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Title: The effect of lighting conditions and use of headlights on drivers' perception and appraisal of approaching vehicles at junctions

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Abstract

Use of Daytime Running Lights (DRL) is mandatory in many countries for motorcycles, and in some for cars. However, in developing countries DRLs may be optional or compliance low. The effect of car or motorcycle headlights and lighting conditions on Malaysian drivers' ability to perceive and judge the safety of pulling out was investigated. Stimuli were photographs depicting either daytime or nighttime taken at a T-junction with approaching vehicles with headlights on or off. Headlights improved drivers' ability to perceive cars and motorcycles in the nighttime photographs but not the daytime photographs, although this could be due to the bright weather in the photographs. Drivers judged it less safe to pull out when approaching motorcycles had headlights on than off, regardless of the lighting conditions, supporting the utility of DRL for motorcycles. Headlights did not affect judgments for cars, questionning the utility of DRL for cars.

Keywords Driving, Headlights, Lighting Conditions, Motorcycle, Perception

Practitioner Summary

The effect of headlights and lighting conditions on drivers' ability to perceive and make judgments about the safety of pulling out was investigated. Daytime Running Lights influenced drivers' decision-making about the safety of pulling out in front of motorcycles, illustrating the importance of having automatic headlights equipped.

1. Introduction

The right-of-way violation is the most common type of collision involving motorcycles. It happens when vehicles fail to give way and pull out at a junction in front of a motorcycle that is approaching on the main carriageway (Clark et al., 2004). Crundall et al. (2008) proposed that there are three key behaviours that drivers need to carry out in order to avoid such collisions at junctions. These include looking in the right direction from where the approaching vehicle is coming, being able to perceive the approaching vehicle, and making the correct judgment about the safety of pulling out. As, typically, real-world driving requires all of these processes to occur near simultaneously, it is not clear to what extent each of these behaviours contributes to the relatively large number of right-of-way violations involving motorcycles.

Crundall et al. (2008); see also Lee et al. (2015) devised a method to separate out the role of failures in perceiving approaching vehicles versus failures to make appropriate judgments about the safety of pulling out. Car drivers were presented with photographs, taken from the point of view of a car that has arrived at a T-junction, the driver of which is looking to the right into the main carriageway to check for oncoming traffic (equivalent to US drivers turning left in the same T junction scenario). Some of the photographs displayed oncoming cars at various distances while others displayed motorcycles, or no vehicle at all. In the first experiment, which isolated the role of perceptual abilities, participants saw each photograph for only 250ms to simulate a single glance at the junction and were asked to judge whether or not a vehicle was present. In the second experiment, which considered appraisal processes, the same photographs were presented for 5 seconds (sufficient time for any vehicle to be perceived) and drivers were invited to judge whether or not it was safe to pull out. These studies demonstrated that drivers were better at perceiving approaching cars than motorcycles but there was no vehicle effect when deciding whether or not it was safe to pull out. Based on this, Crundall et al. (2008) argued that the relatively large number of right-of-way violations involving motorcycles is likely to be due to perceptual failures, rather than faulty decision making about the safety of pulling out.

Using the same methodology, it is possible to investigate how other factors known to affect accident rates for cars and motorcycles influence perceptual and appraisal processes independently. In this paper we consider two such factors associated with the luminance of the environment itself: whether the photo depicts daytime or nighttime conditions, and the use of vehicle headlights. According to Plainis and Murray (2002), at nighttime there is a decrease in target visibility associated with the low luminance conditions, causing an increase in drivers' reaction times and more accidents. Data from various countries shows that more accidents happen at nighttime as compared to daytime (Clark et al., 2006; Laapotti & Keskinen, 1998; Abdul Manan & Várhelyi, 2012; Williams, 2003).

While detection may be generally poorer under low luminance conditions, other research suggests that the contrast between the vehicle and background has an important impact on its conspicuity (luminance contrast theory). Hole et al (1996) found that increasing the luminance contrast (between target object and background) increased motorcycle detection more than solely increasing the luminance itself. If this is true, vehicles with their headlights switched on should be relatively easy to detect and especially when it is dark. Use of vehicle headlights is obligatory in all countries at nighttime and in some during daytime (Daytime Running Lights, DRL). Several countries make it mandatory for motorcyclists to switch on their headlights regardless of time of day, such as Belgium, France, Spain, Germany, Greece, Brazil, Chile, and Singapore (Ferraz, Bezerra, & Bastos, 2010; Nazif-Munoz, Quesnel-Vallée, & van den Berg, 2015; SWOV, 2013, Yuan, 2000), and there is support for the notion that this has resulted in significant reductions in the number of accidents (Henderson et al., 1983). Many countries have implemented 'Automatic Headlamp On' (AHO) for motorcycles, which is a switch that ensures that the (main or dipped beam) headlight (or the DRL) is always on when the engine is running. For instance, the US, Japan, Europe, Australia, and Canada all have mandatory AHO (OCED/ITF, 2015; Paine et al., 2005), and India is soon to introduce this (Vijayraghvan, 2016). However, AHO is not mandatory across all parts of the world and particularly in low- and middle-income countries (OCED/ITF, 2015). Several studies have reported that increasing the conspicuity of motorcycles using DRL increases drivers' ability to detect their presence using various methods, including interviews (Janoff et al., 1971; Janoff, 1973; Kirkby & Fulton, 1978; Ramsey & Brinkley, 1977) and experimental designs (Hole, 1996; Hole & Tyrrell, 1995). These previous studies have tended to focus on motorcycles and not cars, presumably because motorcyclists are vulnerable and harder to detect, perhaps with the assumption that DRL could not further improve detection of cars.

While previous research supports the notion that day or nighttime conditions and use of headlights influence drivers' ability to perceive vehicles, less is known about how these factors may influence decision making about safety independently of perceptual failures. Clarke et al. (2006) argued that the difference in accident rate associated with time of day is not due to low visibility during dark conditions, but a consequence of higher voluntary risk-taking behaviour at nighttime. However, this may not be a consequence of the dark conditions but rather other factors associated with nighttime driving such as lower traffic volume resulting in higher speeds, increased fatigue levels, and higher rates of drink-driving. Therefore, it is not clear whether nighttime conditions in the absence of these other factors would foster more risky decision making.

Malaysia has had the highest road fatality risk (deaths per 100,000 population) in the world since 1996 and a constant increase in road fatalities of 4% in every year in the last 7 years; more than 50% of the fatalities were motorcyclists (Abdul Manan & Várhelyi, 2012). Around 28% of these motorcycle accidents involve collisions with cars (Abdul Manan & Várhelyi, 2012). As in many countries, the fatality rates vary according to the time of day. For instance, Abdul Manan and Várhelyi (2012) reviewed accident data from years 2000 to 2009 in Malaysia and separated it into 2-hour bands starting from 12am to 2am. They report that fatalities were highest between 4pm and 10pm (10.2 % from 4pm to 6pm; 12.4 % from 6pm to 8pm and 12.7 % from 8pm to 10pm respectively), which are dusk and dark hours, although overall more motorcycle fatalities occurred during the daytime than the nighttime (55.6%). In September 1992, Malaysia introduced the use of DRL in motorcycles as a compulsory regulation in the country. Radin Umar et al. (1996) reviewed accident data before and after 1992 and concluded that the accident rate for motorcyclists in Malaysia significantly decreased by 29% after the DRL implementation.

Motorcycle manufacturers in Malaysia have implemented Automatic Headlamp On since the regulation was implemented. However, despite this being the case, in a recent on-road observational study it was reported that among 1850 motorcycles, about 20.27% failed to have their headlights switched on during off peak daytime hours and clear weather (Abdul Manan & Várhelyi, 2015). Given that motorcycle manufacturers have included AHO for many years now, it seems likely that most of these motorcyclists that were observed with the headlights off either had not maintained the headlights in working order or were too old to have headlights wired in – raising the possibility that these riders are also not using headlights at nighttime. Assuming that DRL has decreased accidents involving motorcycles, the question remains whether this improvement is due to an increase in their being perceived by other drivers or a tendency for other drivers to be more cautious when making judgments about safety in relation to them.

This study aimed to investigate the interaction between the effect of headlights and lighting conditions depicted in the photographs on Malaysian drivers' ability to perceive approaching vehicles, and on the judgments they make about the safety of pulling out in front of them. The same methodology developed by Crundall et al. (2008) was used where drivers viewed images of approaching cars or motorcycles, which were located at three different distances. These images were edited so that they either appeared to be shot under daytime (light) conditions or nighttime (dark) conditions, and so that the approaching vehicles' headlights were either on or off. As in Crundall et al. (2008), in the first experiment, images were presented briefly and participants were asked to detect the presence of an approaching vehicle while in the second experiment, the images were presented for much longer and participants were asked to judge whether or not it was safe to pull out. Our first hypothesis predicted that drivers would generally find it easier to perceive vehicles in the daytime than nighttime photographs. According to luminance contrast theory, there should be an advantage for perceiving vehicles with headlights on rather than off (second hypothesis), but this should be greater for the nighttime than daytime photographs (third hypothesis). Given that cars are more conspicuous than motorcycles, DRL for approaching cars may have less impact than for motorcycles, which would be demonstrated by a three-way interaction between use of headlights, lighting conditions, and vehicle type (fourth hypothesis).

In relation to making judgments about the safety of pulling out, based on Clarke et al. (2006), it is possible that drivers will make more risky decisions for the nighttime photographs, i.e. they might be more likely to say they would pull out in front of vehicles when it is dark. On the other hand, drivers might find the vehicles' distance harder to judge within the nighttime stimuli and as a consequence be more cautious in their decisions than for the daytime stimuli i.e. be less likely to say they would pull out. Therefore, the first hypothesis, which was two-tailed, stated that there will be a significant difference in judgments of safety of pulling out for daytime and nighttime photographs. The second hypothesis stated that if drivers are more cautious in their decisions for the nighttime stimuli, we would also expect drivers to make more conservative judgments (be less likely to judge it safe to pull out) when the headlights are off than on.

2. Experiment 1: How lighting conditions depicted in the photographs and the use of headlights affect drivers' ability to perceive approaching vehicles at junctions

2.1. Methods

2.1.1. Participants

19 drivers (10 females and 9 males) were recruited in this experiment. Their average age was 21.37 years (S.D. = 2.01 years) ranging from 19 to 27 years old and they reported an average of 3.25 years of active driving experience since getting their driving license in Malaysia (S.D. = 2.35 years). All reported normal or corrected-to-normal vision and were not colour blind. All participants reported no experience of riding a motorcycle.

2.1.2. Design

A 2 x 3 x 2 x 2 within-subjects design was used. There were four independent variables: type of approaching vehicle (car or motorcycle; 'no vehicle' trials were used as controls but do not contribute to the analysis); distance of approaching vehicle (near, intermediate or far); lighting conditions depicted in the photographs (daytime or nighttime); vehicle headlights (on or off). See Table 1 for an illustration of all independent variables. The dependent variable was the accuracy in perceiving an approaching vehicle. Three hundred and twenty trials were presented across two different blocks (daytime and nighttime). The trials were blocked to simulate real life where it does not suddenly change from day to night and vice versa. In addition to this reason, it was also taken into account that participants might have to adapt their pupil size while looking at brighter versus darker pictures, which could have interfered with performance if the trial types were interlaced (Konstantopoulos et al., 2010). Therefore we separated the stimuli into two blocks.

Each 160-trial block (daytime or nighttime) included 30 trials without approaching vehicles (3 repetitions for each stimulus) and 120 trials with approaching vehicles (car or motorcycle) which consisted of 60 trials where cars had headlights on and 60 with headlights off. These approaching vehicles trials were presented at 'near', 'intermediate' and 'far' distances for each condition. The remaining 10 trials were 'catch trials' which were used to make sure that drivers' eyes were focused on the left edge of the screen ensuring a realistic starting location (Crundall et al., 2008; Lee et al., 2015). Following previous studies, data of participants who scored lower than 40% in the catch trials were to be excluded. However, no participant scored less than 40% in this experiment and therefore no data was excluded.

Table 1. An illustration of 16 different conditions

Distances / Vehicle Type / Time of Day / Headlights		Near		Intermediate		Far	
		Car	Motorcycle	Car	Motorcycle	Car	Motorcycle
Day	Headlights On	Near Car Day On	Near Motorcycle Day On	Intermediate Car Day On	Intermediate Motorcycle Day On	Far Car Day On	Far Motorcycle Day On
	Headlights Off	Near Car Day Off	Near Motorcycle Day Off	Intermediate Car Day Off	Intermediate Motorcycle Day Off	Far Car Day Off	Far Motorcycle Day Off
Night	Headlights	Near Car	Near	Intermediate	Intermediate	Far Car	Far Motorcycle

On	Night On	Motorcycle Night On	Car Night On	Motorcycle Night On	Night On	Night On
Headlights Off	Near Car Night Off	Near Motorcycle Night Off	Intermediate Car Night Off	Intermediate Motorcycle Night Off	Far Car Night Off	Far Motorcycle Night Off

2.1.3. Stimuli

The day versions of photograph stimuli were taken from the viewpoint of a driver who was looking towards the right while approaching various T-junctions in Malaysia (University of Nottingham roads, Broga roads, and Serdang roads). The same cars and motorcycles used in Crundall et al. (2008) were edited onto these roads at locations of near, intermediate and far. The same 70 photograph stimuli (10 roadways x 2 vehicle types x 3 distances + 10 empty versions of each road as control pictures) were edited to create nighttime versions using Photoshop CS6 by decreasing the brightness and exposure of the pictures, thus creating another 70 photograph stimuli for the nighttime versions. These 120 photograph stimuli with approaching vehicles (60 daytime and 60 nighttime) were then edited to create a set of stimuli where the approaching vehicles had the headlights on. In order to do this, the day time stimuli with headlights on were created by increasing the brightness of the headlights (with the Dolge tool using settings of midtones for range, 100% exposure with 10 clicks applied to each headlight), to ensure a difference between headlights on and off for day time stimuli. These set of headlights were then copy pasted to replace the headlights of vehicles in the nighttime stimuli to create the headlights in the nighttime versions. This was also to ensure that the brightness of headlights was controlled in all pictures. All stimuli were edited by the researcher and were 720 x 540 pixels (see examples in Figure 1).

Figure 1. Four sample photographs shown: a far car with the headlights on in daytime photograph (top left); a near motorcycle with the headlights off in a daytime photograph (top right); a far motorcycle with the headlights on in nighttime photograph (bottom left); an intermediate car with the headlights off in nighttime photograph (bottom right). Note that the brightness of the nighttime photographs has been increased for the illustration purposes here, as the pictures were created for on-screen viewing but look darker when printed

2.1.4. Procedure

The procedure of this experiment was similar to Crundall et al. (2008) and Lee et al. (2015). Participants were first asked to fixate on a fixation cross of variable duration (500ms, 1000ms, 1500ms) that appeared at the left of the screen prior to the presentation of each picture. Upon picture onset participants were asked to identify whether there was an oncoming vehicle approaching them from the right, and to respond as quickly as possible by pressing 0 on the numerical keypad of a computer keyboard if the road was empty, or 2 if a vehicle was approaching. They were also required to abort catch trials where the fixation-cross changed shape prior to picture presentation (from a "+" to a "x"). Catch trials were correctly aborted by pressing the space bar on the keyboard.

The picture stimuli were each presented for 250ms, following the variable-duration fixation cross, to simulate a single fixation on the picture. Following offset of each picture, participants were presented with a prompt screen detailing the appropriate buttons to press in order to make correct responses. Consistent with previous studies using similar methodology (e.g. Crundall et al., 2008; Lee et al., 2015), they were presented with visual feedback of the response accuracy before the fixation cross appeared signaling the start of the next trial.

Two blocks of trials were presented (daytime photographs and nighttime photographs). Counterbalancing was used such that half of the participants completed the daytime block first and the other half completed the nighttime block first. Participants were given a practice block of 10 trials (mixture of daytime and nighttime stimuli) before the two blocks of the experiment started, and a self-paced break was allowed between the two experimental blocks. The experiment was carried out for all participants during daytime and in the same room with the same lighting conditions.

2.2. Results

The data for all 19 participants were subjected to a 2 x 3 x 2 x 2 Analysis of Variance (ANOVA) comprising percentage accuracy for spotting an approaching vehicle for different vehicle types (car or motorcycle) at different distances (near, intermediate or far), for daytime or nighttime photographs with the headlights on or off. A normality test revealed that the data is not normally distributed, Kolmogorov-Smirnov, $p < .05$, however ANOVA was performed due to the multifactorial nature of the design and its robustness with not normally distributed data (Ziegler, Danay, & Bühner, 2010). Mean percentage accuracy and standard deviations are shown in Table 2.

Table 2. Accuracy (mean percentage and standard deviation) of perceiving an approaching vehicle at near, intermediate and far distances

Percentage accuracy (%)	Distances	Vehicles	Daytime Photographs		Nighttime Photographs	
			Headlights On	Headlights Off	Headlights On	Headlights Off
	Near	Car	99.47 (2.29)	99.47 (2.29)	97.89 (4.19)	77.89 (17.19)
		Motorcycle	98.95 (3.15)	98.95 (3.15)	99.47 (2.29)	78.95 (14.10)
	Intermediate	Car	100.00 (N/A)	99.47 (2.29)	99.47 (2.29)	69.47 (17.79)
		Motorcycle	99.47 (2.29)	97.37 (5.62)	100 (N/A)	67.26 (20.98)
	Far	Car	87.89 (12.28)	86.84 (11.08)	100 (N/A)	41.58 (21.93)
		Motorcycle	79.47 (12.68)	72.63 (18.81)	96.32 (6.84)	46.32 (25.21)

The ANOVA identified four main effects. There was a main effect of distance, F(2, 36) = 99.79, p < .001, η_p^2 = .847, and a main effect of vehicle type, F(1,18) = 11.46, p < .005, η_p^2 = .389. There was also a main effect of time of day F(1,18) = 64.57, p < .001, η_p^2 = .782 and the used of headlights, F(1,18) = 102.73, p < .001, η_p^2 = .851. These main effects were qualified by several two-way and three-way interactions.

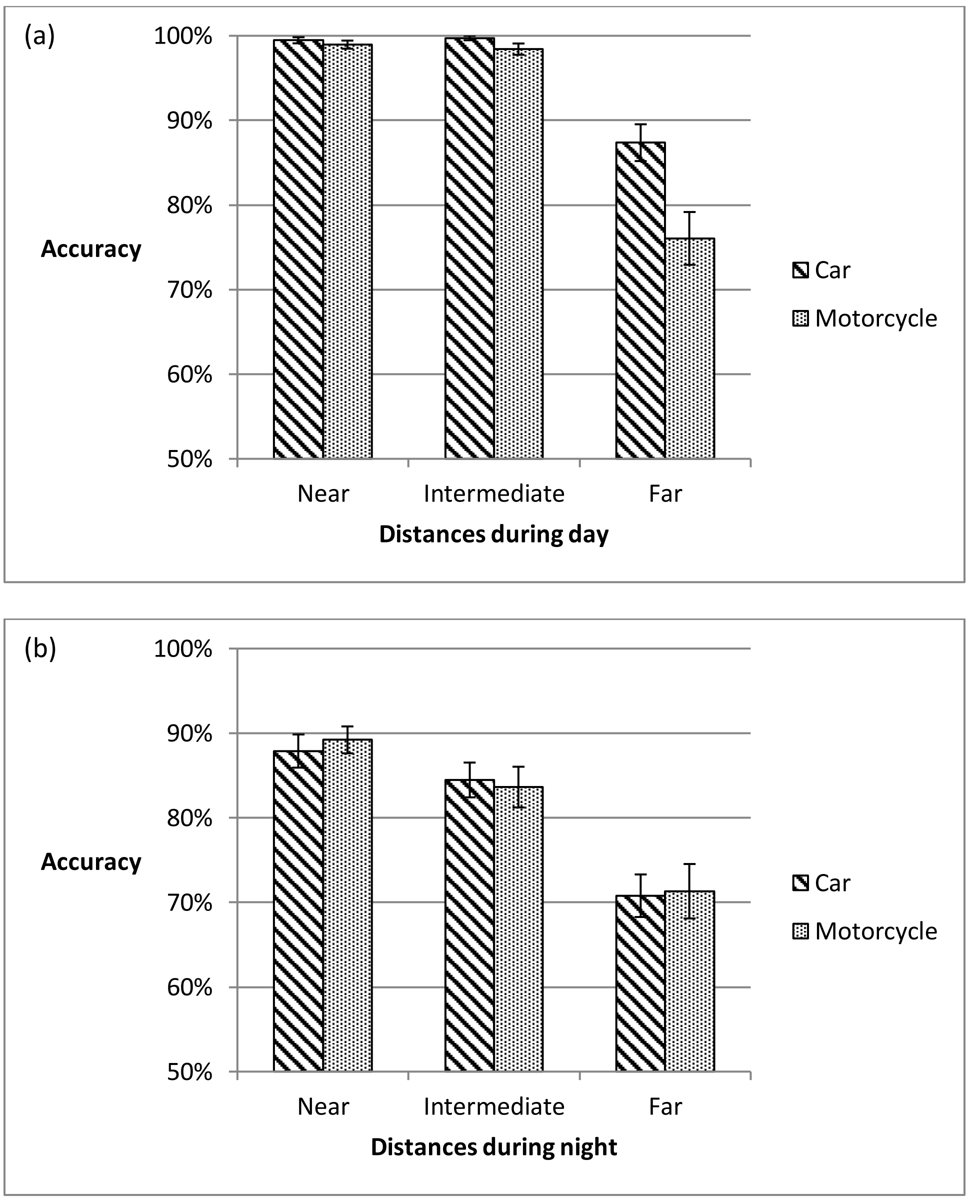


Figure 2. Drivers' percentage accuracy for perceiving approaching cars and motorcycles at different distances for (a) daytime photographs (b) nighttime photographs (error bars depict between-subjects standard error of the mean)

The first interaction was between vehicle type and vehicle distance, $F(2,36) = 4.83$, $p < .05$, $\eta^2_p = .212$; and the second interaction was between vehicle type and lighting conditions, $F(1,18) = 8.96$, $p < .05$, $\eta^2_p = .332$. These two-way interactions were subsumed by a three-way interaction between vehicle type, vehicle distance and lighting conditions, $F(2,36) = 4.77$, $p < .05$, $\eta^2_p = .209$ (see Figure 2). To further investigate the three-way interaction, two 3 x 2 ANOVAs were carried out to investigate the effect of vehicle type and vehicle distance for daytime and nighttime photographs separately. For daytime photographs, a main effect of vehicle type was found, whereby cars were easier to perceive than motorcycles, $F(1,18) = 32.70$, $p < .001$, $\eta^2_p = .645$. There was also a main effect of distance, $F(2,36) = 54.54$, $p < .001$, $\eta^2_p = .752$, where bonferroni pairwise comparisons revealed that approaching vehicles were easier to perceive at intermediate than far ($p < .001$), and near than far ($p < .001$) but there was no difference between near and intermediate locations ($p > .05$). An interaction between vehicle type and vehicle distance was also found for daytime photographs, $F(2,36) = 14.77$, $p = .001$, $\eta^2_p = .451$. Paired-samples t-tests revealed that cars were easier to perceive than motorcycles but only at the far distance, $t(18) = 4.69$, $p < .001$, $d = .966$. For nighttime photographs, only a main effect of vehicle distance was found, $F(2,36) = 38.88$, $p < .001$, $\eta^2_p = .684$. Bonferonni pairwise comparisons revealed that approaching vehicles located at near distances were easier to perceive than at intermediate ($p < .05$), intermediate were easier to perceive than far ($p < .001$), and near were easier to perceive than far ($p < .001$).

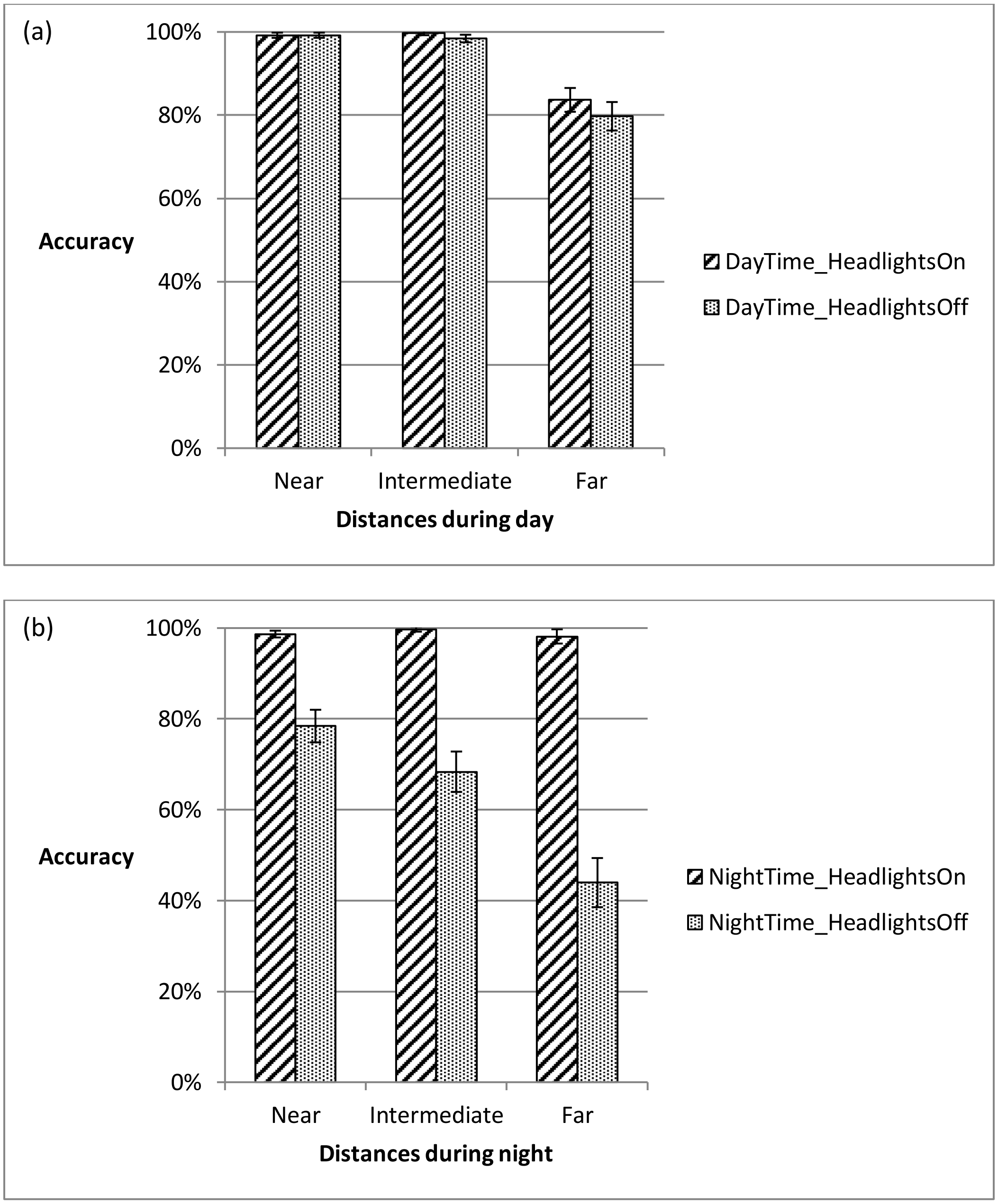


Figure 3. Drivers' percentage accuracy for perceiving approaching vehicles with the headlights on and off in (a) daytime photographs and (b) nighttime photographs at different distances (error bars depict between-subjects standard error of the mean)

There was also a two-way interaction between vehicle distance and use of headlights, $F(2,36) = 40.72$, $p < .001$, $\eta_p^2 = .003$; and another interaction was found between the lighting conditions depicted in the photographs and use of headlights, $F(1,18) = 122.88$, $p < .001$, $\eta_p^2 = .872$. These interactions were also subsumed by a three-way interaction between vehicle distance, headlights and the lighting conditions depicted in the photographs, $F(2,36) = 24.69$, $p < .001$, $\eta_p^2 = .578$ (see Figure 3). For both the daytime and the nighttime photographs there was a main effect of vehicle distance, $F(2,36) = 54.54$, $p < .001$, $\eta_p^2 = .752$ for daytime and $F(2,36) = 39.01$, $p < .001$, $\eta_p^2 = .684$. for nighttime. For daytime stimuli there was a trend towards it being easier to detect vehicles with the headlights on than off, $F(1,18) = 3.42$, $p = .08$, $\eta_p^2 = .159$ whereas for nighttime stimuli there was a much stronger main effect of headlights, $F(1,18) = 119.75$, $p < .001$, $\eta_p^2 = .869$, whereby vehicles with the headlights on were easier to perceive than those with headlights off at all three distances. For nighttime photographs there was also an interaction between vehicle distance and headlights, $F(2,36) = 42.20$, $p < .001$, $\eta_p^2 = .701$. One-way ANOVAs revealed that for nighttime photographs, there was a main effect of vehicle distance only when the headlights were off, $F(2,36) = 41.72$, $p < .001$, $\eta_p^2 = .699$, while there was no effect of vehicle distance when the headlights were on. A summary of the full analyses shown in Table 3.

Table 3. Summary of full analyses for Experiment 1

Main Effects		
Vehicle Distance	$F(2, 36) = 99.79, p < .001, \eta_p^2 = .847$	
Vehicle Type	$F(1,18) = 11.46, p < .005, \eta_p^2 = .389$	
Time of Day	$F(1,18) = 64.57, p < .001, \eta_p^2 = .782$	
Headlights	$F(1,18) = 102.73, p < .001, \eta_p^2 = .851$	
Two-way interactions		
Vehicle Type * Vehicle Distance	$F(2,36) = 4.83, p < .05, \eta_p^2 = .212$	
Vehicle Type * Time of Day	$F(1,18) = 8.96, p < .05, \eta_p^2 = .332$	
Vehicle Distance * Headlights	$F(2,36) = 40.72, p < .001, \eta_p^2 = .003$	
Time of Day * Headlights	$F(1,18) = 122.88, p < .001, \eta_p^2 = .872$	
Time of Day * Vehicle Distance	NS	
Vehicle Type * Headlights	NS	
Three-way interactions		
Vehicle Type * Vehicle Distance * Time of Day	$F(2,36) = 4.77, p < .05, \eta_p^2 = .209$	
	Day	Night
	Vehicle Type $F(1,18) = 32.70, p < .001, \eta_p^2 = .645$	Vehicle Type NS
	Vehicle Distance $F(2,36) = 54.54, p < .001, \eta_p^2 = .752$	Vehicle Distance $F(2,36) = 38.88, p < .001, \eta_p^2 = .684$
	Vehicle Type * Vehicle Distance $F(2,36) = 14.77, p = .001, \eta_p^2 = .451$ Vehicle Type only at Far	Vehicle Type * Vehicle Distance NS

	t(18) = 4.69, p < .001, d = .966	
Vehicle Distance * Headlights * Time of Day	F(2,36) = 24.69, p < .001, η^2_p = .578	
	Day	Night
	Vehicle Distance	Vehicle Distance
	F(2,36) = 54.54, p < .001, η^2_p = .752	F(2,36) = 39.01, p < .001, η^2_p = .684
	Headlights	Headlights
	F(1,18) = 3.42, p = .08, η^2_p = .159	F(1,18) = 119.75, p < .001, η^2_p = .869
	Vehicle Distance * Headlights	Vehicle Distance * Headlights
	NS	F(2,36) = 42.20, p < .001, η^2_p = .701
		Vehicle Distance only when Headlights Off
		F(2,36) = 41.72, p < .001, η^2_p = .699
Vehicle Type * Vehicle Distance * Headlights	NS	
Vehicle Type * Headlights * Time of Day	NS	
Four-way interaction		
Vehicle Type * Vehicle Distance * Time of Day * Headlights	NS	

2.3. Discussion

As in Crundall et al. (2008) and Lee et al. (2015), for the daytime photographs, drivers were more likely to perceive approaching cars than motorcycles (Walton et al., 2013) and nearer approaching vehicles than further. However, for the nighttime photographs there was no effect of vehicle type, regardless of the usage of headlights. Crundall et al. (2008) previously suggested that cars have lower spatial frequency, so are easier to perceive in peripheral vision than motorcycles which have higher spatial frequency. This difference in spatial frequency may not matter when the objects in question are very easy to perceive (nighttime with headlights on) or difficult (nighttime with headlights off). Moreover, although vehicle distance influenced perception for nighttime photos when the vehicle had the headlights off, it did not affect performance for nighttime photographs with headlights on. In this latter context, it is not clear whether drivers were able to perceive the approaching vehicles or whether their judgments were only based on the presence of lights. However, in real driving conditions, the presence of lights would almost always indicate the presence of approaching vehicles so reliance on lights as a cue to a vehicle's presence should be sufficient to avert an accident.

The first hypothesis was only partially supported in that approaching vehicles were easier to perceive in the daytime photographs than in nighttime photographs when the headlights were off, but not when the headlights were on. Likewise, headlights improved the perception of approaching vehicles in nighttime stimuli but only showed a non-significant trend towards improving perception in the daytime stimuli, offering only partial support for hypothesis 2, but consistent with the prediction that headlights would have greater effect at nighttime (hypothesis 3). This might be explained by the luminance contrast theory (Shapley & Enroth-Cugell, 1984), which suggests that the difference in brightness of the headlights and the dark background images will maximise vehicle conspicuity. Our final prediction was that the effect of DRL on detection of approaching cars may be less than for motorcycles. However, in this study headlights had no significant effect on detection during the daytime for either vehicle type – therefore the fourth hypothesis was not supported.

The findings of the current study emphasize the importance of switching on headlights while driving at night, as if there is a failure to do so, drivers will be less able to perceive them. However, for daytime stimuli, where the luminance contrast is less, participants' perception was not significantly affected by the headlights. This could be due to the brightness of the stimuli (as all photos depicted sunny days and clear weather), so switching on headlights might still increase drivers' ability to perceive during duller and rainy days. On the other hand, it is possible that there were ceiling effects for the daytime photographs, masking any advantage conferred by headlights. The fact that there was a non-significant trend towards performance being better in the daytime with headlights on suggests that there is some perceptual advantage conferred by DRL which might become more apparent if the detection task was sufficiently difficult. As recent research suggests relatively high rates of non-compliance with DRL for motorcyclists in Malaysia, despite AHO being in place for many years, the current study highlights the importance of encouraging motorcyclists to maintain their headlights in a good state of repair. Even if a driver accurately perceives an approaching vehicle, an accident could still occur if he or she makes the wrong decision about the safety of pulling out (Crundall et al., 2008). Therefore, the next study investigated how conspicuity influences safety judgments. Using the same stimuli, a modified version of the second experiment of Crundall et al. (2008) was conducted to investigate how lighting conditions depicted in the photographs and use of headlights interact with vehicle types and distances in affecting drivers' judgments about the safety of pulling out at junctions. A two-tailed hypothesis was made in relation to the effect of lighting conditions shown in the photographs. Drivers might be more likely to say they would pull out in front of vehicles in nighttime than daytime photographs due to more risk-taking behaviour (Clarke et al., 2006). Alternatively, drivers might find it harder to judge the distance of approaching vehicles in the nighttime photographs and hence be more cautious in their decisions than for daytime, and say it is less safe to pull out (first hypothesis). The second hypothesis was that if drivers are using a more cautious approach for the nighttime stimuli, they would also be more conservative in their judgments (be less likely to judge it safe to pull out) when the headlights are off than on.

3. Experiment 2: How lighting conditions depicted in the photographs and use of headlights affect drivers' judgments about the safety of pulling out at junctions

3.1. Methods

3.1.1. Participants

19 drivers (10 females and 9 males) were recruited in this experiment. Their average age was 21.68 years (S.D. = 3.2 years) ranging from 17 to 28 years old and they reported an average of 3.07 years of active driving experience since getting their driving license in Malaysia (S.D. = 3.43 years). All reported normal or corrected-to-normal vision and were not colour blind. All participants reported no experience of riding a motorcycle and they did not take part in Experiment 1.

3.1.2. Design

The design of this experiment was similar to Experiment 1. A 2 x 3 x 2 x 2 within-subjects design was used. There were four independent variables: type of approaching vehicle (car or motorcycle); distance of approaching vehicle (near, intermediate or far); the lighting conditions depicted in the photographs (daytime or nighttime); and headlights (on or off). The dependent variable was participants' judgments about whether it was safe to pull out from the junction.

A total of 300 trials (150 trials in day block and 150 trials in night block) were presented. 240 trials were presented with an approaching vehicle included and 60 trials were presented without any approaching vehicles, with three repetitions for each image (10 daytime stimuli and 10 nighttime stimuli). Counterbalancing was used whereby participants either completed the 150 trials for the daytime first, followed by the 150 trials for the nighttime or vice versa. Just like Crundall et al. (2008) and Lee et al. (2015), the fixation cross was located in the middle of the screen.

3.1.3. Stimuli and Procedure

The same stimuli from Experiment 1 were presented without catch trials. As in Crundall et al. (2008) and Lee et al. (2015), participants were asked to press 0 for "safe" to pull out and 2 for "not safe" to pull out. Picture stimuli were presented in random sequence for 5000ms each. This presentation time was used to ensure that any differences in judgments were not due to a failure to perceive the approaching vehicles and all participants made a response within the time frame. Visual feedback of the decision they made was given to the participants for each trial (e.g. "You said pull out" or "You said do not pull out"). Participants were given a practice block of 10 trials before the experiment started.

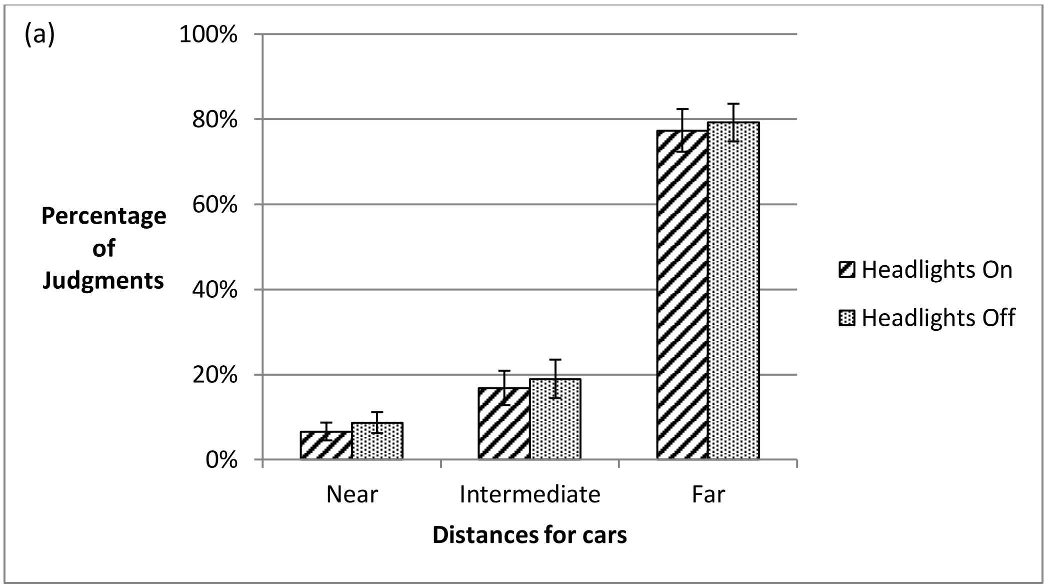
3.2. Results

The data for all 19 participants were subjected to a 2 x 3 x 2 x 2 Analysis of Variance (ANOVA) comprising percentage of judgments that it was safe to pull out in front of an approaching vehicle for different vehicle types (car or motorcycle) at different distances (near, intermediate or far), for daytime or nighttime photographs with headlights on or off. Normality test revealed that the data is not normally distributed, Kolmogorov-Smirnov, $p < .05$. As in Experiment 1, ANOVA was conducted due to the multifactorial design and its robustness in handling data which is not normally distributed (Ziegler et al., 2010). Mean percentage of judgments that it was safe to pull out in front of an approaching vehicle and standard deviations are shown in Table 4.

Table 4. Mean and standard deviation of the percentage of judgments it was safe to pull out in front of an approaching vehicle at different distances

Percentage of judgments of safe to pull out (%)	Distances	Vehicles	Daytime Photographs		Nighttime Photographs	
			Headlights On	Headlights Off	Headlights On	Headlights Off
	Near	Car	8.42 (12.14)	10.00 (11.06)	4.74 (6.12)	7.37 (10.46)
		Motorcycle	8.42 (14.25)	10.00 (12.47)	4.21 (6.07)	7.89 (10.32)
	Intermediate	Car	17.89 (17.19)	18.42 (21.15)	15.79 (18.05)	19.47 (18.40)
		Motorcycle	18.42 (21.41)	30.00 (27.29)	21.05 (22.58)	32.11 (22.99)
	Far	Car	80.00 (22.36)	84.21 (17.42)	74.74 (21.18)	74.21 (21.17)
		Motorcycle	83.16 (15.29)	84.74 (13.49)	76.32 (24.77)	77.89 (22.50)

The ANOVA identified three main effects. First, there was a main effect of vehicle distance, $F(2, 36) = 204.07$, $p < .001$, $\eta_p^2 = .919$. Secondly, there was a main effect of vehicle type, $F(1,18) = 6.27$, $p < .05$, $\eta_p^2 = .258$. Thirdly, there was a main effect of the use of headlights, $F(1,18) = 6.97$, $p < .05$, $\eta_p^2 = .279$.



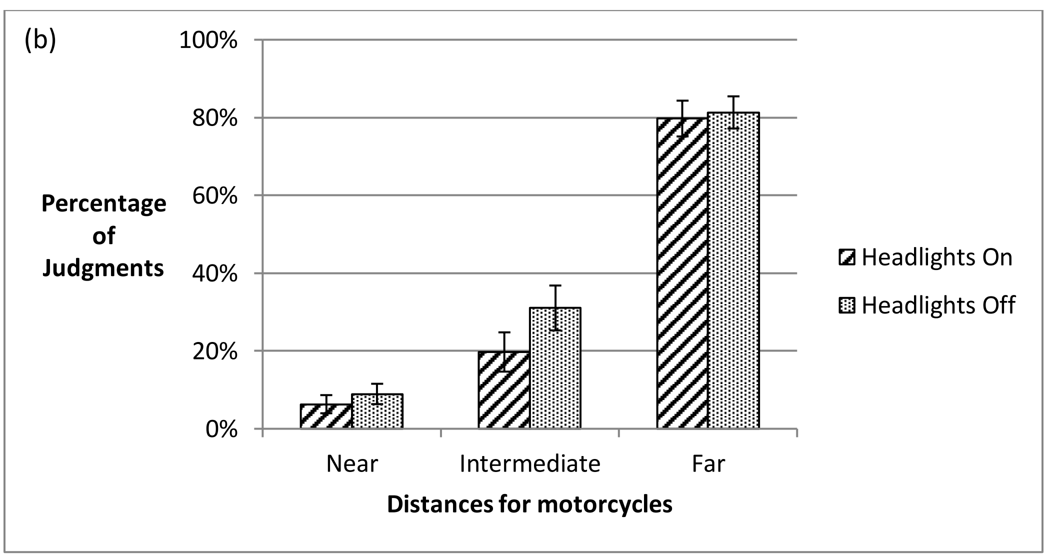


Figure 4. Percentage of judgments it was safe to pull out in front of approaching (a) cars and (b) motorcycles with the headlights on or off at near, intermediate, and far distances (error bars depict between-subjects standard error of the mean)

Two two-way interactions and a three-way interaction were found. One two-way interaction was between vehicle type and vehicle distance, $F(2,36) = 3.72$, $p < .05$, $\eta_p^2 = .154$; and the other was between vehicle type and headlights, $F(1,18) = 5.04$, $p < .05$, $\eta_p^2 = .219$. These were subsumed by a three-way interaction between vehicle type, vehicle distance and headlights, $F(2,36) = 4.11$, $p < .05$, $\eta_p^2 = .186$ (see Figure 4). This interaction appears to arise from the fact that drivers were more likely to judge it was safe to pull out in front of an approaching motorcycle with headlights off than on specifically at the intermediate distance, $t(18) = 5.64$, $p < .001$, $d = 0.712$ while no such effect was observed at the other distances or for cars at any distance. A summary of all analyses is shown in Table 5.

Table 5. Summary of full analyses for Experiment 2

Main Effects	
Vehicle Distance	$F(2, 36) = 204.07$, $p < .001$, $\eta_p^2 = .919$
Vehicle Type	$F(1,18) = 6.27$, $p < .05$, $\eta_p^2 = .258$
Time of Day	NS
Headlights	$F(1,18) = 6.97$, $p < .05$, $\eta_p^2 = .279$
Two-way interactions	
Vehicle Type * Vehicle Distance	$F(2,36) = 3.72$, $p < .05$, $\eta_p^2 = .154$
Vehicle Type * Time of Day	NS
Vehicle Distance * Headlights	NS
Time of Day * Headlights	NS
Time of Day * Vehicle Distance	NS
Vehicle Type * Headlights	$F(1,18) = 5.04$, $p < .05$, $\eta_p^2 = .219$
Three-way interactions	
Vehicle Type * Vehicle Distance * Time of Day	NS
Vehicle Distance * Headlights * Time of Day	NS
Vehicle Type * Vehicle Distance * Headlights	$F(2,36) = 4.11$, $p < .05$, $\eta_p^2 = .186$ Headlights effect only for motorcycles at intermediate distance $t(18) = 5.64$, $p < .001$, $d = 0.712$
Vehicle Type * Headlights * Time of Day	NS
Four-way interaction	
Vehicle Type * Vehicle Distance * Time of Day * Headlights	NS

3.3. Discussion

Drivers were more likely to judge it was safe to pull out in front of further approaching vehicles than nearer, consistent with previous research (Crundall et al., 2008; Lee et al., 2015). However, contrary to our first hypothesis, there was no difference in judgments made for daytime and nighttime photographs. This suggests that the more risky behaviour observed in drivers at nighttime (Clarke et al., 2006) is not because of the low luminance conditions themselves, but due to other associated factors such as higher levels of fatigue or drink-driving at this time of day. However, as the judgments were the same for nighttime and daytime photos, it also suggests that people do not adopt a more cautious approach for the stimuli with poorer lighting conditions.

Our second hypothesis was that drivers would judge it safer to pull out in front of vehicles with headlights on than off. This hypothesis was not supported and in fact, further analysis indicated that the reverse was true for motorcycles at an intermediate distance. Judgments that it is safe to pull out in front of an intermediate motorcycle decreased by about 10% when the headlights were on compared with when off, regardless of time of day. Given that there was no right or wrong answer in terms of judgment in this particular study, it is not possible to know whether switching on headlights provided drivers with a more accurate cue to a vehicle's distance. However, it does seem that drivers were more cautious about saying they would pull out in front of motorcycles with the headlights on, at least at an intermediate distance, which is the distance at which drivers showed lowest levels of agreement about whether it is safe or not. One possible explanation for this finding is that motorcycles with headlights switched on are more salient and so appear to be nearer (despite actually being at the same distance), resulting in more cautious judgments. If this is the case, then one might expect a similar effect in relation to cars with headlights on, which was not observed. However, it is still possible that the larger size of the car offers a clearer basis for judgments and so the headlights are not used as a cue to the same extent in this condition. Another possibility is that headlights are perceived as a warning, and so drivers assume that the motorcycle with headlights on is moving more quickly. However, this does not seem particularly plausible given that the effect was found with the nighttime photographs as well as daytime photographs where the use of headlights is unlikely to be interpreted as a warning.

4. General Discussion

In terms of perception, this study failed to demonstrate an increase in perceptual ability associated with Day Running Lights (DRL), which could be due to the brightness of photographs and/or ceiling effects in the current study, in which case headlights might make a difference in daytime when it is cloudy, foggy or rainy. However, headlights were found to be useful in increasing drivers' ability to perceive approaching vehicles for nighttime photographs regardless of vehicle type. This finding is in line with the luminance contrast theory, which proposes that object detection is aided by increasing the brightness contrast of the object against the background rather than solely increasing the brightness of the object per se (Hole, 1996). In terms of appraisal, drivers were more likely to judge it was safe to pull out in front of motorcycles located at an intermediate position when the headlights were off than when they were on. This is likely to be because the intermediate position is the distance which gives rise to the most indecision, perhaps giving the greatest opportunity for headlights to influence drivers' judgments. It was similarly recently demonstrated in a driving simulator study that innovative headlight configurations (vertical and combined configurations) increased drivers' gap acceptance for approaching motorcycles as compared to the standard configuration (Cavallo et al., 2015). The current study suggests that the mere use of headlights influences gap acceptance, even when no motion information is available. No difference was found in participants' judgments about approaching vehicles for the daytime and nighttime photographs. This suggests that the lighting conditions depicted in the photographs are more likely to be associated with perceptual failure than systematic differences in judgment making.

As it was particularly easy to use headlights as a cue to identify approaching vehicles during nighttime, perhaps even more so than in the daytime, this could result in lower collision rates during nighttime than during daytime. However, according to road accidents reports, this does not seem to be the case in Malaysia, where this study was conducted (Abdul Manan & Várhelyi, 2012) as well as in other countries (e.g. UK; Clarke et al., 2006). One reason may be that some road accidents which happened during nighttime were due to vehicles not having the headlights on. It was reported that in Malaysia, among 1850 motorcyclists observed on the road, 20.27% failed to switch on their headlights (Abdul Manan & Várhelyi, 2015). Although these observations were made during the daytime (and to our knowledge no similar study has been done at night), given that motorcycles in Malaysia are manufactured with Automatic Headlamp On, this may indicate that some vehicles are used with broken lights. Given the benefits of headlight use both at night and during daytime demonstrated in this study, effort will be needed to further increase motorcyclist compliance with laws on DRL in and ensuring that vehicles have fully functional headlights.

Since February 2011, there is a regulation in effect in Europe which requires automobile manufacturers to equip AHO for all vehicles – not just motorcycles (SWOV, 2013). However, there are concerns that car DRL might decrease the visual conspicuity of motorcycles, making them harder to detect (e.g., Knight et al., 2006) and create "visual noise" (Cavallo & Pinto, 2012). It was demonstrated in this study that DRL is not particularly beneficial for cars in terms of either increasing others' ability to perceive them or altering judgments made about them. If DRL on cars decreases drivers' ability to detect motorcycles, the implementation of DRL on cars should be reconsidered. However, this study revealed that the DRL did decrease drivers' judgments that it was safe to pull out in front of motorcycles, which suggests that the usefulness of DRL may be related to decision-making for motorcycles. As this study recruited a fairly homogenous group of young and relatively inexperienced drivers, future work would be needed to determine whether highly experienced drivers are similarly influenced by headlights and lighting conditions.

In summary, this study failed to demonstrate that use of headlights increases drivers' ability to perceive the approaching vehicles during daytime, but this could be due to ceiling effects and the sunny and clear weather when the photographs were taken. In addition, we found that the use of headlights decreases drivers' tendency to judge it was safe to pull out in front of approaching motorcycles regardless of time of day, supporting the utility of DRL for motorcycles, suggesting that the DRL might not only play a role in drivers' perception but also in safety judgment. In terms of application, switching on headlights at night (low luminance conditions) should be encouraged as it increases drivers' ability to perceive approaching vehicles. This study also shows the importance of DRL in motorcycles and demonstrated that the usage of headlights especially during nighttime driving should be reinforced. This is important in developing countries where motorcyclist fatalities tend to be high and in countries where the compliance rate in switching on headlights at night time is reported anecdotally to be low (e.g. Phillipines, Zimbabwe, China) (http://mmda.gov.ph/18-news/news-2011/332-mmda-make-sure-your-lights-are-on ; http://factsanddetails.com/China/cat13/sub86/item409.html ; http://www.herald.co.zw/letthere-be-headlights-please/). Although most motorcycles are now manufactured with AHO, this does not apply everywhere in the world, and especially not in low and middle-income countries (OCED/ITF, 2015). More advanced technologies such as the 'high-beam assist' help to automatically adjust between high and low beam headlights depending on the presence of other vehicles (Reagan et al., 2016). In conclusion, DRL should be implemented especially for motorcycles and the importance of having headlights switched on should be stressed in many countries, especially those countries which have high motorcyclist fatality rates. In addition, new technologies that assist road users to use their headlights appropriately should be applied.

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