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Role of sensory and cognitive conspicuity in the prevention of collisions between motorcycles and trucks at T-intersections

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ABSTRACT

Motorcyclists are particularly vulnerable to injury in crashes with heavy vehicles due to substantial differences in vehicle mass, the degree of protection and speed. There is a considerable difference in height between motorcycles and trucks; motorcycles are viewed by truck drivers from downward angles, and shorter distances between them mean steeper downward angles. Hence, we anticipated that the effects of motorcycle conspicuity treatments would be different for truck drivers. Therefore, this study aims to evaluate the effects of motorcycle conspicuity treatments on the identification and detection of motorcycles by truck drivers. Two complementary experiments were performed; the first experiment assessed the impact of motorcycle sensory conspicuity on the ability of un-alerted truck drivers to detect motorcycles, and the second experiment assessed the motorcycle cognitive conspicuity to alerted truck drivers. The sensory conspicuity was measured in terms of motorcycle detection rates by un-alerted truck drivers when they were not anticipating a motorcycle within a realistic driving scene, while the cognitive conspicuity was determined by the time taken by alerted truck drivers to actively search for a motorcycle. In the first experiment, the participants were presented with 10 pictures and were instructed to report the kinds of vehicles that were presented in the pictures. Each picture was shown to the participants for 600 ms. In the second experiment, the participants were presented with the same set of pictures and were instructed to respond by clicking the right button on a mouse as soon as they detected a motorcycle in the picture. The results indicate that the motorcycle detection rate increases, and the response time to search for a motorcycle decreases, as the distance between the targeted motorcycle and the viewer decreases. This is true regardless of the type of conspicuity treatment used. The use of daytime running headlights (DRH) was found to increase the detection rate and the identification of a motorcycle by a truck driver at a farther distance, but effect deteriorates as the distance decreases. The results show that the detection rate and the identification of a motorcyclist wearing a black helmet with a reflective sticker increases as the distance between the motorcycle and the truck decreases. We also found that a motorcyclist wearing a white helmet and a white outfit is more identifiable and detectable at both shorter and longer distances. In conclusion, although this study provides evidence that the use of appropriate conspicuity treatments enhances motorcycle conspicuity to truck drivers, we suggest that more attention should be paid to the effect of background environment on motorcycle conspicuity.

1. Introduction

In 2012, there were 6230 road deaths in Malaysia, of which about 60% were motorcyclists. The vulnerability of motorcyclists is largely due to substantial differences in vehicle mass and speed between motorcycles and other motor vehicles. Hence, motorcycles are particularly vulnerable when they collide with trucks. According to the Malaysian traffic police road crash statistics, approximately 13% of motorcyclist deaths were the result of collisions with trucks; 40% of which were the result of side collisions between trucks and motorcycles.

In road safety literature, the human factor is identified as the main contributor to road crashes involving motorcycles (ACEM, 2009). More than half of these crashes are due to the late or failed

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detection of motorcycles, which can be attributed to perceptual human errors, such as the failure to perceive the motorcycles within the dynamic traffic environment, and low conspicuity and visibility (ACEM, 2009; Williams and Hoffmann, 1979). An automobile-motorcycle crash most commonly results when an automobile pulls out of a side road into the path of an oncoming motorcycle, without giving the right of way to the motorcycle (Clarke et al., 2007; Hancock et al., 1990; Wulf et al., 1989). This phenomenon is commonly known as the "*look but failed to see*" error (Brown, 2002; Crundall et al., 2012; Shahar et al., 2012; Williams and Hoffmann, 1979). This psychological phenomenon is termed inattentional blindness, which is defined as the failure to perceive an unexpected salient visual stimulus because attention was focused on another attentionally demanding task (Mack and Rock, 1998). Thus, the overrepresentation of motorcyclist deaths in side collisions between trucks and motorcycles is probably because truck drivers fail or are late to detect the approaching motorcycle when they pull out from a minor road into the path of an oncoming motorcycle.

Prior studies reveal that the low detectability of motorcycles is because, by nature, motorcycles are less conspicuous than larger vehicles (Thomson, 1980; Wulf et al., 1989; Hancock et al., 1990; Olson et al., 1981). Conspicuity is defined as the ability a feature has, given its characteristics, to capture an observer's attention, and to be easily located under existing conditions (Wulf et al., 1989). Conspicuity can be determined by two factors, which are sensory and cognitive conspicuity (Engel, 1971, 1976; Hancock et al., 1990). Sensory conspicuity refers to the ability of an object to be distinguished from a given background when an observer is not intentionally looking for it (Hancock et al., 1990). It is dependent on the physical or bottom-up properties of an object, such as object background contrast, location and motion. Cognitive conspicuity indicates the capacity of a target to be located when the observer is deliberately searching for it (Langham and Moberly, 2003). This involves top-down attentional processes and is influenced by the observer's expectations, objectives and knowledge.

Another explanation of the low detectability of motorcycles is that motorcycles require more processing capacity than larger vehicles due to their lower conspicuousness, greater manoeuvrability, additional visual complexity and unpredictable movement (Crundall et al., 2012; Shahar et al., 2012). Moreover, car drivers perceive that larger vehicles pose more of a threat than motorcycles, and thus they put less effort into searching for motorcycles (Mannering and Grodsky, 1995). According to the perceptual theory (Lavie, 1995, 2005), there is only finite amount of perceptual capacity and all task-relevant and −irrelevant stimuli are processed automatically until this capacity is exhausted. If the perceptual load of a task is high, most of the attentional resources are devoted to the processing of higher-priority information, and leave no capacity for the processing of lower-priority information. In contrast, for a task with low perceptual load, only minimal attentional resources are allocated to process the higher-priority information, and the spare resources will spill over to process lower-priority information.

Available studies in road safety literature reveal that motorcycle crash risk is associated with the conspicuity of the motorcyclist (Peek-Asa and Kraus, 1996; Brenac et al., 2006; Gershon et al., 2012). Previous studies show that reflective materials, bright outfits and helmets can improve the conspicuity of motorcyclists (Olson et al., 1981; Hole et al., 1996; ACEM, 2004; Wells et al., 2004; Shinar, 2007). However, the effectiveness of these conspicuity treatments is dependent on the contrast between the motorcyclist and the background environment (Hole et al., 1996; Shinar, 2007; Gershon et al., 2012). For example, Gershon et al. (2012) pointed out that in urban roads, where the background surrounding the motorcycle was more complex and multi-coloured, a motorcyclist wearing a reflective or white outfit was more detectable than a motorcyclist wearing a black outfit. Conversely, in inter-urban roads, where the background was solely a bright sky, a motorcyclist wearing a black outfit was more detectable than a motorcyclist wearing a reflective or white outfit. Wells et al. (2004) indicates that the enhancement of motorcyclist conspicuity results in the reduction of motorcycle accidents by 37%. Moreover, in urban environments, drivers accept larger gaps to cross or merge into the major road (Olson et al., 1981), and respond sooner to a motorcycle (Hole et al., 1996) when the motorcyclist is wearing a bright or reflective outfit, compared with a motorcyclist wearing a dark outfit.

Several previous studies indicated that the use of DRH enhances motorcycle conspicuity by increasing its contrast with the background (Thomson, 1980; Brouwer et al., 2004; Olson et al., 1981; Shinar, 2007; Torrez, 2008). The use of DRH is associated with improving drivers' speed-distance judgments of motorcycles (Koornstra et al., 1997) and increases motorcycle detection rate (Hole et al., 1996; Janoff and Cassel, 1971; Fulton et al., 1980). However, the effectiveness of DRH is dependent on the speed of the motorcycle (Howells et al., 1980), the distance of the motorcycle from the viewer and environmental factors (Hole et al., 1996). Hole et al. (1996) revealed that DRH is more effective in increasing motorcycle conspicuity in semi-rural environments compared with urban environments. In addition, they also indicated that DRH enhances conspicuity only when the proximity of a motorcycle to the viewer exceeds a specified distance. Previously published studies provide evidence that the use of DRH reduces the risk of serious injury or fatality to motorcyclists (Wells et al., 2004), and also that conspicuity-related motorcycle accidents are reduced after the implementation of DRH legislations (Radin Umar et al., 1996; Radin Umar, 2005; Yuan, 2000; Quddus et al., 2002).

In view of the considerable difference in height between motorcycles and trucks; motorcycles are viewed by truck drivers from downward angles, and shorter distances between them mean steeper downward angles. Hence, we anticipated that the effects of motorcycle conspicuity treatments would be different for truck drivers. Therefore, the aim of this study is to evaluate the effects of motorcycle conspicuity treatments on the identification and detection of motorcycles by truck drivers. Two complementary experiments were performed; the first experiment assessed the impact of motorcycle sensory conspicuity on the ability of un-alerted truck drivers to detect motorcycles, and the second experiment assessed the motorcycle cognitive conspicuity to alerted truck drivers. The sensory conspicuity was measured in terms of motorcycle detection rates by un-alerted truck drivers when they were not anticipating a motorcycle within a realistic driving scene, while the cognitive conspicuity was determined by the time taken by alerted truck drivers to actively search for a motorcycle. In light of this, the following hypotheses were tested.

Hypothesis 1. A motorcycle with DRH is less detectable and identifiable by truck drivers as the distance between them decreases.

Previous studies, which consistently suggested that the use of DRH for motorcycles significantly increases a motorcycle's conspicuity to car drivers, have not examined a similar effect on truck drivers. One reason for this concern is that the seating height of truck drivers is considerably higher than a motorcycle headlight, especially at a shorter distance between them. The truck drivers look at the headlight from a larger angle, and hence, it was anticipated that the use of DRH would enhance a motorcycle's conspicuity at a longer distance, but diminish as the motorcycle got closer to the truck. This can be illustrated in Fig. 1.

Hypothesis 2. A motorcyclist wearing a black helmet with a reflective sticker would increase the detection rate and identification by truck drivers when there was a shorter distance between them.