# *INFLUENCE OF HEADLIGHT DESIGN ON SENSORY CONSPICUITY OF POWERED TWO WHEELERS*

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**Summary**: Conspicuity of Powered Two Wheelers (PTW) according to their frontal headlight design was evaluated in a car Daytime Running Light (DRL) environment. Three innovative headlight arrangements were studied: a triangle configuration, a lighted helmet and a colored frontal headlight. It was found that the helmet and the colored configuration led to better PTW detection performances than the standard configuration (a unique white headlight), especially when the PTW was far away. The triangle configuration did not prove to be effective. The theoretical and practical implications of these results are discussed.

## INTRODUCTION

It is well known that the relative lack of PTW sensory conspicuity when compared to cars is one of the most important factors causing PTW accidents (e.g., Hurt et al., 1981; Wulf et al., 1989). The main measure adopted to improve PTW conspicuity was the obligation to turn on PTW headlights during the day. By increasing the visual contrast between the PTW and the background, DRLs increase the PTW conspicuity. The positive effect of this measure has been clearly proven in preventing PTW accidents (e.g., Zador, 1985; Yuan, 2000) and more recently in improving PTW detectability (Smither and Torrez, 2010).

However, the conspicuity advantage of PTWs seems to be threatened by the increase of automobilists who also light their headlights in the daytime. Currently, some form of car DRLs is compulsory in many countries. Since January 2011, legislation has made dedicated DRLs mandatory in the E.U. for all new cars and small delivery vans. As for PTWs, car DRLs are known to enhance car detectability under weak luminosity conditions (e.g., Cairney and Styles, 2003). But what about PTW detectability in a car DRL environment?

Some researchers and road-safety specialists assumed that car DRLs may decrease the effectiveness of the PTW DRL and have a detrimental impact on PTW safety (e.g., Cobb, 1992; Knight et al., 2006), but empirical evidence was lacking. A recent study we conducted highlights a negative effect of car DRLs: PTWs, cyclists and pedestrians were less well detected and identified in an urban environment when the headlights of cars in their vicinity were on (Cavallo and Pinto, 2011). Car DRLs are likely to compete with PTW DRLs by creating "visual noise" that hinders the perception of PTWs.

In this context, it seems essential to seek new means of improving the detectability of PTWs and providing them again with a unique visual signature, which clearly differentiates them from cars and facilitates their perception by the other road users. The present experiment aimed at identifying such a visual configuration by focusing on two aspects particularly: the positioning and lay-out of PTWs' frontal headlights and their color. Two configurations were chosen for the positioning and lay-out of headlights. The first one consisted of a standard frontal headlight plus 2 additional position lamps on the rear view mirrors. This triangle arrangement is thought to be reminiscent of a "face", which is naturally highly recognized and could thus enhance PTW detection (Maruyama et al., 2009). The second arrangement consisted in adding a position lamp on the motorcyclist helmet, in order to accentuate the vertical dimension of the PTW which could favor a better detection, but also a better perception of its distance, speed and time to arrival (Tsutsumi and Maruyama, 2008). The color of the frontal headlight is another way of differentiating PTWs from other lit road users, as color can be used as a highlighting feature to attract attention to an area of a display and reduces the search time (e.g., Fisher et al., 1989). We know that under certain circumstances users may identify targets that differ in color more accurately than those that differ in other attributes such as size, shape and brightness (for a survey on this question see for example Christ, 1975). McDonald and Cole (1988) also found that color-coding facilitates both visual search and identification and that this advantage tends to increase with visual scene complexity.

Regarding methodology, we consider that the more or less great conspicuity of a PTW can only be appreciated in a complex environment which includes elements of distraction, in tasks which involve a time constraint and consist more in noticing the PTW rather than seeking it. These are situations which require selective attention and call upon *attention conspicuity* rather than *search conspicuity* (Hughes and Cole, 1984). We also know that daytime situations are the ones that are most visually complex and accident-prone for PTWs (e.g., Hurt et al., 1981; ACEM, 2009). Given these considerations, we propose to evaluate the 3 above mentioned PTW frontal headlight designs in a detection task which refers to attentional conspicuity, in a car DRL and dense urban environment, in daytime conditions and with a time limit. We assume that the headlight arrangements enhance PTW detectability in these circumstances, when compared to a standard single white PTW frontal headlight.

## METHOD

### Participants

Sixty adults (27 women and 33 men) divided into 4 groups of 15 participants with a mean age per group of 28 years old (SD per group around 3.55) participated in the experiment. They were all licensed drivers and had normal or corrected-to-normal vision (at least 8/10 binocular acuity). All participants performed normally in UFOV visuo-attentional tests.

### The Detection Task

The participants were shown photographs which represent road-traffic scenes. They had to detect the presence of vulnerable road users and if one was detected, determine whether it was a motocyclist, cyclist, or pedestrian. Three visual targets were used to prevent the observers from looking specifically for PTWs.

## Experimental Design

A mixed experimental design was used, with Headlight Design as a between subjects variable (Standard, Triangle, Helmet, Yellow), and 3 within subject variables: Targeted Vulnerable Road User (Motocyclist, Cyclist, Pedestrian), Distance (Far, Near) and Excentricity (Central, Off-centered). The experiment was conducted in a car DRL environment exclusively. Three different photographs in each of the 12 conditions per Headlight Design group were presented, making a total of 36 experimental trials per group. Fifty four distractor trials were added for each Headlight Design Group. Among them, 9 trials contained a vulnerable road user located at different distances from those used in the experimental trials. As we had 45 trials containing a target, 45 other distractor trials without a vulnerable user were added in order to balance the design. Thus 50% of the trials contained a target. Distractor trials were not analyzed. Although we did not analyze performances for pedestrian and cyclist detection as well, we chose to display all combinations of variables, in order to vary the visual situations and prevent the observers from looking specifically for PTWs.

## Apparatus and Stimuli

Photographs of real-world traffic scenes were used as stimuli. They were presented on a 40” LCD flat panel display (Samsung SyncMaster PXn), which offered a high-quality visual rendering (image contrast ratio of 1200:1, 1366 x 768 resolution, brightness 500cd/m², 16.7 million colors). Digital photographs of urban traffic at intersections (mainly in Paris) in overcast weather were taken at a height of 1.20 m (average viewpoint of a driver), using a Nikon D90 camera with a 35-mm lens. The photographs were edited in Photoshop by a computer graphics designer. Their luminosity and contrast levels were made uniform, undesirable items (e.g., salient objects like billboards that might interfere) were eliminated, and the various elements needed to create the experimental conditions were inserted. We were careful to keep the images realistic so that the participants' attention would not be attracted to any incongruities.

*Experimental stimuli*. The stimuli included a number of cars (between 3 and 6) stopped at or approaching a red light, and a single vulnerable road user (a motocyclist, cyclist, or pedestrian), which was the target the participants had to detect. Vehicle headlights, realistic halos and reflections on the road surface were edited into the pictures using Photoshop. The experimental headlight configurations comprised a Standard configuration (1 frontal white headlight) (see Figure 1, A), and three new PTW Headlight Designs : Triangle (Standard + 2 position lights on rear view mirrors), Helmet (Standard + 1 position light on the helmet) and Yellow (1 frontal yellow headlight) (see Figure 1, BCD). The height of the targets in the image was controlled: if needed, the targets were resized so that their height on the viewing screen was 6 cm (angular size 2.15°) or 4 cm (angular size 1.43°) for the Near and Far conditions of the Distance variable, respectively. Target Excentricity was a function of the vulnerable user's location in the picture. Three locations were defined by drawing two imaginary vertical lines which divide the image into three equal parts. The area between the two lines was defined as the Central location, whereas the other areas were the Off-centered ones.

*Distractor stimuli*. Two kinds of distractor stimuli were used. The first type contained vulnerable road users at distances that differed from the experimental trials, and vehicles whose headlights were (all or partly) on or off. The second type contained no targets, but depicted a wide variety of traffic situations. The vehicles could be at very different distances (in the foreground or background) and in all kinds of positions with respect to the observer's viewpoint (turning right or left, etc.).


**Figure 1. Examples of the PTW's specific frontal headlight design studied: (A) Standard, (B) Triangle, (C) Helmet, and (D) Yellow configurations**

## Procedure

All participants first took the visual acuity test (Ergovision), and the UFOV test. Then they were seated 160 cm from the monitor. The images displayed on the screen subtended a visual angle of approximately 32° x 18°. Next, the participants read the instructions and performed a practice block of 8 trials to familiarize themselves with the procedure. According to their age and their UFOV part 3 test score, the subjects were assigned to one of the 4 Headlight Design groups (Standard, Triangle, Helmet, orYellow). The 90 stimuli were then presented in 3 blocks of 30 trials, each block containing 12 experimental and 18 distractor trials. The photographs were presented for 250 ms to simulate the amount of time a driver might have when glancing in the direction of oncoming traffic, which also corresponds to the observation time needed to define a conspicuous object (Cole and Jenkins, 1980). Each trial started with a fixation point displayed in the center of the screen for 1500 ms. Then the stimulus appeared, followed by the question "Apart from the four-wheel vehicles, which other road user did you see?". The choices were (1) a pedestrian, (2) a motorcyclist, (3) a cyclist, (4) none of the above. The question remained on the screen until the participants selected an answer using the computer mouse. No feedback on the response accuracy was given. After an inter-stimulus interval of 500 ms, the next fixation point was displayed. A short break was proposed between the blocks. The whole experimental session lasted between 30 and 35 minutes.

## RESULTS

The percentages of correct detections for the trials that contained a PTW were computed on the basis of the participants' responses. Detection rates were calculated for each participant and for each experimental combination of variables. Since the detection rate was not normally distributed, non parametric Mann–Whitney U tests with an α-level of .05 were conducted to compare each headlight design to the standard configuration. These comparisons were made globally; to study interactions, the data were grouped together in order to analyze them in each modality of the Distance (Near and Far) and Excentricity (Central and Off-centered) variables.

*Triangle configuration.* Although the majority of comparisons were in favor of the Triangle configuration, analyses didn't reveal any significant difference between Triangle and Standard PTW detection performances.

*Helmet configuration.* Data indicate that PTWs signaled by the helmet configuration were globally better detected (by 10 percentage points) than PTWs equipped with the Standard headlights (see Figure 2, left panel), but this difference failed to be statistically significant ($Z = 1.7$, $p = .09$). An effect of the Headlight Design was found only at Far distances ($Z = 3.34$, $p < .001$), which corresponds to better detection performances for the Helmet configuration (61%) compared to the Standard one (39%). The helmet configuration also tended to be better detected in the Central position ($Z = 1.7$, $p = .09$). No other effect was observed.

*Yellow configuration.* PTWs were globally more often detected when equipped with a Yellow headlight (67%) than with a Standard one (56%), but this difference was not statistically significant (see Figure 2, right panel). An effect of Headlight Design was found for Far ($Z = 2.39$, $p < .05$) and Central ($Z = 2.3$, $p < .05$) conditions, corresponding to better detection performances for the Yellow configuration (54% and 90% for Far and Central conditions, respectively) compared to the Standard one (39% and 71%, respectively).

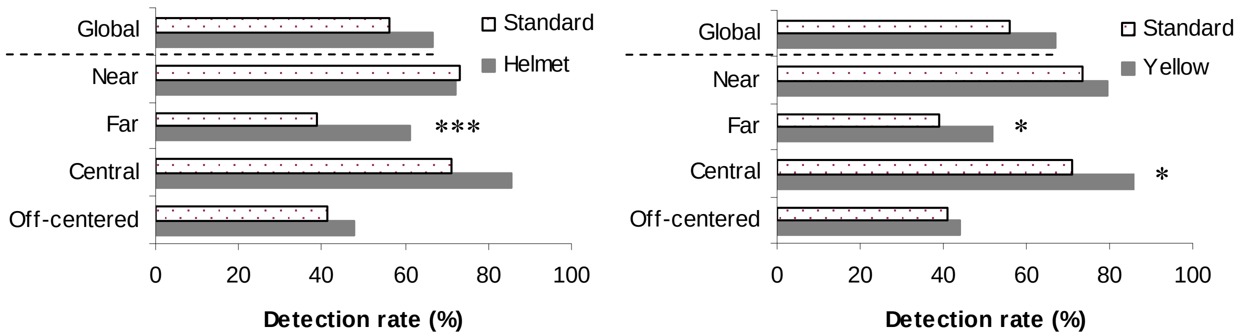


**Figure 2. Means of PTW detection rates for the Helmet (left) and the Yellow (right) configurations compared to the Standard one, globally and as a function of Distance and Excentricity modalities**
(* = $p < .05$; *** = $p < .001$)

## DISCUSSION

The purpose of this experiment was to contribute to the definition of new headlight designs which could enhance PTW conspicuity and improve their detection in a car DRL environment. The results obtained are promising insofar as the yellow and the helmet configurations led to significantly better PTW detection performances compared to the standard headlight. These improvements were found when the PTW was far away and when it appeared in the central part of the scene (for the yellow headlight only). We also noted that the tendency of performance improvement with these two headlight arrangements was observed in all experimental conditions, although not always in a statistically significant way.

The three lighting arrangements were chosen because of their potential to enhance PTW conspicuity in comparison to a white standard headlight, by giving them different visual features. Results suggest that the yellow configuration can help PTWs to get clearly differentiated from all other white light sources, and thus enhance their conspicuity. A similar explanation holds true for the helmet configuration, which represents the highest source of light in the visual scene and thus contributes to distinguish PTWs from other lighted road users. Both of these headlight arrangements have real distinctive features in a car DRL environment and are likely to constitute new visual signatures able to minimize the detrimental effect of car DRLs on PTW detection as observed by Cavallo and Pinto (2011). The triangle configuration did not prove to be effective, although it contained elements of a face and formed an original headlight design with regard to the existing PTW lighting. This headlight design had no features that could clearly distinguish it from car DRLs, since position lights on rear mirrors often remained in the lighted area of car DRLs in urban traffic. Similarly to PTWs with white standard headlights whose detection is reduced in car DRL environments (Cavallo and Pinto, 2011), the triangle configuration did not prevent the PTW from being masked by car DRLs in this situation where PTWs were embedded in an environment which contained other light sources.

It's also interesting to note that the yellow and the helmet configurations enhanced PTW detection especially in conditions where the car DRL environment was shown to have a major detrimental effects, i.e., when PTWs are far away and in the central position of the visual scene (Cavallo and Pinto, 2011). These findings are in line with the hypothesis of competing light patterns, whereby adverse effects may have been reduced here thanks to the strong conspicuity enhancement produced by the yellow and helmet configurations. When it was difficult to see a PTW because of its small angular size at great distance in a car DRL environment, adding a visual signature like a yellow headlight or a helmet light enhanced the PTWs' conspicuity and improved its detection. In the central part of the visual scene, where PTWs were easily detected, we can assume that the yellow light acted as a conspicuity feature that improved more specifically PTW identification.

All in all, our study suggests that research should be intensified to improve PTW conspicuity in a car DRL environment. Our findings regarding PTW light configurations indicate ways for defining a new visual signature for PTWs in future research. Regarding the validity of our study, the present findings need to be confirmed by using complementary methods. In particular the impact of movement information (as present in dynamic visual scenes) as well as higher contrast and luminance levels (as obtained in real-world conditions) deserve to be studied further. Technical studies are also needed for helmet lights regarding power source and duration; batteries can make the helmet heavy and are likely to impact rider balance and behavior when involved in a crash. Another crucial point for future studies is that research on PTW headlights ergonomics should not only aim at facilitating PTW detection and identification by car drivers, but also at improving their perception of the PTW's movement, i.e., their speed, distance and time-to-arrival. A number of studies considering these two aspects of PTW safety are already in progress (e.g., Marayuma et al., 2009).

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