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Measurement of Riding Situation Awareness Among Malaysian Motorcyclists Using a Video-Based Assessment Approach

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ABSTRACT

A video-based Motorcycle Riding Situation Awareness Assessment method (MRSAA) was developed in-house by a team of researchers from the Malaysian Institute of Road Safety Research (MIROS) and used to assess motorcyclists' situation awareness (SA). A total of 264 participants comprised of an older adult motorcyclist group (n = 79, mean age = 35.5 years, mean riding exposure = 1,029.1 km per month) and a young motorcyclist group (n = 185, mean age = 19.7 years, mean riding exposure = 722.2 km per month) completed the assessment. Results indicated that the average total SA score (maximum 100%) for all participants was very low (23.2%), with the average score for Level 1 SA (*perception*) of only 27.5%. Results of an independent samples t-test indicated a significant difference in the SA total score between younger and older motorcyclists ($t_{111.12} = 5.93$, $p < .001$). The average SA total score for the older motorcyclist group was 17.4% higher than the average SA total score for the younger group. The differences in Level 1 SA scores between the two groups was also significant ($t_{131.82} = 4.64$, $p < .001$). Pearson correlation analysis indicated that motorcyclists with higher kilometres driven per month tended to have higher total SA scores and give more accurate responses to level 3 SA queries. Results of the Pearson correlation also indicated that age is positively correlated with all individual levels of SA. For older adult motorcyclists, their performances in the assessment of the lower level SA were found to have a significant influence on their performances in the assessment of the higher level SA. Considering the impact of age and riding exposure on situation awareness, the present study recommends that the learner motorcyclists to be trained and tested for a competency related to SA to increase their readiness to ride safely on the Malaysian roads.

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1. Introduction

Safe operation of a motor vehicle or in this case, a powered two-wheeler, involves a series of complex real-time information and decision-making processes. In essence, maintaining safe control of the vehicle during a motorcycle ride requires a motorcyclist to capture and process the most important information within the driving environment, and respond accordingly (Bolstad et al., 2010). The safe accomplishment of the driving task requires perception, identification, and correct interpretation of the elements within the traffic situation (e.g., unexpected hazards, the adjacent traffic, road signs, travelling direction, etc.) while also making projections of near-future traffic conditions to maintain safe vehicle control (Baumann et al., 2007). This process requires an individual to be fully aware of his or her driving environment at all time. It is understood from the previous studies that this situational awareness (SA) is a key factor in safe driving performance.

1.1. Definition of Situation Awareness (SA)

The definition of SA by Endsley (1995) is one of the most widely used in this field of research. Endsley (1995) defined SA as ''the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future''. This is the awareness that an individual has of a situation and his or her dynamic understanding of 'what is going on'. Endsley (1995) stated that SA is an important part of a driver's decision-making process, which in turn, influences safe driving performances. The following are three distinct phases that define SA (Endsley, 1995a):

- Level 1 SA (*perception*) involves the perception of the relevant elements in the driving environment;

- Level 2 SA (*comprehension*) is the understanding of 'what is going on' (i.e., the current situation) using the data and information collected in Level 1 SA; and
- Level 3 SA (*projection*) involves the prediction of future events based on the understanding achieved in Level 2 SA, allowing for timely and effective decision making.

Applying all SA levels increases the motorists' awareness of their situation. From the definition of SA, three important components of SA can be extracted (Alyamani & Kavakli, 2017): time, space, and the dynamic aspect of real-world situations (e.g., speed). Time refers to the time available at disposal until it is too late to react safely to avoid a collision, whereas space refers to how far away a hazard is and the dynamic aspect of the situations refers to the spatial and temporal changes pertaining to the hazards and the safety of a motorist. SA can be influenced by a motorist's abilities, experience, training, goals and expectations (Endsley, 1995).

Another definition of SA was provided by Gugerty (2011) who stated that SA is "the updated, meaningful knowledge of an unpredictably-changing, multifaceted situation that operators use to guide choice and action when engaged in real-time multitasking". During a driving task, this meaningful knowledge (e.g., the motorists' route location, location of nearby traffic, potential hazards, etc) is maintained and updated via a perceptual and cognitive process that could involve three levels of cognitive processing. These levels are:

- Level 1: automatic, pre-attentive processes that occur unconsciously and place almost no demands on cognitive resources;
- Level 2: recognition-primed decision processes that may be conscious for brief periods (< 1 s) and place few demands on cognitive resources; and
- Level 3: conscious, controlled processes that place heavy demands on cognitive resources.

Gugerty categorized a four-wheeled vehicle control as mostly an automated process (e.g., maintaining speed and lane position), recognition-primed processes requiring some regular conscious decision making (e.g., lane changing or stopping at a red light) and requiring a controlled, conscious process (hazard anticipation and making navigational decisions). Whether these definitions can be comparably applied for a two-wheeler vehicle control cannot be ascertained due to lack of evidence from the literature. The authors believe that the impact of SA on motorcyclists are more significant on the basis that they are more vulnerable and highly susceptible to a crash compared to the operators of the four-wheeled vehicles. For instance, a review by Elliott et al. (2003) found that motorcycle capability of quick acceleration and high speeds, instability during braking or leaning on a curve, and challenges in trajectory control are three key factors of increased difficulties in the vehicle control compared to a four-wheeled vehicle.

1.2. Situation Awareness and Crash Risk Involving Motorcyclists in Malaysia

In terms of a crash risk involving motorcyclists in Malaysia, the role of SA could be estimated by looking into the type of motorcycle-involved collisions. 'Out of Control' collision, where motorcyclists are often found lying off-road and by themselves, is the second most common types of collision resulting in motorcycle fatalities in Malaysia (Abdul Manan & Várhelyi, 2012). Also, 25% of the motorcycle fatal collisions in Malaysia involved 'single-motorcycle-crash'. From the perspective of motorcyclists' riding skills and behaviours, concerns regarding impaired hazard perception and responding skills among Malaysian newly licensed motorcyclists were highlighted in a study by Ibrahim and Mohd Yusoff (2011). Another study highlighted that Malaysian motorcyclists who used their motorcycle for parcel and documents delivery encountered 30 hazardous riding events and 5 near misses on average for each hour of delivery trips (Ibrahim et al., 2018).

1.3. Measurement of Situation Awareness

Many different techniques have been developed to measure SA. These techniques were categorized as (i) Online, where the SA is measured directly during a simulated driving environment with little or no interruption, and (ii) Offline – where the driving scenario is hidden from the view of a motorist during the measurement of SA (Gugerty, 2011). Situation Awareness Global Assessment Technique (SAGAT) proposed by Endsley (1995a) is an example of an offline SA measurement technique. SAGAT evaluates SA based on motorists' objective opinion. During the test, the display of driving scenarios is made temporarily blank periodically during randomly timed freezes (Endsley et al., 1998; Jannat et al., 2018). The test subjects are queried using memory-based questions to assess their knowledge of the situation at the time, across all three levels of SA defined by Endsley.

2. Method

2.1. Instrument

A video-based Motorcycle Riding Situation Awareness Assessment (MRSAA) tool and a questionnaire form were used to collect the data in this study. The MRSAA was developed in-house, based on SAGAT queries technique. The copyright of MRSAA is owned by MIROS and was registered with the Intellectual Property Corporation of Malaysia (MyIPO) under the name *Ujian Kewaspadaan Persekitaran Semasa Menunggang Motosikal* with application number FM2019006829 (MyIPO, 2020). The MRSAA assesses Level 1 SA by tapping into a subject's ability to recall relevant elements in their driving environments, such as the last road sign they saw or any potential hazards they encountered, before the simulation freeze. Assessment of Level 2 SA taps into a subject's ability to integrate various Level 1 elements for a comprehension of the significance of objects and events in the driving environment, such as a comprehension of the rate of a vehicle's speed change for a particular perceived stopping distance. Assessment of Level 3 SA taps into a subject's ability to project times to certain events, such as the location of his or her vehicle relative to a developing hazard (e.g., an oncoming motorcycle) to avoid a collision.

2.2. Participants

A total of 264 motorcyclists completed the MRSAA. The participants were predominantly male (95.1%) with only 13 (4.9%) female participants. In terms of gender and motorcycle crash involvement, this percentage is 3% lower than the five-year average (2005-2009) of female motorcyclists' involvement (7.9%) in fatal motorcycle crashes in Malaysia (Abdul Manan & Várhelyi, 2012). The majority of the participants were young with a mean age of 24.4 years old (SD = 8.2 years old), with the youngest was 16 years old and the oldest was 57 years old. In terms of age and gender, motorcycle fatalities in Malaysia are highest for 16 to 25-year-old males (Abdul Manan & Várhelyi, 2012). The average monthly riding distance (km) was 817.6 km (SD = 1070 km), with the lowest of 4 km and the highest of 10,000 km. Using a 10-year motorcycle total km travelled and motorcycle fatalities data between 1998 and 2009, Abdul Manan and Várhelyi (2012) found that motorcycle casualties in Malaysia increased with the increase in riding exposure.

2.3. Measurement and Calculation of SA Score

The MRSAA uses a set of video clips of actual motorcycle riding scenarios recorded from a motorcyclist's perspective at random locations in the Klang Valley. The recordings were part of MIROS Naturalistic Motorcycle Riding Database (Ibrahim, 2019; Ibrahim et al., 2018b; Ibrahim et al., 2018c; Ibrahim et al., 2019). The riding speed (km/h) of the subject's motorcycle was displayed on each clip (Figure 1). Each clip was made temporarily blank during randomly timed freezes. For each clip, motorcyclists were queried using certain questions to measure their SA. Each question measures a motorcyclist's level of SA at a specific level across the three levels of SA defined by Endsley (1995a). The participants were asked to select one correct answer from the multiple answer options provided to them. Due to the time constraint related to data collection procedures, not all queries and video clips for each level of SA were presented to the participants throughout data collection. Instead, the queries listed in Table 1 and their corresponding video clips were conveniently selected to measure the participants' SA. A questionnaire form was used to collect demographic and riding exposure data.

Total SA score and the average per cent of correct responses to Level 1, Level 2 and Level 3 queries (maximum score of 100%) was calculated to measure the motorcyclists' SA. The participants' overall SA was determined by calculating the average per cent of correct responses to all queries across the three SA levels. Data reduction and statistical analysis were performed in SPSS (IBM SPSS Statistics, V23.0).

Figure 1: Screenshot of a sample video clip included in the MRSAA.

2.4. Queries Corresponding to Each Level of SA

Extensive literature review and video analysis were conducted to determine the queries to reflect the different levels of SA based on the riding scenarios. Table 1 lists all the queries available in the current version of MRSAA and the level of riding situation awareness they represent.

Table 1: SA queries and the level of riding situation awareness.

Level of SA	Queries
Level 1 (*Perception*)	o Did you see a motorcycle from the oncoming direction? o Did you see a taxi before the video ends? o What was the color of a car waiting to turn to the right at the signalized junction? o What was the last road sign you saw before the video ends? o How many lanes were there in your direction of travel, before the clip ended?
Level 2 (*Comprehension*)	o The speed of the oncoming motorcycle was…. o From the first time you saw the taxi until just before the clip ended, the speed of the taxi was… o At your last position (before the video ends), how long have you passed a bicyclist who was riding against the traffic? o What is the distance between you and the motorcycle when it overtakes you from the left? o The width of the bike you were riding was 0.9 m. Could it fit into the space available to the right of the motorcycle in front, before the clip ended?
Level 3 (*Projection*)	o If you make that U-turn, how much time there is before a collision could happen with the oncoming motorcycle? o If the taxi changes lane onto your travelling direction at the point of the clip ended, how much time is available before a collision could happen between you and the taxi? o Assuming you are travelling at 106 km/h constantly, how much time do you think it will take to reach the last position of the car directly in front of you before the video ends? o Assuming you are travelling at 113 km/h constantly, how much time do you think it will take to reach the last position of the motorcycle directly in front of you before the video ends? o How long does it take for the motorcycle from the left to reach your last position (before the video ends)?

Continued on next column.

Table 1 – *Continued from previous column.*

3. Results

3.1. Descriptive Data Analysis

The dependent variable in this study was the participants' situation awareness (SA), which was measured through their responses to queries relevant to all levels of SA. The sum of the correct responses was calculated to determine the participants' overall SA and their performances at each level of SA measurement. Age and riding exposure in the form of the average monthly riding distance (km) were the main independent variables in this study. Considering the age distribution of the participants and their rate of motorcycle crash involvement as reported by Abdul Manan and Várhelyi (2012), the participants were classified as younger motorcyclists (16-25 years) and older motorcyclists (26 years and older). This classification is also in line with the average age of learner motorcyclists in Malaysia reported in a previous study (Ibrahim & Mohd Yusoff, 2011).

Table 2 lists the descriptive statistics of the independent and dependent variables across the two groups of participants. Overall, the total SA score (all SA levels) for both groups was very low (M = 23.2%, SD = 20.5%), with the average score for Level 1 SA (*perception*) of only 27.5%. Seventy-seven participants (29.2%) were not able to answer correctly in all SA queries (0 % score). The highest SA total score for this cohort was 83.3%.

Figure 2 and Figure 3 display the percentage frequency distributions of the participants' SA score for the younger motorcyclist group and the older motorcyclist group respectively. The plot revealed that the majority of younger motorcyclists (more than 60%) were not able to answer all queries correctly for all SA levels. A lower percentage of participants was recorded for a 0% score across all SA levels for the older group. For the total SA scores, the highest percentage of participants in the older group was in the 50%-74% range, while the highest percentage of participants from the younger group was for the 0% total score.

Table 2: Descriptive statistics and comparison (*t*-test) between the two groups of participants.

Variables	Younger motorcyclists (16-25 years)			Older motorcyclists (26 years and older)			*t*-test
	n	*M*	*SD*	*n*	*M*	*SD*	
Age	185	19.7	1.8	79	35.5	6.5	21.21**
Riding exposure (avg. km per month)	175	722.2	894.7	79	1,029.1	1,365.7	1.83
Total SA Score (%)	184	17.9	16.4	79	35.3	23.8	5.93**
Level 1 SA Score (%)	185	20.0	31.8	79	41.8	36.2	4.64**
Level 2 SA Score (%)	185	19.7	29.5	79	34.2	28.6	3.67**
Level 3 SA Score (%)	184	13.8	23.6	79	30.1	27.3	4.62**

*$p < .05$. **$p < .01$

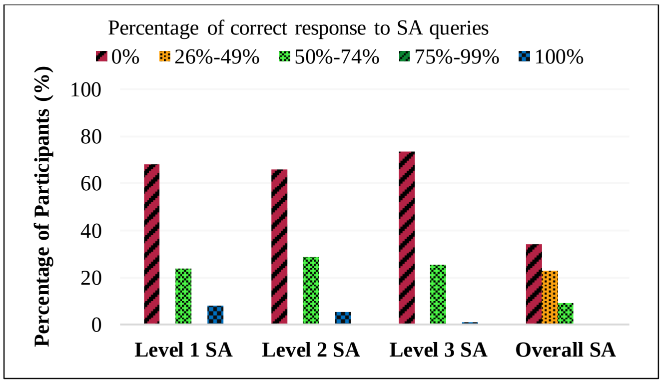

Figure 2: Distribution of participants' SA score for the younger motorcyclist group (16-25 years).

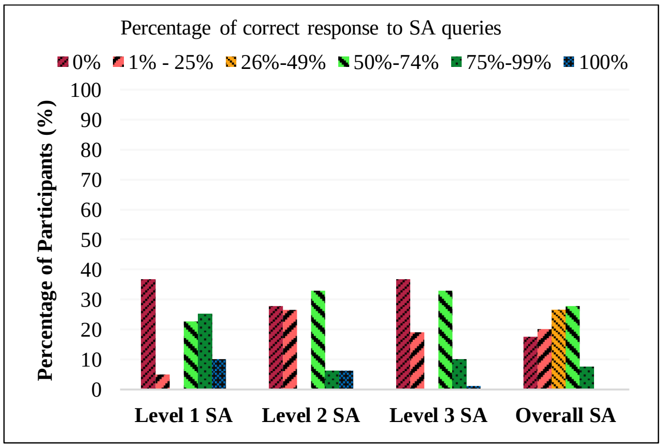

Figure 3: Distribution of participants' SA score for the older motorcyclist group (26 years and older).

3.2. Statistical Analysis

An independent-samples t-test was conducted to compare SA scores for the younger and the older motorcyclist group. There was a significant difference in the SA total score for the 16-25 years old motorcyclists (M = 17.9%, SD = 16.4%) and the 26 years old and older motorcyclists (M = 35.3%, SD = 23.8%); $t_{111.12}$ = 5.93, p < .001). The average SA total score for the older group was 17.4% higher than the average SA total score for the younger group. The differences in Level 1 SA scores between the two groups was also significant ($t_{131.82}$ = 4.64, p < .001). The average Level 1 SA scores for the older group was 21.8% higher than the younger group. Significant differences were also observed between the two groups in Level 2 and Level 3 SA scores (see Table 2). The average score for the older group was 14.5% and 16.3% higher in Level 2 SA and Level 3 SA respectively compared to their younger counterparts.

3.3 Correlation Analysis

Driving experience and exposure (km driven) have been found to have a significant influence on hazard perception skills among car drivers and motorcyclists (Ab Rashid & Ibrahim, 2017; Ibrahim & Ab Rashid, 2016; Wallis & Horswill, 2007). However, studies that focus on the relationship between improvement in SA and exposure or age is limited, especially for the operator of powered-two-wheelers. To determine if there was any significant relationship between motorcyclists' riding exposure (average km per month), their age and SA, a Pearson correlation analysis was conducted. The age and riding exposure of the participants were found to be significantly correlated, $r(252)$ = 0.16, p = 0.012. Thus, a partial correlation was conducted to determine the relationship between a participant's SA and age whilst controlling for riding exposure. There was a moderate, positive partial correlation between total SA score (M = 23.9%, SD = 20.5%) and age (M = 24.6 years, SD = 8.3 years) whilst controlling for riding exposure (M = 807.4 km/month, SD = 1,060.1 km/month), which was statistically significant, $r(250)$ = 0.39, p < .001. However, zero-order correlations showed that there was a statistically significant, moderate, positive correlation between total SA score and age, $r(251)$ = 0.40, p < .001, indicating that riding exposure had very little influence in controlling for the relationship between total SA score and age.

Results of the Pearson correlation also indicated that age is positively correlated with all individual levels of SA. Older motorcyclists tended to have better situational awareness than their younger counterparts. A significant positive association was also found between riding exposure and total SA score, $r(251)$ = 0.13, p = 0.036. Riding exposure was also positively correlated with Level 3 SA score, $r(252)$ = 0.13, p = 0.035. Motorcyclists with higher kilometers driven per month tended to have higher total SA score and give more accurate responses to level 3 SA queries. Table 3 lists the descriptive statistics and correlations for the study variables involving all participants.

Table 3: Descriptive statistics and correlations for the study variables involving all participants.

Variable	*n*	*M*	*SD*	1	2
1. Age	264	24.4	8.19	—	
2. Riding exposure (avg. km per month)	254	817.6	1,070.4	.16*	—
3. Total SA Score (%)	263	23.2	20.5	.40**	.13*
4. Level 1 SA Score (%)	264	27.5	34.2	.31**	.07
5. Level 2 SA Score (%)	264	25.4	31.8	.22**	.06
6. Level 3 SA Score (%)	263	19.5	25.2	.30**	.13*

*$p < .05$. **$p < .01$.

Pearson correlation analysis was also conducted to determine if there are any significant associations between scores of SA at individual levels. Considering the impact of age and exposure on SA and the significant differences in SA scores between the two groups, the association between scores of SA was determined only for the older participants. For the older adult motorcyclist group, a statistically significant, moderate, and positive association was found between the score for Level 1 SA and Level 2 SA, $r(77)$ = 0.36, p < 0.001.

Table 4: Descriptive statistics and correlations for the older adult motorcyclist group

Variable	*n*	*M*	*SD*	1	2	3	4	5	6
1. Age	79	35.5	6.5	—					
2. Riding exposure (avg. km per month)	79	1,029.1	1,365.7	.09	—				
3. Total SA Score (%)	79	35.3	23.8	.18	.05	—			
4. Level 1 SA Score (%)	79	41.8	36.2	.27*	.07	.83**	—		
5. Level 2 SA Score (%)	79	34.2	28.6	.02	-.06	.72**	.36**	—	
6. Level 3 SA Score (%)	79	30.1	27.3	.12	.11	.76**	.49**	.35**	—

*p < .05. **p < .01.

A similar association was also found between Level 1 SA score and Level 3 SA score, $r(77) = 0.49$, $p < 0.001$. Interestingly, a moderate positive association was also found between Level 2 SA and Level 3 SA score, $r(77) = 0.35$, $p < 0.001$. The significant associations between individual SA scores could indicate that the MRSAA tool has successfully classified the video-based motorcycle riding scenarios according to the individual SA level defined by Endsley (1995a). Another important deduction is that a motorcyclist's performances in the lower level of SA significantly influenced the performances in the higher level of SA. Table 4 lists the descriptive statistics and correlations for the older adult motorcyclist group.

4. Discussion

The main objective of this study was to investigate motorcyclists' situation awareness using a video-based SA measurement method. To the best of our knowledge, there was no similar attempt involving Malaysian motorcyclists prior to this study. Specifically, this study sought to determine the level of situation awareness among motorcyclists of different age and riding exposure. Motorcyclists were over-represented in the numbers of traffic-related deaths and injuries in Malaysia. According to the 2018 police statistics, casualties involving riders and pillions of the motorcycles in Malaysia made up more than two-thirds (67.1%) of all traffic-related casualties (Zainal Abidin et al., 2018). The numbers of motorcycle casualties recorded that year were 3.7 times more than the casualties involving passenger cars, the second-highest casualties group in the statistics. This staggering difference shows the degree of vulnerability of motorcyclists on Malaysian roads. One of the contributors to this vulnerability is the risky driving environment in the mixed-traffic scenarios, in which large and small vehicles with substantial speed differences share the same roads. Considering this factor, SA is one of the crucial elements required for a motorcyclist to anticipate a risky situation and to avoid a collision.

The findings of this study indicated a worryingly low overall SA among the participants across all age groups and levels of riding exposure. Almost a third of the participants were not able to answer correctly in all SA queries (0% score) with the majority of younger motorcyclists (more than 60%) were not able to answer all queries correctly for all SA levels. This could indicate a major competency-related issue among Malaysian motorcyclists. Further, the significant differences between the younger and older motorcyclist groups across all levels of SA suggest that age and exposure have a significant influence on a motorcyclist's SA. A better situational awareness was observed among motorcyclists who are older or ride the powered-two-wheeler more frequently. The significant positive correlation between riding exposure and SA scores could indicate that SA is a skill that, a mastery of which requires a motorcyclist to be exposed to the actual traffic scenarios. Thus, in the case of motorcycle training and licensing, exposure to the actual riding scenarios is needed during the training period. Some of the viable options to achieve this is through the use of a motorcycle simulator and the inclusion of video-based SA training and assessment activities in the curriculum.

5. Conclusion and Recommendations

This study contributes to the field of motorcycle safety research through the development and validation of a method to measure a motorcyclist's situational awareness objectively. One of the key advantages of the MRSAA was the utilization of the local motorcycle riding scenarios recorded from the perspective of a motorcyclist. The findings of this study have important implications for safe riding skill development and training, especially for the young and inexperienced learner motorcyclists.

The findings of this study provide some support for the premise that the learner motorcycle riders need to be tested in terms of their riding situational awareness and hazard perception skill to achieve a minimum competency level for the certification of a motorcycle riding license. Adoption of the SA test as part of the national driver training and testing system is expected to improve the impact of the system on the safety of young motorcyclists in Malaysia. Thus, it is strongly recommended that the Road Transport Department (JPJ) considers the exposure, training and assessment of SA for a learner motorcyclist in the motorcycle training and licensing program.

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