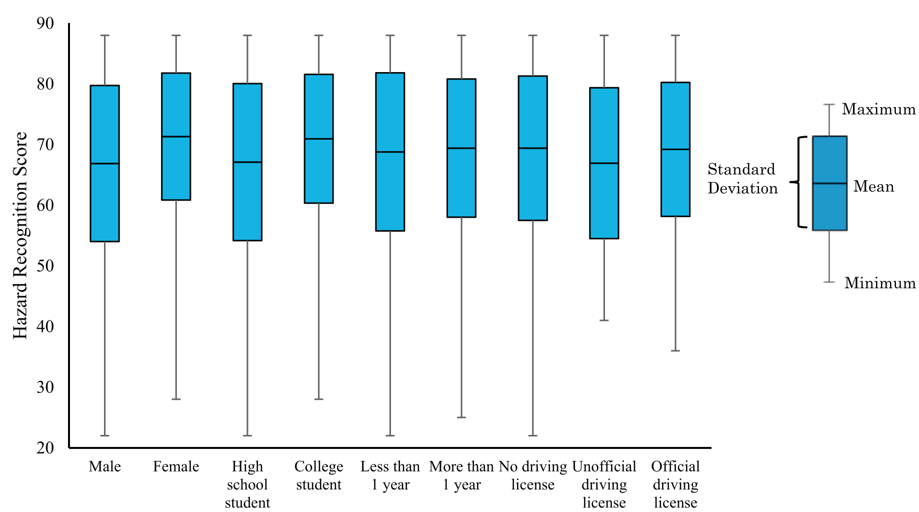

Fig. 4. Comparison of hazard recognition score by individual attribute.

"rushing" in descending order, and mindsets for these factors had serious influences on hazard perception.

4.2. Relationship between hazard recognition and driving behavior

Table 9 lists the hazard recognition rate for individual questions in the questionnaire survey, and number of observations and frequency of driving behavior in 542 intervals on arterial roads with a median strip and 2 lanes in each direction before and after the WS, as well as three items indicating driving conditions—lane changing, passing a motorcycle, and being passed by a motorcycle. Comparing hazard

Table 7
Multiple regression analysis taking average score per person for all questions as response variable.

	Coefficient	t-value
Constant term	13.71	8.23**
Female dummy variable	6.04	4.37**
College student dummy variable	5.43	3.89**
More than one year dummy variable	0.39	0.24
Possessing official driving license	−0.11	−0.05
Possessing unofficial driving license	−2.53	−0.80
Coefficient of determination	0.05	
Sample size	557	

* Significance level 5%.
** Significance level 1%.

Table 8
Multiple regression analysis with total scores from responses to survey questions as response variables and individual attributes and factor scores as explanatory variables.

	Coefficient	t-value
Constant term	69.25	2848.59**
Female dummy	−0.02	−0.63
College student dummy	0.01	0.31
Dummy for over a year	0.01	0.47
Holds an official driver's license	0.03	1.37
Holds an unofficial driver's license	−0.01	−0.51
Serious offense	7.03	281.42**
Subjectively mild offense	5.87	236.25**
Rushing level	5.46	216.62**
Coefficient of determination	0.998	
Sample size	557	

* Significance level 5%.
** Significance level 1%.

Table 9
Hazard recognition rate for driving items in common with questionnaire and number of observations of corresponding driving behavior.

Items concerning driving behavior	Hazard recognition rate	No. of video observations		Average interval frequency	
		Before WS	After WS	Before WS (267 intervals)	After WS (275 intervals)
Q. 10 Not paying attention to doors opening when passing parked cars (no. of times)	71.8%	51	29	0.191	0.105
Q. 21 Driving closer to the car in front when it seems as though other cars might try to cut in (no. of times)	81.3%	45	25	0.169	0.091
Q. 4 Weaving between cars on a congested road (no. of times)	68.4%	15	12	0.056	0.044
Q. 6 Passing when cars turning left/right ahead are stopped (no. of times)	81.0%	5	5	0.019	0.018
Q. 2 Driving motorcycle on sidewalk for a few meters (no. of times)	62.7%	3	2	0.011	0.007
Q. 8 Turning directly in front of an oncoming car when turning left at an intersection (no. of times)	82.6%	0	1	0	0.004
Q. 3 Driving in the wrong direction on a one-way road (no. of times)	80.0%	0	0	0	0
Q. 5 Driving off sooner than other cars after waiting for a traffic light at an intersection (no. of times)	71.8%	0	1	0	0.004
Lane changing (no. of times)		53	132	0.199	0.480
Passing a motorcycle (no. of times)		355	386	1.330	1.404
Being passed by a motorcycle (no. of times)		565	436	2.116	1.585

recognition rate and number of video observations, little relationship is found between the two, and despite the high proportion of responses stating that “Q. 10 Not paying attention to doors opening when passing parked cars” and “Q. 21 Driving closer to the car in front when it seems as though other cars might try to cut in” are dangerous, these driving behaviors were in fact observed. This result shows that assessment of hazard recognition level differs between oneself and others, and there was no consistency between hazard recognition level and actual driving behaviors that avoid danger. On the other hand, the results of the factor analysis showed that much of the observed driving behavior had to do with "rushing." Hazard perception tended to decrease slightly when offensive driving behavior was observed in reality; this suggests that "rushing" had an impact on actual driving behavior.

4.3. Comparison of driving behavior before and after WS by attribute

To examine the effect of the WS on driving behavior, the average number of occurrences of the three driving behaviors indicating driving conditions were compared before and after the WS according to gender and student category. The results (Figs. 5–7) show a change before and after the WS in the attribute groups other than female high school students, and the average number of occurrences of “lane changing” and “passing a motorcycle” increased greatly among the male high school students and female college students. However, in the male college student group, although there was little change in “lane changing,” the average number of occurrences of “passing a motorcycle” was roughly halved. These changes are considered to be effects of the traffic safety WS, and specifically, the skills training is thought to have had an effect on aggressive behavior and the hazard anticipation training on defensive behavior.

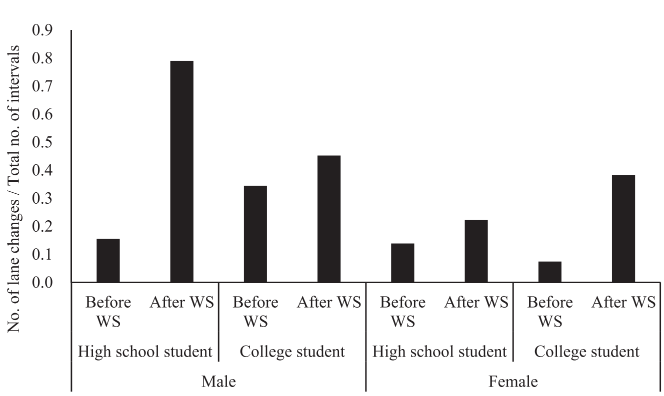

Fig. 5. Comparison of the average number of occurrences of lane changing in an interval by individual attribute.

4.4. Analysis of effect of WS on driving behavior

To statistically verify the effect of the WS on driving behavior, a Poisson regression analysis of driving behavior frequency was carried out using a WS dummy variable, interval length, vehicle density, average interval speed, and individual attributes as explanatory variables. The results (Table 10) show that the frequency of lane changing and passing a motorcycle increased significantly after participating in the WS, and the frequency of being passed by a motorcycle, not paying attention to doors opening when passing parked cars (Q. 10), and driving closer to the car in front (Q. 21) decreased significantly after participating in the WS.

Vehicle density was shown to affect specific driving behavior, such as "passing a motorcycle" and "passing between cars on a congested road (Q.4)." On the other hand, high average interval speed resulted in an increase in "passing a motorcycle," while items such as "passed by motorcycles," "does not mind doors opening when passing a parked vehicle (Q.10)," and "reduces space between cars when another vehicle attempts to cut in (Q.21)" declined.

In terms of individual attributes, "being passed by a motorcycle" was frequent, while "does not mind doors opening when passing a parked vehicle (Q.10)" and "reduces space between cars when another vehicle attempts to cut in (Q.21)" were infrequent among women. Among college students, "being passed by a motorcycle" was frequent, while "passing between cars on a congested road (Q.4)" and "does not mind doors opening when passing a parked vehicle (Q.10)" were infrequent. Drivers with over a year of experience reported frequently "passing a

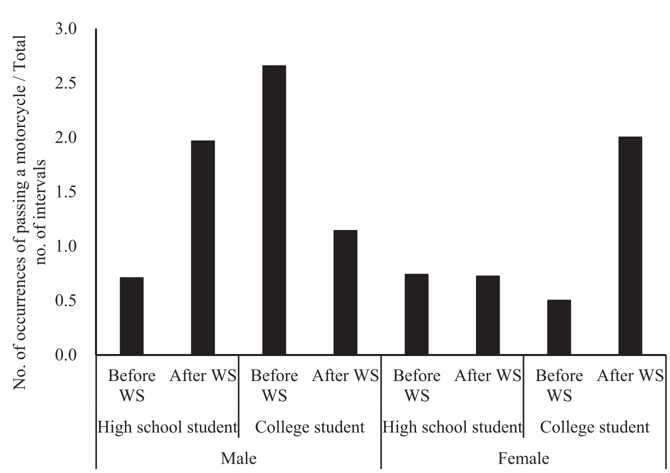

Fig. 6. Comparison of the average number of occurrences of passing a motorcycle in an interval by individual attribute.

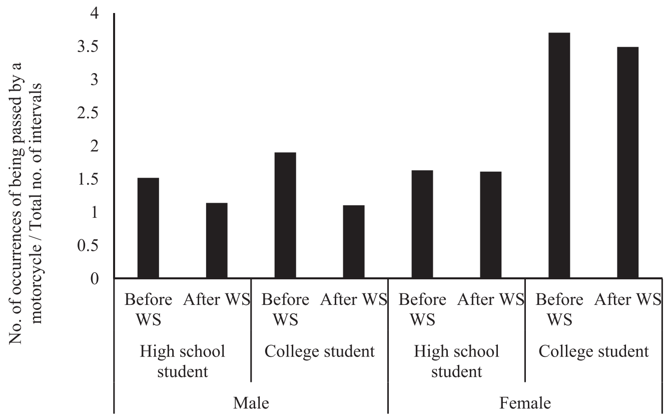

Fig. 7. Comparison of the average number of occurrences of being passed by a motorcycle in an interval by individual attribute.

motorcycle" and "reducing space between cars when another vehicle attempts to cut in (Q.21)," while "being passed by a motorcycle" was infrequently reported.

In light of the analysis above, assuming that the WS enabled improvements in both hazard perception and driving skills, "lane changes," "passing a motorcycle," and "being passed by a motorcycle" changed due to improvements in both hazard perception and confidence in driving skills, while driving behaviors such as "does not mind doors opening when passing a parked vehicle (Q.10)" and "reducing space between cars when another vehicle attempts to cut in (Q.21)" changed due to improvement in hazard perception. Behaviors such as "changing lanes," "passing a motorcycle," and "being passed by a motorcycle" may have been caused by multiple psychological factors; "passing a motorcycle" and "being passed by a motorcycle" are affected by "driving experience" and are therefore due to improved confidence in driving skills. Vehicle density, which represents traffic conditions, only affected "passing a motorcycle" and "passing through a congestion," and these driving behaviors are unique to road congestion that also causes rushing. Providing a consistent explanation is difficult for attributes, but "passing between cars on a congested road (Q.4)" and "does not mind doors opening when passing a parked vehicle (Q.10)" were both unique to high school students and may be due to immaturity of their driving skills.

Next, a Poisson regression analysis was performed on the frequency of driving behavior occurring in four individuals for whom video monitoring was conducted before and after WS; a WS dummy, interval length, vehicle density, and average interval speed were used as explanatory variables. In the results (Table 11), WS dummy was no longer significant (in comparison to Table 10) for "being passed by a motorcycle," "cautious of car doors," and "reducing space between cars," which was due to the scarce number of samples. However, an increased impact was observed after WS for "lane changes" and "being passed by a motorcycle," similar to Table 10, and changes in driving behavior were brought about due to improvements in both hazard perception and confidence in driving skills during the WS.

4.5. Analysis of effect of WS on travel speed

To examine the effect of the WS on travel speed, a multiple regression analysis was carried out on 542 non-intersection intervals on arterial roads with a median strip and 2 lanes in each direction, using average interval speed as the response variable and vehicle density, individual attributes, etc. as explanatory variables. The results (Table 12) show that travel speed decreased by approximately 2 km/h after the WS. Overall, the analysis showed that, although traffic conditions are the dominant factor in travel speed, with vehicle density having the greatest effect on speed reduction, travel speed is high in the “male” and “college student” attribute groups, and even considering traffic flow, speed differences between attributes vary widely.

Next, a multiple regression analysis was performed using WS dummy, vehicle density (Table 13), and average interval speed as response variables for four individuals (a Total of 133 intervals) who were monitored on video before and after the WS, with individual attributes removed. The results (Table 13) showed that a significant difference was not observed for the WS dummy, while a significant difference was observed for sign conditions, similar to Table 12.

Table 10
Results of analysis of driving behavior on arterial roads.

	Lane changing		Passing a motorcycle		Being passed by a motorcycle		Weaving in congestion		Passing cars		Attention to doors opening		Driving closer	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Constant	−0.78	−1.16	−1.21	−3.52[b]	4.54	18.86[b]	−2.28	−1.38	−0.97	−0.37	2.68	2.91[b]	0.67	0.71
log (Interval length (km))	0.98	9.39[b]	1.25	24.42[b]	1.14	25.82[b]	1.00	3.18[b]	1.05	2.06[a]	0.86	4.80[b]	1.04	6.54[b]
Average vehicle density	0.77	0.83	3.13	6.67[b]	−0.56	−1.47	8.00	4.08[b]	0.20	0.05	−2.13	−1.46	2.26	1.88
Average interval speed (km/h)	0.02	1.56	0.06	12.04[b]	−0.07	−11.50[b]	-0.01	−0.39	−0.04	−0.64	-0.07	−3.27[b]	-0.06	−3.19[b]
Female dummy variable	-0.38	−1.75	0.08	0.88	0.45	6.11[b]	-0.46	−0.88	−0.04	−0.04	-0.81	−2.48[a]	-0.66	−2.25[a]
College student dummy variable	−0.13	−0.81	−0.05	−0.63	0.52	7.12[b]	−1.10	−2.63[b]	−1.36	−1.91	−0.78	−3.05[b]	0.03	0.12
More than one year dummy variable	0.22	0.59	0.99	4.48[b]	−0.43	−4.53[b]	0.54	0.82	0.53	0.46	−0.21	−0.64	1.59	2.63[b]
90–125cc motorcycle dummy variable	0.21	0.63	0.30	1.82	−0.47	−5.12[b]	0.19	0.22	−0.14	−0.14	−0.21	−0.50	-0.73	−1.93
WS dummy variable	0.88	4.84[b]	0.20	2.46[a]	−0.23	−3.27[b]	−0.52	−1.14	−0.17	−0.23	−0.64	−2.35[a]	-0.99	−4.18[b]
Sample size	542		542		542		542		542		542		542	
Null deviance	567.98		1885.73		2017.90		164.74		79.85		356.37		347.12	
Residual deviance	417.66		931.52		1047.40		113.86		70.26		302.96		245.42	

[a] Significance level 5%.
[b] Significance level 1%.

Table 11
Results of analysis of driving behavior for 133 intervals on arterial roads.

	Lane changing		Passing a motorcycle		Being passed by a motorcycle		Weaving in congestion		Passing cars		Attention to doors opening		Driving closer	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Constant	−0.80	−0.59	0.09	0.13	4.40	8.39[b]	−3.57	−1.15	1.20	0.27	−0.79	−0.43	−1.57	−0.64
log (Interval length (km))	1.08	5.33[b]	1.18	11.71[b]	1.27	14.65[b]	0.77	1.48	0.74	0.84	0.19	0.54	0.84	2.09[a]
Average vehicle density	−1.51	−0.71	2.34	2.15[a]	−2.07	−2.31[a]	10.33	2.25[a]	−4.20	−0.51	−3.16	−0.97	4.04	1.09
Average interval speed (km/h)	0.01	0.32	0.05	2.75[b]	−0.06	−3.74[b]	0.02	0.22	−0.10	−0.80	0.00	−0.01	−0.02	−0.34
WS dummy variable	1.65	3.17[b]	0.40	2.24[a]	−0.19	−1.42	−0.79	−1.10	−1.63	−1.26	−0.60	−1.30	0.48	0.61
Sample size	133		133		133		133		133		133		133	
Null deviance	167.09		392.05		514.98		54.53		22.75		92.42		68.24	
Residual deviance	112.25		210.55		298.47		37.19		19.93		88.01		56.41	

[a] Significance level 5%.
[b] Significance level 1%.

5. Conclusion

This study performed an analysis of hazard perception and driving behavior among high school and college students in Phnom Penh, Cambodia to identify issues related to traffic safety education for motorcycles. First, the analysis results for hazard perception showed that women, college students, and those with over a year of driving experience had high levels of hazard perception; these results demonstrated that past research results also apply to young motorcycle drivers in Cambodia. On the other hand, possession of a driver's license contributed little to differences in hazard perception, while ideas on subjectively mild offenses significantly impacted differences in hazard perception, which suggests that educational opportunities for knowledge and skills when obtaining a driver's license are not sufficient. With regards to the contents of education, this study found that subjectively mild offenses may lead to serious accidents and also that basic rules were not understood sufficiently. A factor analysis showed that "serious offenses," "subjectively mild offenses," and "rushing" had significant impacts on hazard perception, and mindsets regarding these factors had significant impacts on hazard perception.

Next, an analysis of driving behavior was performed by first comparing hazard perception and actual driving behaviors and then comparing driving behavior on arterial roads before and after a traffic safety WS. The WS focused on improving the ability to predict hazards and acquiring basic driving maneuver skills through classroom lectures and on-site training. The relationship between hazard perception and driving behavior did not show consistency between the level of hazard perception and actual frequency of dangerous driving behavior. Many of the observed driving behaviors were concerned with "rushing," and such behaviors tended to be related to slightly lower hazard perception when actual offensive driving behaviors tended to be observed, which suggested that psychological factors for "rushing" affected hazard perception and further impacted actual driving behavior.

A post-WS comparison of driving behavior on arterial roads showed that changing lanes and passing a motorcycle increased, while driving speed decreased. Such changes in behavior are due to an improved ability to recognize hazards and greater confidence in driving skill following the WS. This pair of psychological factors may have different impacts on different attribute groups and driving behaviors in various traffic situations, but it is nonetheless difficult to clearly separate these impacts with the methods used in this study. However, if safe motorcycle driving behavior is defined as "no lane changes even when the adjacent lane is open, the speed limit is observed, and a safe distance is maintained between cars," including psychological state, then the impact of traffic knowledge and norms, ability to recognize hazards, and confidence in driving skills may be determined from (1) the ability understand and observe basic rules, such as places to drive, (2) the ability to follow rules and refrain from driving in search of open spaces on the road, (3) the ability to drive within the speed limit, even when another vehicle is not ahead, and (4) the ability to drive safely and to avoid hazards by predicting dangers. A detailed description of the state of driving, including indicators that show traffic conditions, such as vehicle density, is essential. Because this study was able to partially show a relationship between driving conditions and driving behavior, an analysis that focuses on changes in motorcycle driving behaviors is needed in the future.

In this study, only four samples could be observed in terms of driving behavior before and after the WS due to various constraints, and there is a need to investigate a greater number of samples as well as a control group in the future. This study also assumed driving improvement in terms of technique and perception after the WS, and by combining these ability improvements individually, a more effective delivery of knowledge can be achieved through traffic safety education specific to motorcycles.

Table 12
Speed analysis results for 542 intervals on arterial roads.

	Coefficient	t-value
Constant term	32.44	22.03[b]
Average vehicle density	−43.79	−16.02[b]
Female dummy variable	−5.36	−5.80[b]
College student dummy variable	2.64	3.73[b]
More than one year dummy variable	1.03	0.99
90–125cc motorcycle dummy variable	−0.72	−0.72
Morning dummy variable	−0.31	−0.40
Evening dummy variable	−0.47	−0.49
Clear weather dummy variable	1.53	2.10[a]
WS dummy variable	−2.02	−2.71[b]
Coefficient of determination	0.39	
No. of intervals	542	

[a] Significance level 5%.
[b] Significance level 1%.

Table 13
Results of speed analysis for four individuals (a Total of 133 intervals).

	Coefficient	t-value
Constant term	28.77	32.72[b]
Average vehicle density	−37.60	−10.69[b]
WS dummy variable	0.19	0.21
Passing a motorcycle / km	0.18	2.95[b]
Being passed by a motorcycle / km	−0.08	−2.23[a]
Coefficient of determination	0.49	
Number of intervals	133	

[a] Significance level 5%.
[b] Significance level 1%.

Acknowledgments

The questionnaire and video surveys in this study were conducted with substantial cooperation from the Faculty of Education of the Royal University of Phnom Penh. We would like to take this opportunity to express our gratitude.

References

[1] International Transport Forum, Road Safety Annual Report, OECD Publishing, 2017.
[2] K. Sano, W. Wisetjindawat, C.C. Minh, W. Sattayaprasert, A study on the behavior of delivery motorcycles in Bangkok, J. East Asia Soc. Transport. Stud. 6 (2005) 157–172.
[3] M. Ichikawa, W. Chadbunchachai, E. Marui, Effect of the helmet act for motorcyclists in thailand, Accid. Anal. Prev. 35 (2003) 183–189.
[4] T.Y. Pang, R.S. Radin Umar, A. Azhar Abdul, S. Harwant, A.W. Shahrom, M. Abdul Halim, N. Zahari, O. Mohd Shafiee, Fatal injuries in Malaysian Motorcyclist, Int. Med. Res. J. 3 (2) (1999) 115–119.
[5] To Quyen Le, Zuni Asih Nurhidayati, A study of motorcycle lane design in some Asian Countries, Process. Eng. 142 (2016) 292–298.
[6] M.-R. Lin, J.F. Kraus, A review of risk factors and patterns of motorcycle injuries, Accid. Anal. Prev. 41 (2009) 710–722.
[7] J.A. Michon, The mutual impacts of transportation and human behaviour, in: P. Stringer, H. Wenzel (Eds.), Transportation Planning for a Better Environment. Nato Conference Series, 1, Springer, Boston, MA, 1976.
[8] M. Hatakka, E. Keskinen, N.P. Gregersen, A. Glad, K. Hernetkoski, From control of the vehicle to personal self-control: broadening the perspectives to driver education, Transp. Res. Part F Traffic Psychol. Behav. 5 (2002) 201–215.
[9] E. Keskinen, M. Peräaho, S. Laapotti, K. Hernetkoski, A. Katila, The fifth level to the GDE-model—5soc and 5pro Presentation in the 3rd Joined NORBIT and the 5th Japanese–Nordic Conference in Traffic and Transportation Psychology, 22, University of Turku, Finland, 2010 24.8.2010.
[10] S. Laapotti, E. Keskinen, S. Rajalin, Comparison of young male and female drivers' attitude and self-reported behaviour in Finland in 1978 and 2001, J. Saf. Res. 34 (2003) 579–587.
[11] P. Woratanarat, A. Ingsathit, P. Chatchaipan, P. Suriyawongpaisal, Safety riding program and motorcycle-related injuries in Thailand, Accid. Anal. Prev. 58 (2013) 115–121.
[12] D. Parker, S.G. Stradling, A.S.R. Manstead, Modifying beliefs and attitudes of exceeding the speed limit: an intervention study based on the theory of planned behavior, J. Appl. Soc. Psychol. 26 (1996) 1–19.
[13] B. Watson, D. Tunnicliff, K. White, C. Schonfeld, D. Wishart, Psychological and social factors influencing motorcycle rider intentions and behavior, Aust. Transp. Saf. Bur. (2007) https://eprints.qut.edu.au/9103/ ISBN:9780642255648.
[14] N. Dragutinovic, D. Twisk, The effectiveness of road safety education, a literature review, R-2006-6, SWOV Inst. Road Saf. Res. (2006) https://www.swov.nl/en/publication/effectiveness-road-safety-education.
[15] D. Twisk, Improving safety of young drivers: in search of possible solutions, D-93-2, SWOV Inst. Road Saf. Res. (1994) https://www.swov.nl/publicatie/improving-safety-young-drivers-search-possible-solutions.
[16] S. Barua, B. Sidawi, S. Hoque, Assessment of the role of training and licensing systems in changing the young driver's behavior, Int. J. Transp. Sci. Technol. 3 (2014) 63–78.
[17] S. Espié, A. Boubezoul, S. Aupetit, S. Bouaziz, Data collection and processing tools for naturalistic study of powered two-wheelers users' behaviours, Accid. Anal. Prev. 58 (2013) 330–339.
[18] C.W. Yuen, M.R. Karim, A. Saifizul, Investigation on motorcyclist riding behaviour at curve entry using instrumented motorcycle, Sci. World J. (2014) 1–9.
[19] Safety science, Scientific research on road safety management, Special issue, Saf. Sci. 48 (9) (2010) 1081–1224.
[20] M.A. Wetton, A. Hill, M.S. Horswill, The development and validation of a hazard perception test for use in driver licensing, Accid. Anal. Prev. 43 (2011) 1759–1770.
[21] T. Rosenbloom, A. Perlman, A. Pereg, Hazard perception of motorcyclists and car drivers, Accid. Anal. Prev. 43 (2011) 601–604.