



# Motorcycle Conspicuity Issues and Intervention: A Systematic Review

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## Abstract

**Background:** Conspicuity has been one of the key factors in motorcycle road crashes around the world. The inability and difficulty of other road users in detecting motorcycles either at day or at night have contributed to conspicuity related motorcycle crashes. This literature review attempts to understand the motorcycle conspicuity issues in road traffic. The review also analyses relevant types of conspicuity intervention in terms of its effectiveness in enhancing motorcycle conspicuity that had been discussed in past studies.

**Methods:** Using specific keywords and search terms, relevant articles were screened, identified and analyzed systematically using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

**Results:** Twenty-seven final articles were reviewed and found that almost every part of motorcycle and motorcyclist's conspicuity intervention have been covered in past studies. In terms of conspicuity aids, the majority of past studies discussed conspicuity enhancement in the frontal area, particularly on motorcycle daytime running headlight (DRH) color and configurations. Few other studies have discussed in other areas, particularly on rear running and brake light and motorcycle color. There were also numerous studies looking at motorcyclists' appearances in terms of their attire and helmet color.

**Conclusion:** Motorcycle and motorcyclist's appearances are highly associated with the risk of motorcycle crashes. The most important part of enhancing motorcycle conspicuity is to ensure motorcycle appearance is always in contrast with the road traffic environment.

**Keywords:** Conspicuity; Motorcycle conspicuity; Motorcyclist conspicuity; Motorcycle safety; Road safety

## Introduction

In recent years, road traffic injuries and fatalities involving motorcycle users have been a growing concern worldwide (1–10). The WHO reported that road accident has contributed to more than 1.2 million of deaths all around the globe and it may be the leading cause of premature death if there is no action taken (11–16).

In Malaysia, the motorcyclists' death figures remain more than 60% for many years and the trend does not show any signs of improvement despite the various initiatives and interventions that have been carried out from national to community levels (1, 17). Previous researches had looked into various perspectives of motorcycle safety including road environment and road types

(2, 3, 6), helmet-wearing (10, 18–21), speeding and motorcyclist behaviors on roads (2, 6, 10, 22–24).

One of the prevalent factors associated to the high crash rates among motorcyclists is the conspicuity issue of the motorcycles and motorcyclists in which they were unnoticeable by other road users (1, 25). The study classified conspicuity related crashes as “any crash involving motorcycles moving straight or turning with the right of way when pedestrians and other vehicles cross their paths” (1, 25). Such crashes constituted about 26% of the total fatalities (1, 2, 25). Motorcycle conspicuity is commonly associated with one of these three definitions: the ability for motorcycle to be detected when the location is known (visibility), when it has to be searched within a scene (search conspicuity), and when it is not deliberately searched although the observer is viewing the scene (attention conspicuity) (26). Usually, an observer is able to see the motorcycle clearly if the vehicle is expected to appear in a certain direction. However, the characteristic of motorcycle riding with multi-directional movement (non-lane based and frequently changing

lane position) has diminished anticipation by other road users, particularly from the peripheral visual field. In a mixed-traffic environment, such characteristics may likely make motorcycles more susceptible to crashes (27–30).

The purpose of this literature review attempted to understand the motorcycle conspicuity issues in road traffic. We analysed relevance and types of conspicuity intervention programs that have been implemented and highlight the findings and effectiveness in enhancing motorcycle conspicuity in an effort to reduce the risks of motorcycle conspicuity related crashes.

## Methods

Background searches were done by utilizing online databases. The searches commenced in the whole month of Dec 2018 using appropriate keywords selected randomly yet related to motorcycle conspicuity and visibility issues as described in Table 1. In this review, only articles published from the year 2000 until 2018 were included.

**Table 1:** Keywords or search terms used in articles searching

| <i>Databases</i>   | <i>Group</i>                      | <i>Keywords/search terms</i>  |
|--|-----------------------------------|---|
| Google Scholar, Scopus, PubMed, Science Direct, IEEE, SAGE | Vehicle                           | Motorcycle, motorbike, Moped, powered two-wheeler, PTW, two-wheeled vehicles  |
|  | User                              | Motorcyclists, riders, bikers   |
|  | Condition/ Issue/ Conspicuity aid | Conspicuity, visibility, reflective, colour, identification, headlamp, headlight, taillamp, taillight, lamp, light, daytime running light (DRL), daytime running headlight (DRH), daytime running taillight (DRT), brake light, attire, cloth, helmet |

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline was implemented in selecting related and quality articles (31, 32) and the process described in Fig. 1. Articles can be considered relevant if they met all of the following criteria:

1. Published or accepted proceedings, journal articles, and reports;

2. Related to motorcycle conspicuity issues;
3. Discussion on intervention or recommendation in improving motorcycle conspicuity; and
4. Positive outcome or findings from the experiments, other methods, and approaches.

Selected articles were analyzed and recorded into a data extraction form in Excel format. Data

were categorized and extracted accordingly to each element including title, authors, objectives,

and scope of the study, methodologies, area of study, results, discussions, and findings.

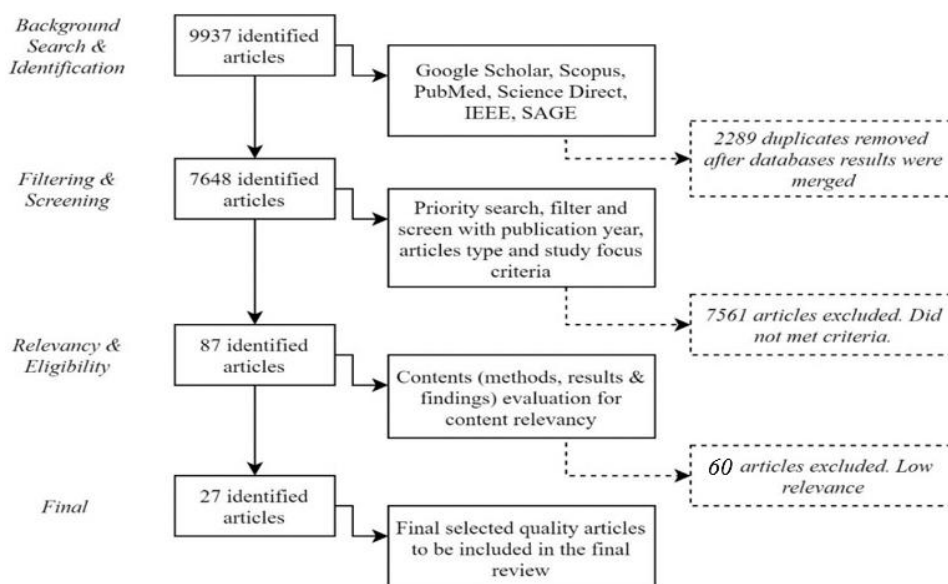


Fig. 1: The articles selection process for inclusion in the systematic review

### Results and Discussion

Almost ten thousand related articles were found during the background searches. Duplicates were removed while the remaining 7648 articles were screened further. Using priority level assessment, further screening continued using the advance search settings in all databases. Only 87 related articles managed to be identified after the searches were filtered with the selection criteria. The final screening was done to the remaining articles for content relevancy. Twenty-seven final quality articles were selected to be assessed and

reviewed. The reviewed articles were tabulated according to the conspicuity aid covered in each study.

Six categories of conspicuity aids had been covered in previous studies, which are daytime running headlight (DRH), daytime running taillight (DRT), and motorcycle body whereby all of these aids are considered under motorcycle conspicuity scope (Tables 2-4). Meanwhile, for motorcyclists, attire, and helmet were the aids variables covered under this group (Fig. 2).

Table 2: Details of articles related to conspicuity aid on motorcyclist’s scope only

| <i>Authors</i>        | <i>Conspicuity Aid Measures</i> | <i>Method/Study Design</i> | <i>Sample Size</i> | <i>Main Findings</i>   |
|-----------------------|---------------------------------|----------------------------|--------------------|--|
| Gershon et al (33)    | Attire & Helmet                 | Image clips                | 64                 | An appropriate outfit that distinguishes rider from the background scenery can improve PTW conspicuity |
| Gershon & Shinar (34) | Attire & Helmet                 | Video clips                | 20                 | Environmental context has a strong effect on the probability of detecting the PTW                      |
| Rogé et al (35)       | Attire                          | Driving simulator          | 43                 | Yellow jacket is insufficient as a visibility aid  |

**Table 3:** Details of articles related to conspicuity aid on motorcycle scope only

| <i>Authors</i>                  | <i>Conspicuity Aid Measures</i> | <i>Method/Study Design</i> | <i>Sample Size</i> | <i>Main Findings</i>  |
|---------------------------------|---------------------------------|----------------------------|--------------------|---|
| Farmer & Williams (36)          | DRH                             | Accident data              | n/a                | Vehicles with DRL involved in 3.2% fewer multiple-vehicle crashes than without DRL  |
| Binder et al (37)               | DRH                             | Real driving               | 25                 | DRL with modulating lights provide better conspicuity aid to the driver compared to normal and without DRL  |
| Smither & Torrez (38)           | DRH                             | Video clips                | 150                | The effective detection of motorcycles is associated with motorcycle DRL and lighting   |
| Pai (39)                        | DRH                             | Literature review          | n/a                | Lack of motorcycle conspicuity is one of the major causes of the crash  |
| Rößger et al(30)                | DRH                             | Video clips                | 56                 | Motorcycles with a T-shaped light configuration is more quickly identified  |
| Cavallo & Pinto (40)            | DRH                             | Image clips                | 24                 | Motorcycle detection is hampered by car DRL   |
| Ledbetter et al (27)            | DRH                             | Video clips                | 100                | Motorcycles with headlights on and modulating headlights are more conspicuous   |
| Mitsopoulos-Rubens & Lenné (41) | DRH                             | Driving simulator          | 23                 | Motorcycles with headlights on benefit drivers' decision compared to headlights off   |
| Cavallo & Pinto (28)            | DRH                             | Image clips                | 24                 | Car DRLs have affected motorcycle detection in mix traffic scenarios  |
| Mohd Khairudin et al (42)       | DRH & DRT                       | Real driving               | 15                 | APL introduction may enhance motorcycle conspicuity especially for rear lamp position   |
| de Craen et al (43)             | Motorcycle Body                 | Accident data              | n/a                | No significant difference between dual-drivers and regular car drivers in terms of interaction and detection towards motorcycle   |
| Mohd Khairudin et al (44)       | DRH & DRT                       | Video clips                | 52                 | APL implementation improves motorcycle conspicuity  |
| Davoodi & Hosayni (45)          | DRH & DRT                       | Literature review          | n/a                | Motorcycle DRLs managed to reduce about 4 to 20% of motorcycle crash risk   |
| Ranchet et al(29)               | DRH                             | Image clips                | 57                 | Standard yellow configuration and the vertical yellow configuration improved motorcycle detectability   |
| Crundall et al (4)              | Motorcycle Body                 | Image clips                | 60                 | Perceptual training for motorcycle detection helps to improve driver safety   |
| Costa et al (46)                | Reflective Tape                 | Real driving               | 16                 | Reflective tape applied to the rear of a bicycle can increase bicycle conspicuity and safety at night   |
| Lee & Sheppard (47)             | Motorcycle Body                 | Image & Video clips        | 17                 | Error in judgment most likely to happen to motorcycles than other vehicles due to its size  |
| Lee & Sheppard (9)              | DRH                             | Image clips                | 19                 | Drivers judged it is less safe to pull out when approaching motorcycles had headlights on than off, regardless of the lighting conditions. Headlights do not affect judgments for cars. |

**Table 4:** Details of articles related to conspicuity aid on both motorcycle and motorcyclist's scope

| <i>Authors</i>          | <i>Conspicuity Aid Measures</i>                  | <i>Method/Study Design</i> | <i>Sample Size</i> | <i>Main Findings</i>   |
|-------------------------|--|----------------------------|--------------------|--|
| Wells et al (48)        | DRH, Attire & Helmet                             | Accident data & interview  | 1233               | Low conspicuity may increase the risk of motorcycle crash-related injury   |
| de Craen et al (43)     | DRH, Attire & Helmet                             | Accident data              | n/a                | Changing the appearance of a motorcycle or its rider may improve motorcycle detection in traffic and reduces risks of crashes  |
| Shaheed et al (49)      | DRH, Attire & Helmet                             | Accident data              | n/a                | Failure to yield ROW, light conditions and other conspicuity variables play significant roles in motorcycle crash-injury outcome   |
| Rogé et al (50)         | Motorcycle Appearance, Attire & Helmet           | Driving simulator          | 42                 | High level of color contrast-enhanced the visibility of motorcycles  |
| Shaheed et al (51)      | DRH & Attire                                     | Driving simulator          | 36                 | Motorcycles with modulating headlights have longer detection distances than high beams or DRLs   |
| Helman et al (26)       | DRH, Attire & Helmet                             | Literature review          | n/a                | High visibility and reflective clothing, and headlights or DRL on motorcycles, have been effective in increasing motorcyclist conspicuity                                      |
| Pinto et al (28)        | DRH, Attire & Helmet                             | Image clips                | 60                 | Motorcycle detection performance improved with a yellow headlight and helmet configuration   |
| Mohd Syazwan et al (52) | DRH, Attire & Helmet                             | Field observation          | 950                | Wearing bright attire and adding a helmet reflector could improve the conspicuity of a motorcyclist while riding   |
| Rogé et al (53)         | DRH, DRT, Motorcycle Appearance, Attire & Helmet | Driving simulator          | 34                 | The film (safety messages) enhances VRU visibility and leads to safer driving behavior   |
| Law et al (7)           | Motorcycle Appearance, Attire & Helmet           | Video clips                | 64                 | Motorcyclists wearing a white helmet and riding a motorcycle with DRH, as well as motorcyclists wearing a white helmet and white outfit, would improve truck drivers' judgment |
| Law et al (13)          | DRH, Attire & Helmet                             | Image & Video clips        | 100                | Motorcyclists wearing a white helmet and white outfits is more identifiable and detectable at both shorter and longer distances  |

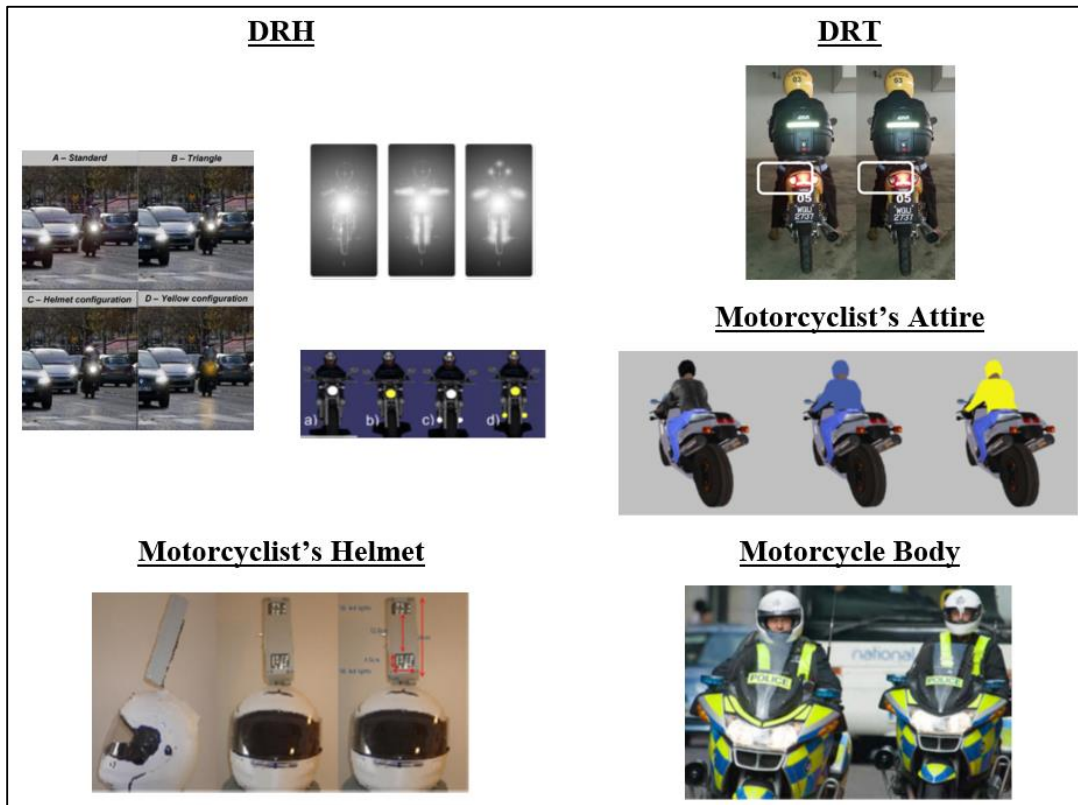


Fig 2: Conspicuity aids measure in the past researches (25, 26, 28, 29, 33, 34)

### ***DRH***

The majority of the articles found were evaluating and assessing the use of motorcycle lighting in improving motorcycle conspicuity from the front area. DRH is the part that most of the studies have assessed where its effectiveness was discussed. Based on the review, it is believed that motorcycle DRH has effectively contributed to better motorcycle conspicuity and detection (27, 36, 38, 41).

From accident data analysis and literature review, it was found that motorcycle with DRH will reduce crash risk and involvement in road crashes (36, 43, 45, 48, 51, 52).

However, manufacturers of current private vehicles have widely introduced the DRL on their vehicles and it can be seen that recent models are equipped with DRL. This suggested that the adoption of DRL to other vehicles may affect motorcycle detection and thus, increase the risk of motorcycle-related crashes especially in a mix mode traffic situation (26). In the past study,

Cavallo & Pinto (40) investigated the effects of the car DRL on motorcycle perception and detection. Twenty-four participants undergo the image clips test represents a complex urban traffic scene with mix vehicle mode at different locations and distances. The result indicated that motorcycle detection is hampered by car DRL. It gets worse when the motorcycle is located at a further distance as the size of a motorcycle is smaller thus less visible and detectable in the mix mode traffic scene (39, 40, 47).

To cater to the mix mode traffic issues, several studies have invented a new configuration for motorcycle DRH by changing the design and function. A new frontal light configuration was designed for motorcycles in order to identify the best pattern to improve motorcycle Conspicuity (30). Three lights configurations comprised of normal DRL, T configuration lights with DRL and T configuration plus helmet lights with DRL were analyzed using video clips of real traffic scene. The findings concluded that motorcycles

with T configuration plus helmet lights with DRL could be identified quicker than other configurations. However, it may cause a glare distraction towards other road users.

On the other hand, Pinto et al (28) and Ranchet et al (29) modified the headlight color and configurations in order to identify the effects of different headlight configurations on motorcycle detectability at different perspectives. Both studies have modified to yellow headlight color and vertical configuration includes helmet and comparing it with normal configuration. Both studies implemented image clips of real traffic scene. Motorcycle detection performance improved with yellow headlights and helmet configurations compared to standard configurations in mix mode traffic situations (28). Meanwhile, vertical yellow configuration has benefitted motorcycle detectability (29).

Other studies (27, 51) evaluated the effect of headlight configuration by adding modulating headlights on motorcycle conspicuity and safety. Ledbetter et al (27) utilized video clips of real traffic scene to 100 participants while Mohammad Saad Shaheed et al (51) utilized driving simulator to 36 participants in their experiments. Both studies identified that by adding modulating headlights with DRH, motorcycle detection distance is higher than standard DRH.

Based on the review on motorcycle DRH, it is suggested that several interventions were discussed to improve motorcycle conspicuity. First, it is to ensure the motorcycle DRH to always function. Second, in mix mode traffic with other vehicles equipped with DRH, modify or change the DRH color to other colors that can differentiate motorcycle from other vehicles. Finally, improving the current DRH design by adding new configuration designs such as triangle, vertical, T configurations with lights or by adding modulating headlights may help to distinguish motorcycles in mix mode traffic.

### ***DRT***

Only two articles found to have assessed the motorcycle conspicuity from the rear area. Mohd Khairudin et al (42) evaluated the conspicuity

level of motorcycles from its DRT with the addition of Amber Position Lamp (APL) to enhance conspicuity from the rear. Fifteen participants involved in the real observation method. The findings suggested that APL introduction might enhance motorcycle conspicuity and improve their detectability from the rear. However, it may cause confusion towards other road users as it may affect the turn signal detection.

Mohd Khairudin et al (44) again repeated the study in order to identify the effect of APL on turn signal detection. Video clips of traffic scenes were used to assess 52 participants' responses. The results of this study concluded that APL does have a relationship with conspicuity enhancement. However, APL introduction appeared to result negatively on the turn signal as it caused confusion towards participants.

Based on the review, it can be concluded that there is still a lack of motorcycle conspicuity intervention in the rear area. Furthermore, it is believed that the motorcycle rear area has contributed to conspicuity issues as much as frontal. Besides, the addition of APL on DRT may enhance rear conspicuity; however, it may affect and confuse other road users.

### ***Motorcycle Body***

Nevertheless, motorcycle appearance in terms of its color and presentation is another area that can be looked into in improving motorcycle conspicuity.

Through analysis of accident data, changing motorcycle appearances has improved motorcycle detection in traffic and risks to crashes(43).

A study from Rogé et al (50) revealed the same findings where participants were able to detect motorcycle further when motorcycle color contrast is high. The findings of both studies revealed that high-level color contrast between a motorcycle and the environment has significantly contributed to motorcycle detection.

Mohd Syazwan et al (52) carried out a field observation and a survey to assess conspicuity contribution towards motorcycle crashes. The findings suggested that the risks of motorcycle crash-

es could reduce by using brighter motorcycle color.

On the other hand, Costa et al (46) conducted a conspicuity enhancement experiment by using reflective tape applied to the rear area of a bicycle. By employing real driving method, the study found that bicycle with reflective tape is more detectable than otherwise. Thus, a parallel outcome is expected if the experiment is done on a motorcycle.

Therefore, motorcycle appearance is also important in improving its conspicuity. What more important is a motorcycle has to be in contrast with the environment to be more detectable. Reflective tape can also be used as a conspicuity enhancement especially at night time.

### ***Motorcyclist's Appearances***

Motorcyclist's appearances on the road play an important role in improving their conspicuity. Furthermore, it is believed that the use of fluorescent, bright or reflective colors of attire in day and night time may improve motorcyclist conspicuity (26). Several studies have been carried out on motorcyclist's appearances in search of the best solution to motorcycle conspicuity.

From accident data, De Craen et al (43) and Wells et al (48) conducted a case-control study in exploring the role of motorcyclist conspicuity on motorcycle crashes. The findings of both studies found that changing the motorcyclist appearances by wearing reflective or fluorescent color of attire and brighter color of helmets have improved motorcycle detection and reduced motorcycle crash risks. The only way to improve motorcyclist conspicuity is by changing motorcyclists' appearances and concluded that high visibility and reflective attire color selection have effectively increased motorcycle conspicuity (26). Meanwhile, field observation and survey conducted by Mohd Syazwan et al (52) to 950 motorcyclists found that wearing a brighter color of attire and helmet with reflector could possibly improve motorcyclists' conspicuity.

Law et al (7) investigated the judgment on motorcycle time-to-arrival (TTA) with different motorcycle conspicuity treatments. Sixty-four truck

drivers participated in the study by analysing the video of traffic scenes view from a truck. The study suggested that motorcyclists wearing a white helmet and white outfit would improve truck drivers' judgment on motorcycle TTA. In 2016, Law et al (13) again repeated the same conspicuity treatment variables to evaluate its effect on the identification and detection of motorcycles among truck drivers. The same method with the addition of image clips was employed to 100 truck drivers. The finding showed a similar outcome where motorcyclists with a white helmet and outfit are more identifiable and detectable at both shorter and longer distances.

In other studies, (33) (34) evaluated the powered-two-wheelers' (PTW) attention and search conspicuity from other viewers perspective. Through image clips (33) and video clips of traffic scenes (34), the results from both studies proved that higher detection rates were found when PTW is wearing a white and reflective color outfit. Thus, the findings discover that the conspicuity of a PTW can be enhanced by using appropriate motorcyclists' outfit colors that distinguish them from the environment.

A review of past studies on motorcyclist conspicuity suggested that motorcyclist's appearances are highly associated with the risk of motorcycle crashes. With brighter appearances, motorcyclists can be detected easier compared to normal motorcyclists. However, it depends on the environment as darker outfits may benefit motorcyclists at day time (26, 33, 34). What more important is that motorcyclist's appearances always contrast with the environment and it may help in improving motorcycle conspicuity.

### ***Others***

A few studies examined some more novel approaches. Rogé et al (53) used a film of safety messages during a driving experiment to look for the possibility of enhancing motorcycle and pedestrian (VRU) detectability. Two groups of 17 motorists participated in two VRU detection tasks whereby each group was given different treatment during the break between task one and task two. The outcome of the study showed that



the group that was presented with a film of safety messages during the break was able to detect VRU better than the other group which suggested that the film has successfully enhanced VRU detectability.

Image clips of traffic scenes were used by Crundall et al (4) as a perceptual training for car drivers in order to identify whether perceptual training may improve their abilities to detect motorcycle. Thirty car drivers and 30 dual drivers participated in the experiment whereby two groups were formed and undergo two different stimuli of Pelmanism-based training: one group have to match motorcycle images while another group has to match fruits images. Both groups were then re-tested with the image clips task and the results recorded that the group who had undergone the motorcycle match training was able to identify motorcycles better than the other group. Thus, it suggested that the perceptual training game of a motorcycle might improve driver detection on a motorcycle. Both studies used different approaches in an effort to improve motorcycle detectability. The findings showed positive outcomes and proved that safety messages and perceptual training have the possibility to improve driver ability to detect motorcycles as well as driver ability to drive safely.

## Conclusion

Multiple ways can be considered and employed in order to improve motorcycle conspicuity and detectability such as headlights configurations, usage of modulating lights, usage of bright color of helmet and attire, driver trainings and many more. What matters the most is the motorcycles and motorcyclists have to be in contrast with the road environment as their appearances are highly associated with the risk of motorcycle crashes. Lack of intervention studies demands future research to look further into motorcycle conspicuity on the rear and side area as these areas also contributed to motorcycle conspicuity-related crashes.

## Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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## Conflict of interest

The authors declare that there is no conflict of interest.

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