Accident Analysis and Prevention 43 (2011) 1464–1471

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

A comparison of the hazard perception ability of accident-involved and accident-free motorcycle riders

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ARTICLE INFO

Article history:
Received 20 October 2010
Received in revised form 19 January 2011
Accepted 22 February 2011

Keywords:
Hazard perception
Motorcycle rider
Visual attention
Driving behavior
Neuropsychological test
Driving simulator

ABSTRACT

Hazard perception is the ability to read the road and is closely related to involvement in traffic accidents. It consists of both cognitive and behavioral components. Within the cognitive component, visual attention is an important function of driving whereas driving behavior, which represents the behavioral component, can affect the hazard perception of the driver. Motorcycle riders are the most vulnerable types of road user. The primary purpose of this study was to deepen our understanding of the correlation of different subtypes of visual attention and driving violation behaviors and their effect on hazard perception between accident-free and accident-involved motorcycle riders. Sixty-three accident-free and 46 accident-involved motorcycle riders undertook four neuropsychological tests of attention (Digit Vigilance Test, Color Trails Test-1, Color Trails Test-2, and Symbol Digit Modalities Test), filled out the Chinese Motorcycle Rider Driving Violation (CMRDV) Questionnaire, and viewed a road-user-based hazard situation with an eye-tracking system to record the response latencies to potentially dangerous traffic situations. The results showed that both the divided and selective attention of accident-involved motorcycle riders were significantly inferior to those of accident-free motorcycle riders, and that accident-involved riders exhibited significantly higher driving violation behaviors and took longer to identify hazardous situations compared to their accident-free counterparts. However, the results of the regression analysis showed that aggressive driving violation CMRDV score significantly predicted hazard perception and accident involvement of motorcycle riders. Given that all participants were mature and experienced motorcycle riders, the most plausible explanation for the differences between them is their driving style (influenced by an undesirable driving attitude), rather than skill deficits per se. The present study points to the importance of conceptualizing the influence of different driving behaviors so as to enrich our understanding of the role of human factors in road accidents and consequently develop effective countermeasures to prevent traffic accidents involving motorcycles.

1. Introduction

Motorcycle riders are more at risk of being killed or injured in road accidents than any other type of vehicle user (Elliott et al., 2007). They are greatly overrepresented among crash victims at a global level (Peden et al., 2004) and are at high risk of crash-related disability (Mayou and Bryant, 2003). The burden related to these vulnerable road users is largely borne by low-income and middle-income countries, where factors such as the intensity of traffic mix and lack of separation of these vulnerable groups from fast-moving motorized vehicles heighten the risk of injury for less-protected road users (Ameratunga et al., 2006). The ability to identify potentially dangerous traffic situations (Crick and McKenna, 1992) is an important aspect of driving competency to prevent road traffic accidents. This ability, commonly known as hazard perception, involves detecting stationary or moving objects in the road that have the potential to increase the risk of a crash (Haworth et al., 2005). It is also defined as the process whereby a road user notices the presence of a hazard (Evans and Macdonald, 2002). Hazard perception is typically measured by calculating response latencies to potentially dangerous traffic situations presented on video or film.

Hazards to motorcycle riders can be classified into those that involve the road surface (road-surface-based hazards) and those that arise from the behavior of other road users (road-user-based hazards) (Liu et al., 2009). Between them, other road users who perform unexpected actions are the major source of hazards to be negotiated (Underwood et al., 2009). Therefore, when a motorcycle rider is on the road, he or she not only needs to identify specific features of the road (such as road surfaces and alignment), but also to

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doi:10.1016/j.aap.2011.02.024

detect specific actions of other road users that may be hazardous. Fitzgerald and Harrison (1999) stated that hazard perception is a skill composed of both cognitive and behavioral components. Within the cognitive component, visual attention is an important function in the driving context. It refers to the processes that find, pull out, and help define features in the visual environment (Jenkin and Harris, 1999). Recent theories have posited that attention is not considered a unitary function but is divided into several component processes including vigilance or sustained attention, selective attention, and divided attention (Sturm et al., 1997; Strauss et al., 2006). Vigilance or sustained attention is the ability to maintain an attentional capacity over a period of time (Lezak et al., 2004). Selective attention is the ability to focus on certain features of a task and at the same time suppresses responses to irrelevant features voluntarily (Sturm et al., 1997). Lastly, divided attention involves the ability to respond to more than one task at a time or to multiple elements or operations within a task (Lezak et al., 2004). Thus, when a motorcycle rider navigates the road, he or she must prioritize locations in the visual scene according to their importance and frequently monitor the most likely hazardous spots, while inhibiting the impulse to fixate on nonhazardous-related information.

Visual attention is a significant outcome measure of traffic violations and accidents (Owsley et al., 1998) and is associated with a threefold increased risk of crashes and/or traffic violations (Richardson and Marottoli, 2003). During driving, there are many situations both within and outside the motorcycle that require the attention of the driver. For example, while analyzing traffic movements, motorcycle riders need to read the instrumentation on their dashboard to stay within the speed limit. Moreover, to stay safe on the road, motorcycle riders constantly utilize their visual attention to detect potential hazards and make necessary maneuvers to avoid collisions (Ball, 1997). Distraction of visual attention can be endogenous and exogenous (Underwood et al., 2003). An endogenous shift of visual attention is prompted by reduced cognitive resources at a time of high workload, adversely influencing the drivers' anticipations of emergent problems and their use of knowledge to avoid hazards. For example, driving in an unfamiliar area is more likely to cause traffic accidents because drivers in this situation require more concentration to process road and traffic conditions, which reduces their resources to detect potential hazards on the road. On the other hand, an exogenous shift of visual attention is prompted by sudden changes in the visual field of the driver, such as when other road users move into the driver's field of view in T-junctions or merging lanes. Other concurrent factors may also cause drivers to fail to allocate their visual attention optimally, particularly age (Lee et al., 2003; Lee and Lee, 2005) and inexperience (Falkmer and Gregersen, 2005; Underwood et al., 2005). Analysis of visual search patterns can provide relevant information on drivers' attentional issues (Recarte and Nunes, 2009). Many studies have recorded and analyzed drivers' eye movements to provide insights about visual attention during training (Hosking et al., 2010; Pradhan et al., 2005; Underwood et al., 2002). Differences in visual search patterns to identify road hazards and subsequent responding abilities were found between experienced and novice drivers as well as young and old drivers (Hosking et al., 2010; Liu et al., 2009; Underwood, 2007).

Driving attitude, which is manifested by driving behavior, can also affect the hazard perception of drivers. Several studies have shown that certain groups of drivers, particularly young ones, tend to overestimate their own skill while underestimating the skill of other drivers (Groeger and Brown, 1989; McKenna et al., 1991; Sexton et al., 2006). In addition, studies have shown that traffic accidents are related to how drivers perceive traffic risks. Traffic risk perception is defined as a subjective interpretation of the risk involved in various traffic situations (Deery, 1999). This subjective appraisal of traffic risk depends on the drivers' ability to correctly perceive the risk involved in various traffic situations. Mannering and Grodsky (1995) pointed out that risk perception is afflicted with biases, a general tendency to underestimate one's own likelihood of accident involvement, and a lack of awareness of true accident probabilities. Biases in risk perception have been linked to risky driving behavior (Deery, 1999; Harre, 2000). Risky driving behavior is manifested through the assessment of risk-taking attitudes in driving. Such attitudes have been found to correlate with aggressive driving behavior (Parker et al., 1998), fast driving, self-reported accident involvement (West and Hall, 1997), and intention to commit driving violations (Parker and Manstead, 1996). Indeed, some research suggests that driving attitudes are more important than skills (Rolls and Ingham, 1992). However, few studies have investigated the relative importance of visual attention and driving behavior on the hazard perception of motorcycle riders. The primary purpose of this study is to identify the correlation of different subtypes of visual attention and driving violation behaviors, and their effect on hazard perception, between accident-involved and accident-free motorcycle riders.

2. Methods

2.1. Participants and sampling

All participants were recruited by convenience sampling. Potential participants were selected from the administrative database of insurance companies providing motor vehicle insurance to licensed motorcycle riders. The inclusion criteria were: (1) having at least three years post-license driving experience; (2) having an annual mileage of at least 8000 km; (3) being literate enough to read and understand simple questions; and (4) signing the informed consent form and agreeing to allow us to check their driving record. Participants were excluded from the study if they (1) were unable to read Chinese and (2) requested that their participation be terminated. In this study, accident-involved motorcycle riders were those who had committed "active" accidents during the past three years in which they were held liable, and whose insurance companies were required to pay for the third-party claim. All potential participants who met the selection criteria were telephoned individually and informed of the purpose of the study. Ethical approval was obtained before the commencement of the study from the Human Research Ethics Committee of The Hong Kong Polytechnic University.

2.2. Procedures

The participants in this study were seen individually at the Ergonomics and Human Performance Laboratory at The Hong Kong Polytechnic University. Prior to the tests, they were required to fill in a questionnaire asking for basic demographic information and driving history, including an estimation of how many kilometers they drove annually. After the completion of the questionnaire, each participant was guided to a private room to undergo a battery of neuropsychological tests of visual attention.

2.2.1. Neuropsychological tests

Four neuropsychological tests were selected in this study. All of these tests have been demonstrated as successful screening tools for driving competency (Elkin-Frankston et al., 2007; Weinger et al., 1999; Worringham et al., 2006). In addition, these tests were used since there are Chinese versions available in Hong Kong.

2.2.1.1. Digit Vigilance Test. The Digit Vigilance Test (DVT), a subtest of the Lafayette Clinic Repeatable Cognitive Perceptual-Motor Battery, was used to assess visual vigilance and thus sustained attention (Mulet et al., 2007; Naunheim et al., 2008; Chen et al., 2009). Participants are asked to cross out, as quickly as possible, a specific target number (6 or 9) that appears randomly within a number matrix composed of 59 rows of 35 single digits on two pages. If a participant spends more than 400 s completing the first page, the second page is not administered. Two types of scores are provided, a total time score in seconds, derived by adding the times from the first and second pages, and a total errors score, calculated by adding the number of omissions (i.e. the number of 6 s or 9 s not crossed out on the two pages) and commissions (i.e. the number of misidentified digits that are crossed out on the two pages). In this study, the total time score was used since it is a better substantiated measure than total errors (Lewis, 1995), demonstrating higher test–retest reliability ($r = 0.91$) than total errors ($r = 0.66$) with healthy young adults (Kelland and Lewis, 1996) and even those with cognitive impairment (ICC = 0.91) (Chen et al., 2009). A high total time indicates a greater possibility of attention problems.

2.2.1.2. Color Trails Test. The Color Trails Test (CTT) is a culturally fair test of visual attention, graphomotor sequencing, and effortful executive processing abilities relative to the Trail Making Test (Dugbartey et al., 2000). It consists of two parts. In CTT-1, the participants are required to make pencil line connections between 25 encircled numbers randomly arranged on a test sheet in proper numerical order. In CTT-2, the participants are required to make pencil line connections on another test sheet with 25 encircled numbers in an alternating color order. The times required for CTT-1 and CTT-2 are recorded. CTT-1 is a test of sustained attention involving visual tracking and simple sequencing, while CTT-2 assesses selective attention and psychomotor performance (Chan et al., 2002). The test–retest reliability with healthy normal adults has been demonstrated to be fair to good ($r = 0.64$ for CTT-1 and $r = 0.79$ for CTT-2) (D'Elia et al., 1996). In this study, both CTT-1 and CTT-2 were used. A high time in each test indicates a greater possibility of attention problems.

2.2.1.3. Symbol Digit Modalities Test. The Symbol Digit Modalities Test (SDMT) is used to assess complex scanning and visual tracking (Smith, 1991). This visual-scanning test is widely used as a test of divided attention (Ponsford and Kinsella, 1992), in which complex visual scanning and tracking (Shum et al., 1990), perceptual and motor speed, and memory (Lezak et al., 2004) are required. The SDMT consists of both written and oral trials, giving this test the added advantage of providing a comparison between visuo-motor and oral responses. All participants were first required to examine a series of nine meaningless geometric designs, search for a key for each symbol, and substitute, in writing, a digit for the symbol in the sequence within 90 s. The procedure was repeated for the oral trial, which required the participants to read aloud the number for each symbol presented. The number of correct substitutions was recorded. The test–retest reliability with normal adults has been shown to be good ($r = 0.80$ for the written SDMT and $r = 0.76$ for the oral SDMT) (Smith, 1991). The correlations between the written and oral versions of the SDMT have been found to be high for normal adults ($r = 0.78$) (Smith, 1991). In this study, the written trial was used since, in addition to divided attention, the visuo-motor response is also very important in driving. A low number of correct substitutions indicates a greater possibility of attention problems.

2.2.2. Assessment of driving behavior

The Chinese Motorcycle Rider Driving Violation (CMRDV) Questionnaire was used, which consists of 19 items measuring the aggressive and ordinary driving violations of motorcycle riders (Cheng and Ng, 2010). Participants are asked to indicate how often they committed any of the listed violations. Responses are recorded on a 5-point Likert scale ranging from "never" (which scored 1) to "very often" (which scored 5). The test–retest reliability of CMRDV items has been shown to be good, with intra-class coefficients between 0.729 and 0.891. Acceptable screening accuracy has also been demonstrated between accident-involved and accident-free motorcycle riders. In one study, the area under the receiver operating characteristic (ROC) curve was 0.715 with sensitivity of 0.706 and specificity of 0.610 (Cheng and Ng, 2010). A high CMRDV score indicates a greater degree of driving violation behavior.

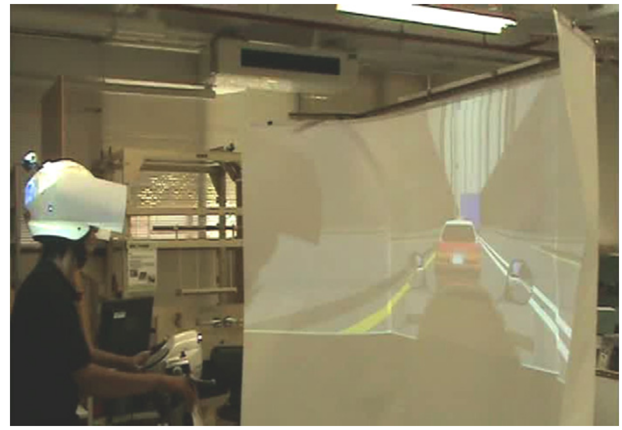

Fig. 1. The experimental set-up.

2.2.3. Assessment of hazard perception

All participants took part in simulated motorcycle riding developed by Ergonomics and the Human Performance Laboratory at The Hong Kong Polytechnic University. The motorcycle simulator was built on an abandoned motorcycle with different sensors connected to the handlebar, accelerator, front and foot brake, clutch, and gear shift to capture the responses of the participant in dealing with different traffic scenarios. The motorcycle was not connected to a motion platform but the participant could operate the motorcycle in response to the traffic scenarios displayed on a curved screen (Fig. 1). The visual display system provided 160° of horizontal viewing field and 35° of vertical viewing field to the participant seated 60 cm from the center of the curved screen. The iView X^{TM} HED head-mounted eye tracker system was used to capture participants' eye movements on different traffic scenarios on the screen simultaneously. Both the eye and scene camera were mounted on the helmet. Data from the iView X^{TM} HED system were recorded in real time at 60 Hz. Therefore, the output from this system consists of traffic scenes at 60 frames/s. Each frame had a "marker" indicating the location of the eye fixation of the participant at that particular moment. The synchronized recording of eye movements and traffic scenarios enabled us to conduct a frame-by-frame analysis of a participant's attention in a 0.016-s interval.

The experiment used two simulated riding scenarios. All traffic scenarios were presented by pre-rendered 3D animation that was projected onto the curved screen in front of the motorcycle simulator. One scenario was set for practice purposes so that every participant could become familiar with the testing environment and learn how to operate the rider simulator. Another scenario was set for testing the hazard perception of the participants. The practice scenario involved driving on a one-lane dual carriageway in a central business district (speed limit: 50 km/h) and attempting to turn right at a T-intersection with a vehicle travelling from the left on the continuing road. The testing scenario involved a road-user-based hazard situation. After driving on a dual carriageway for two minutes in a residential area at a speed of 60–70 km/h, a few boxes fell from the truck in front of the driver (Fig. 2). The time that this hazard appeared was recorded as T_h, and the time that the hazard was first seen by the participant (i.e. the first hazard fixation time) as T_f. Two independent raters were trained to use Sony Vegas Pro

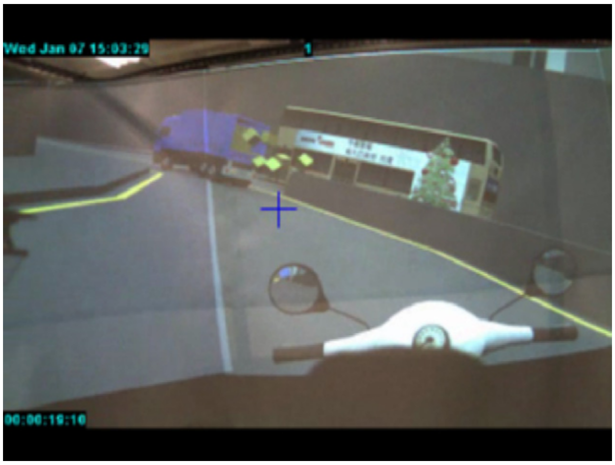

Fig. 2. Screen-shot showing what the motorcycle rider was viewing. The cross in the screen indicates the eye gaze of the participant.

8.0 to conduct a frame-by-frame analysis and identify T_h and T_f. The functions of the motorcycle were completely computer-controlled. All participants were instructed to shift gears and accelerate when they heard a double "beep" sound from the computer. By doing so, a traffic scenario would project on the curved screen, setting the time clock in motion. Each of the traffic scenarios simulated dry weather conditions with bright ambient lighting. A 10-min break was scheduled between practicing and testing scenarios. All scenarios were given by a working group comprising a principal motorcycle driving instructor from the Hong Kong School of Motoring, a commercial motorcycle accident avoidance instructor, and a licensed motorcycle rider with more than 15 years' post-license driving experience and an annual driving mileage of about 10,000 km. The two instructors had more than 20 years' experience training novice and veteran motorcycle riders.

2.3. Data analysis

Descriptive statistics were used to describe the demographic characteristics of all participants. The time difference between hazard presence and the first hazard fixation time (i.e. $T_f - T_h$), which reflects the hazard perception of each participant, was calculated. An intra-class correlation coefficient (ICC) of hazard perception was done to evaluate the inter-rater reliability of the two independent raters. Pearson product-moment correlation was done first to assess any correlation among different demographic variables, neuropsychological tests, driving behavior, and hazard perception. A composite score for the correlated neuropsychological tests was analyzed by one-way multivariate analysis of covariance (MANCOVA) to reveal any significant difference in assessing visual attention between accident-involved and accident-free motorcycle riders after controlling the covariates. Afterwards, univariate analysis of covariance (ANCOVA) was done to examine any significant difference between accident-involved and accident-free motorcycle riders on each neuropsychological test. An independent *t*-test was performed to reveal any significant difference between accident-involved and accident-free motorcycle riders in aggressive driving violation scores and ordinary driving violation CMRDV scores, as well as in hazard perception. Multiple regression analysis was conducted to evaluate the relative contribution of significantly related neuropsychological tests, as well as aggressive and ordinary driving violation CMRDV scores, on the influence of hazard perception. Finally, univariate logistic regressions were performed to examine the effect of demographic characteristic, neuropsychological tests, and hazard perception on the accident involvement of motorcycle riders. Those variables reached p value > 5% were eliminated. The remaining variables with p value < 5% were entered into the multivariate backward stepwise logistic regression to see its contribution on the probability that the motorcycle riders will have an accident. All statistical analyses were performed using the SPSS program version 17.0 for Windows; the significance level was set at $p < 0.05$.

Table 1
Characteristics of the participants ($n = 109$).

	Without accident ($n = 63$)	With accident[a] ($n = 46$)
Mean age (S.D.)	35.4 (2.9)	37.8 (4.1)
Gender	Male: 95.2% Female: 4.8%	Male: 89.1% Female: 10.9%
Education level	Illiterate: 0% Primary: 0% Secondary: 92.1% University: 7.9%	Illiterate: 2.2% Primary: 6.5% Secondary: 87% University: 4.3%
Mean post-license driving experience (S.D.)	15.2 (6.4)	17.4 (7.1)
Mean annual mileage in km (S.D.)	12,801.4 (2421.3)	10,770.8 (5448.1)

[a] Refers to a traffic accident that the participant was held responsible for in law.

3. Results

One hundred and nine motorcycle riders were recruited for this study. They were mainly men (92.7%), with a mean age of 36.4 years (S.D. = 3.1). The mean post-license driving experience was 16.1 years and the mean annual mileage was 11,944.5 km. Among the participants, 46 had been involved in an accident during the past three years. The demographic characteristics of accident-free and accident-involved motorcycle riders are shown in Table 1. An inspection of the intra-class correlation coefficient of the two sets of data on the time difference between hazard presence and the first hazard fixation time rated by two independent raters, ICC (2.1) was 0.885, which revealed a very high inter-rater reliability (Portney and Watkins, 2009) on assessing hazard perception.

3.1. Correlation among demographic variables, neuropsychological tests, driving behavior, and hazard perception

Bivariate correlations were computed to explore the interrelationships among demographic variables, neuropsychological tests, driving behavior, and hazard perception (Table 2). The results showed that hazard perception was only positively related to CTT-2 ($r = 0.314$, $p < 0.001$), which was used to assess selective attention. It was also unrelated to any demographic variables of the participants in this sample. However, it was significantly positively related to aggressive driving violation CMRDV score ($r = 0.537$, $p < 0.001$) and ordinary driving violation CMRDV score ($r = 0.290$, $p < 0.001$). Among the neuropsychological tests, DVT was positively related to CTT-2 ($r = 0.246$, $p < 0.001$) only. SDMT was inversely related to both CTT-1 ($r = -0.257$, $p < 0.001$) and CTT-2 ($r = -0.507$, $p < 0.001$). In addition, CTT-1 was positively related to CTT-2 ($r = 0.449$, $p < 0.001$). CTT-2 was positively related to aggressive driving violation score ($r = 0.174$, $p < 0.05$) and ordinary driving violation CMRDV score ($r = 0.208$, $p < 0.05$). Age and post-license driving experience were two demographic variables co-varying with SDMT and CTT-2 in which age was inversely related to SDMT ($r = -0.534$, $p < 0.001$) but positively related to CTT-2 ($r = 0.452$, $p < 0.001$). Post-license driving experience was also inversely related to SDMT ($r = -0.357$, $p < 0.001$) but positively related to CTT-2 ($r = 0.283$, $p < 0.001$).

Table 2
Correlation matrix for demographic characteristic, neuropsychological tests, and hazard perception ($n = 109$).

Variables	1	2	3	4	5	6	7	8	9	10	11
Age (1)	–	0.11	0.740**	0.008	0.102	−0.534**	0.109	0.452**	0.061	0.033	0.096
Gender (2)		–	0.176	−0.099	−0.098	0.045	−0.014	0.049	0.284	0.136	−0.012
Post-license driving experience (3)			–	−0.035	0.188	−0.357**	0.077	0.283**	0.090	0.079	0.040
Annual mileage (4)				–	−0.046	−0.096	0.169	−0.070	−0.100	−0.052	−0.012
DVT (5)					–	−0.164	0.060	0.246**	−0.053	−0.037	0.127
SDMT (6)						–	−0.257**	−0.507**	−0.116	−0.137	−0.186
CTT-1 (7)							–	0.449**	0.001	0.094	−0.101
CTT-2 (8)								–	0.314**	0.174*	0.208*
Hazard perception (9)									–	0.537**	0.290**
Agg. violation score of CMRDV (10)										–	0.448**
Ord. violation score of CMRDV (11)											–

Note: DVT = Digit Vigilance Test; SDMT = Symbol Digit Modalities Test; CTT = Color Trails Test; Agg. = aggressive; Ord. = ordinary; CMRDV = Chinese Motorcycle Rider Driving Violation.
* $p < 0.05$.
** $p < 0.001$.

Table 3
Means and standard deviations of the scores on different neuropsychological tests for accident-free and accident-involved motorcycle riders.

Test item	Without accident ($n = 63$)		With accident ($n = 46$)	
	Mean	S.D.	Mean	S.D.
DVT (second)	326.06	58.74	339.83	95.15
SDMT (number)	58.11	10.55	52.35	10.00
CTT-1 (second)	39.11	11.91	41.74	14.68
CTT-2 (second)	65.87	19.66	76.47	24.52

Note: DVT = Digit Vigilance Test; SDMT = Symbol Digit Modalities Test; CTT = Color Trails Test.

3.2. Performance of neuropsychological tests between accident-free and accident-involved motorcycle riders

The results of the one-way MANCOVA, in which participants' age and post-license driving experience served as covariates, revealed that there was insufficient data to reject the null-hypothesis of no difference between accident-free and accident-involved motorcycle riders on the composite score of the neuropsychological tests (DVT, SDMT, CTT-1, and CTT-2) (Pillai's Trace: $F(4, 102) = 1.856$, $p = 0.124$, effect size = 0.068, power = 54.6%). However, in the ANCOVA, the performances by accident-free and accident-involved motorcycle riders on each neuropsychological test indicated statistically significant differences on SDMT ($F(1, 105) = 5.722$, $p = 0.019$, effect size = 0.052, power = 65.9%), and CTT-2 ($F(1, 105) = 4.248$, $p = 0.042$, effect size = 0.039, power = 53.3%) after controlling for the effects of age and post-license driving experience. Table 3 summarizes the means and standard deviations of the scores on different neurological tests between accident-free and accident-involved motorcycle riders. We noted that accident-involved motorcycle riders had a lower number of correct substitutions on SDMT and spent more time on CTT-2. These results revealed that their divided and selective attention was inferior to those of accident-free motorcycle riders. With regard to driving behavior and hazard perception, the results of an independent *t*-test showed a statistically significant difference between accident-free and accident-involved motorcycle riders. The accident-involved motorcycle riders had higher scores for both aggressive and ordinary driving violations ($p < 0.001$) than did accident-free motorcycle riders, revealing that they engaged in driving violations more often. In addition, they took a longer time to identify the hazard compared to their accident-free counterparts ($p < 0.001$) (Table 4).

3.3. Prediction of hazard perception

Since only CTT-2 demonstrated a significant relationship to hazard perception, it was included as one of the independent variables together with aggressive and ordinary driving violation CMRDV scores in the multiple regression analysis. The results of the regression analysis showed that only the aggressive driving violation CMRDV score significantly predicted hazard perception ($\beta = 0.537$, $p < 0.001$). It had a positive influence and accounted for 28.1% of the variance in hazard perception.

3.4. Accident likelihood of motorcycle riders

Result of univariate logistic regressions on demographic characteristic, neuropsychological tests, and hazard perception showed that five variables, namely SDMT (crude odds ratio [OR] = 0.946, 95% confidence interval [CI] = 0.909–0.985); CTT-2 (crude odds ratio [OR] = 1.022, 95% confidence interval [CI] = 1.004–1.042); aggressive driving violation CMRDV score (crude odds ratio [OR] = 3.060, 95% confidence interval [CI] = 1.725–5.430); ordinary driving violation CMRDV score (crude odds ratio [OR] = 1.446, 95% confidence interval [CI] = 1.242–1.684); and hazard perception (crude odds

Table 4
Independent *t*-test comparison of hazard perception, CMRDV aggressive score, CMRDV ordinary score, and total CMRDV score between accident-free and accident-involved motorcycle riders.

Test item	Without accident ($n = 63$)		With accident ($n = 46$)		*t* statistic	*p*-Value
	Mean	S.D.	Mean	S.D.		
Hazard perception (second)	0.62	0.23	0.90	0.32	−4.98	0.000
Aggressive driving violation CMRDV score	13.19	1.84	25.26	6.62	−13.79	0.000
Ordinary driving violation CMRDV score	12.43	2.82	16.57	4.04	−6.29	0.000
Total CMRDV score	25.62	3.69	41.83	7.85	−14.38	0.000

Table 5
The effect of demographic characteristic, neuropsychological tests, and hazard perception on the accident involvement of motorcycle riders ($n = 109$).

Variable	Crude OR	95% CI	Adjusted OR	95% CI
Age	1.039	0.990, 1.090		
Gender				
Female	1			
Male	2.439	0.552, 10.773		
Post-license driving experience	1.045	0.990, 1.102		
Annual mileage	1.037	0.992, 1.193		
DVT	1.002	0.997, 1.008		
SDMT	0.946	0.909, 0.985*	0.775	0.624, 0.963*
CTT-1	1.016	0.986, 1.046		
CTT-2	1.022	1.004, 1.042*		
Agg. violation score of CMRDV	3.060	1.725, 5.430**	4.674	1.702, 12.834*
Ord. violation score of CMRDV	1.446	1.242, 1.684**		
Hazard perception	25.701	5.342, 43.653**		

Model summary: −2 log likelihood: 17.309, Nagelkerke R square: 0.941.
* $p < 0.05$.
** $p < 0.001$.

ratio [OR] = 25.701, 95% confidence interval [CI] = 5.324–43.653); have statistically significant effect on the accident involvement of motorcycle riders. In the multivariate logistic regression analysis, only SMDT and aggressive driving violation CMRDV score continued to play a significant role to predict the accident likelihood of motorcycle riders. With 1-point increase in SDMT will decrease the likelihood of 0.775 times of accident involvement whereas 1-point increase in aggressive driving violation CMRDV score will increase the likelihood of 4.674 times of accident involvement of motorcycle riders (Table 5).

4. Discussion

The results of the present study support the premise that although sustained, selective, and divided attention have been identified as distinct processes, they are interdependent and are discerned with overlapping processes (Kinsella, 1998; Strauss et al., 2006). Divided attention measured by SDMT was inversely related to both sustained and selective attention measured by CTT-1 and CTT-2 respectively. This inverse relationship is due to opposite direction in measuring performance. In SDMT, a low number of correct substitutions indicates a greater possibility of attention problems, whereas in CTT-1 and CTT-2, a longer duration for each test indicates a greater possibility of attention problems. Therefore, these three subtypes of attention are in fact positively correlated. During driving, they operate separately but interact to optimize stimulus detection, discrimination, and processing. From the bivariate correlation analysis, divided attention and selective attention displayed the highest correlation coefficient ($r = 0.507$), because many of the same principles associated with selective attention also apply in situations of divided attention, notwithstanding the multiple foci for attentional processing (McDowd, 2007). Inattention is one of the single most cited causes of road traffic accidents (Neyens and Boyle, 2008; Ledesma et al., 2010). Studies have found that selective and divided attention are correlated to driving performance (Avolio et al., 1985; Lengenfelder et al., 2002) and serve as good predictors of traffic crashes (Lengenfelder et al., 2002; Pietras et al., 2006). The results of our study were consistent with this observation in that both selective and divided attention of accident-involved motorcycle riders were inferior to those of accident-free motorcycle riders after controlling for the effects of age and post-license driving experience.

In addition, we substantiated the results of previous studies that reveal hazard perception to be associated with accident involvement (Quimby et al., 1986; Horswill and McKenna, 2004). A statistically significant difference emerged between accident-involved motorcycle riders and accident-free motorcycle riders in that the accident-involved motorcycle riders took longer to identify the hazard. We also showed that selective attention was positively related to hazard perception. Hazard perception is an awareness of dangerous situations in a traffic environment (Horswill and McKenna, 2004). There are three levels of situation awareness (Endsley, 1995) that can be used to distinguish among drivers with different skills and help explain why drivers scan roads in different ways. The first level of situation awareness requires the driver to perceive the environment without interpreting the relevance of the individual elements that are recognized. At this level, the driver may be aware of other road users, but may not calculate the trajectories or risks. At the second level, the driver usually has an understanding of the current situation and will integrate the perceptions gained at the first level to develop an understanding of where other drivers have come from and what they are doing at the present time. Only the third level of situation awareness is associated with the prediction of the behavior of other road users, and the anticipation of how the current situation might develop as other vehicles maneuver, thus leading to a course of corresponding action (Underwood, 2007). This explains why there is a difference in visual search to identify roads hazards and the subsequent responding abilities between experienced and novice drivers as well as between young and old drivers.

However, in this study, the participants had comparable age and post-license driving experience, and they could be regarded as mature and experienced drivers. So what accounted for their differences in hazard perception and accident involvement? The results of this study revealed that accident-involved motorcycle riders had significantly higher CMRDV scores for both aggressive and ordinary driving violations than did accident-free motorcycle riders, and that these two scores were positively related to hazard perception and selective attention. Furthermore, the results of the regression analysis showed that aggressive driving violation CMRDV score significantly predicted hazard perception and accident involvement of motorcycle riders. Based on this finding, we think that the difference in hazard perception was due to differences in driving attitudes, which manifested in driving styles. Previous studies have identified attitudinal and personality factors related to driving violation behaviors (Assum, 1997; Parker et al., 1995a,b). Personality factors implicated in aggressive driving include sensation seeking, impulsiveness, and trait driving anger (Dahlen et al., 2005; Schwebel et al., 2006). These factors in turn influence one's driving style. Driving style refers to the way drivers choose to drive or to their customary driving mode, including speeding, headway, and habitual level of attentiveness and assertiveness (Elander et al., 1993). There are four broad driving styles, the first one being a reckless and careless style, which refers to the deliberate violation of safe driving norms and thrill seeking while driving (Taubman-Ben-Ari et al., 2004). The construct underlying this driving style is consistent with the definition of a driving violation as a deliberate deviation from those practices believed necessary to maintain the safe operation of a potentially hazardous system (Reason et al., 1990). A higher CMRDV scores among accident-involved motorcycle riders reveals a reckless and careless driving style. Therefore, the most plausible explanation for the inferior performance of the accident-involved drivers on the neuropsychological tests and hazard perception could be related to their assigning fewer attentional resources as a result of their undesirable driving attitude and style, rather than skill deficits per se. However, this explanation is highly speculative and requires replication and additional research to verify it so that it may be generalized to a broader driver population.

A risk-taking attitude has been proven to be a significant determinant in road accidents, particularly among young drivers (Clarke et al., 2005; Hatfield and Fernandes, 2009). However, few studies have been conducted to investigate the effects of a risk-taking attitude on mature and experienced motorcycle riders. In addition, traffic risk perception and driving behavior are influenced by contextual factors in social, cultural, and traffic environments (Xie and Parker, 2002; Retting et al., 2003; Braitman et al., 2007; Goldenbeld and van Schagen, 2007). Motorcycle riders are tempted to travel faster, pull out into small gaps, and overtake more often than car drivers, particularly in the congested traffic common in China, Taiwan, and Hong Kong. These practices place the motorcycle rider and general public at great risk of injury and death. It is necessary to advance our understanding of risk-reducing factors so that appropriate education, enforcement, and engineering can be developed for different types of motor vehicle drivers.

5. Limitations

Some limitations of the current study should be noted. First, the sample used in this study was not representative of motorcycle riders in Hong Kong as a whole. Because only a few of the participants were female, young, and had been involved in road accidents, the study sample was not evenly distributed, making the results subject to bias. Second, convenience sampling method was used in this study; potential bias of self-selection may exist among the participants. Third, the classification of accident-free and accident-involved motorcycle riders relied on the administrative records of insurance companies to report whether the motorcycle riders required them to pay third-party claims. There may have been a situation in which motorcycle riders settled the claim by themselves, particularly in minor accidents lest their driving record be downgraded, resulting in a higher premium. However, we think this approach is more reliable than self-reported data, which are subject to response styles, demand characteristics, and imperfect recall of retrospective events. Forth, confounding variables such as type of motorcycle, use of motorcycle and the size of motorcycle ridden were not investigated and controlled in this study. Their variables may cause differences between two samples. Lastly, as the study data are cross-sectional in nature, the direction of causality may not be properly inferred from any significant relationships. Therefore, the present study can only provide a foundation for future research employing longitudinal and experimental methodologies.

6. Conclusion

Similar to previous studies, the results of this study showed that hazard perception is associated with accident involvement. Within both the cognitive and behavioral components of hazard perception, driving attitude plays an important role in modulating the attentional resources involved in driving. This phenomenon was reflected in our study sample, which consisted of mature and experienced motorcycle riders. The real challenge is therefore how to conceptualize the influence of different driving behaviors to enrich our understanding of the role of human factors in road accidents and to consequently develop effective countermeasures in driver training and testing, education campaigns aimed at changing driving styles, and improvements in the design of road systems and signage.

Acknowledgements

The authors are grateful to all the experts, particularly Mr. Clement Chung and Mr. Eddie Cho of the Hong Kong School of Motoring, for their valuable comments on the traffic scenarios of the motorcycle simulator. The authors would like to thank all the participants, as well as Jardine Matheson Limited for funding this study.

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