

EVALUATION OF MOTORCYCLE CONSPICUITY IN A CAR DRL ENVIRONMENT

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Summary: Daytime Running Lights (DRL) on motorcycles have been shown to counteract the inherently lower sensory conspicuity of these vehicles and to significantly improve their safety. The advantage of the use of DRL exclusively by motorcycles is presently becoming lost by the increasing use of DRLs on cars. The present experiment aimed at evaluating the effects of car DRLs on motorcycle perception in a situation that specifically brought attentional conspicuity to bear. Photographs representing complex urban traffic scenes were displayed to 24 participants who were asked to detect vulnerable road users (motorcyclists, bicyclists, pedestrians) appearing at different locations and distances. Car DRLs noticeably hampered motorcycle perception compared to conditions where car lights were not on, especially when the motorcycle was at a greater distance from the observer and when it was located in the central part of the visual scene. Car DRLs were also detrimental to the perception of bicyclists and pedestrians. These findings suggest that more attention should be paid to motorcyclists and other vulnerable road users when introducing car DRLs. Several means of improving motorcycle conspicuity in car DRL environments are discussed.

INTRODUCTION

Accident studies (ACEM, 2004; Hurt, et al., 1981; Vis, 1995) have shown that collisions between motorcycles and other vehicles represent the most frequent type of motorcycle accidents (70 and 75 %, according to ACEM, 2004, and Hurt et al., 1981, respectively) and that in two thirds of such collisions the motorcycle had the right-of-way (Hurt et al., 1981; Wulf, et al., 1989). Most of these accidents occurred in urban areas, in daylight, in clear weather, and with a motorcycle bearing from 11 to 1 o'clock relative to the other vehicle (Brooks et al., 2005). These accidents typically happen when an automobile turns left into the path of an oncoming motorcycle. In-depth accident studies point to the high frequency of perception failures of the drivers in other vehicles (in 37, 50, and 70 %, according to ACEM, 2004, Van Elslande, 2005, and Hurt et al., 1981, respectively). The failures are most often identified as no or late detection of the motorcycle, but distortions in speed, distance and time-to-arrival are also mentioned.

Prior research has shown that motorcycles have a lower conspicuity in traffic compared to cars. Conspicuity can be defined as the property of an object to attract attention (Engel, 1971). Two forms of conspicuity are generally distinguished (Hancock et al., 1990). The motorcycles' sensorial conspicuity is reduced due to their small size and their irregular contours. Their cognitive conspicuity is poor because of low exposure frequencies and unusual behaviors such as high speeds

(Brenac et al., 2004) and unexpected locations (riding between cars), which are inconsistent with car driver expectations.

In the past, the sensory conspicuity of motorcycles was improved by the use of Daytime Running Lights (DRL) which became compulsory in many countries. DRLs provide a high contrast with the background and improve motorcycle detectability by attracting the attention of the other road users. Furthermore, as long as motorcycles were the only vehicles using headlights at daytime, DRLs provided motorcycles with a consistent feature facilitating their search and identification by the drivers of other vehicles (Brouwer et al., 2004). DRLs in motorcycles therefore were considered to counteract the inherently lower conspicuity of these road users.

The advantage from the exclusive use of DRLs in motorcycles is presently getting lost by the increasing, and often mandatory, use of DRLs on passenger cars. Surprisingly, only very few experimental studies have provided evidence of an adverse effect of car DRLs on the detection of motorcyclists. Regarding possible masking effects, Cobb (1992) studied various car DRL intensity levels in real-world conditions. He found that DRLs improved the perception of automobiles in cloudy weather without decreasing that of motorcycles, provided no high-intensity lamps (> 600 cd) were used. Brouwer, et al. (2004), who used slides of traffic scenes including one car and sometimes another road user, even observed a slight detection advantage for the other road user when car DRLs were lit. Brendicke et al. (1994) also used slides of traffic scenes and found a detrimental effect of car DRLs on motorcycle detection, but the ecological validity of their findings is questionable insofar as the participants' task was to count the number of vehicles in the scene.

On the basis of previous studies it is therefore not clear whether car DRLs affect the detectability of motorcycles. It can be assumed that these inconclusive results are due to methodological choices, and to how the very notion of sensory conspicuity is operationalized. Most studies have used simplified experimental tasks and situations, such as searching for a motorcycle in an impoverished environment and/or with an unlimited or long exploration time. Such situations are not representative of the attentional demands of real driving, however, and are therefore much less likely to generate perception errors.

The present experiment aimed at investigating the effects of automobile DRLs on motorcycle detection in a situation calling upon attention conspicuity rather than search conspicuity. We therefore used a complex environment and a time-limited task where the observer had to "notice" a motorcycle, not look for one. We hypothesized that in these conditions, the use of daytime lights by automobilists decreases the detectability of motorcycles.

METHOD

Participants

Twenty-four adults (4 women and 20 men) with a mean age of 35.6 years (SD: 11.1) participated in the experiment. They were all licensed drivers, had normal or corrected-to-normal vision and exhibited normal performance at attentional tests.

Task

The participants were shown photographs representing road-traffic scenes. They had to detect the presence of vulnerable road users, and if one was detected, determine whether it was a motorcyclist, cyclist, or pedestrian. Three visual targets were used to prevent the observers from looking specifically for motorcycles. 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 (Crundall et al., 2008).

Experimental Design

A repeated measures design was employed. The four independent variables were i) car DRLs (on vs. off), whereas motorcycles always had their front lights on; ii) the targeted vulnerable road user (motorcyclist, cyclist, or pedestrian); iii) the distance of the vulnerable road user (near vs. far location); iv) the excentricity of the vulnerable road user, (central area of the photograph vs. off-centered). Combining these variables led to a total of 24 experimental conditions. Three different photographs in each of the 24 conditions were presented in the experiment, making a total of 72 experimental trials. One hundred and eight distractor trials were added. Among them, 18 trials contained a vulnerable road user whereas the other 90 distractor trials did not contain any target.

Stimuli and Apparatus

Photographs of urban traffic at intersections in overcast weather were used as stimuli. They were presented on a 40" LCD flat panel display. The photographs displayed a wide variety of traffic scenes in order to reduce participants' expectations about the location of the visual targets. The photographs were edited in Photoshop, their luminosity and contrast levels were made uniform, undesirable items were eliminated, and the various elements needed to create the experimental conditions (motorcycles, vehicle lights, etc.) were inserted.

The experimental stimuli included a number of cars (between 3 and 6) stopped at or approaching a red light, and a single vulnerable road user, which was the target the participants had to detect. The visual characteristics of the targets were highly diverse, but their height in the image was controlled: the 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. 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 vehicles at a wide variety of distances, positions and headlight conditions.

Procedure

The participants were seated 160 cm from the monitor. The images displayed on the screen subtended a visual angle of approximately $32^\circ \times 18^\circ$. The participants first performed a practice block of 8 trials. The 180 stimuli were then presented in 3 blocks of 60 trials. The presentation order of the trials within the blocks was random for all participants, and the order of the blocks was counterbalanced across participants. Each trial started with a fixation point displayed in the

center of the screen for 1500 ms. Then a stimulus appeared for 250 ms, followed by the question “Apart from the four-wheel vehicles, which other road user did you see?”. The answer choices were (1) a pedestrian, (2) a motorcyclist, (3) a bicyclist, (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 40 and 45 minutes.

RESULTS

Data analysis

The percentages of correct detections were computed for those trials that contained a vulnerable road user. Detection rates were calculated for each participant and for each experimental variable and condition. Since the detection rate was not normally distributed, a non-parametric analysis using the Wilcoxon matched-pairs signed-rank test with an α -level of .05 was conducted.

The overall effects of the main variables will be presented first (car DRLs, distance, and excentricity). The effect of the road user was studied solely for a sub-set of stimuli with similar characteristics, namely the motorcyclists and the cyclists in the central and left-of-center positions. Given that the Wilcoxon test does not bring out interactions, the data were grouped together in order to analyze combinations of variables. We then present detection rates for motorcyclists as a function of car DRLs, distance and excentricity. Findings related to pedestrian and cyclist detection will not be presented here.

Global results

The analysis yielded a significant effect of DRL ($T = 3$, $p < .01$) indicating that vulnerable road users were more often detected when the car head lights were off (56%) than when they were on (49%). The partial analysis of the road-user variable revealed a significant effect ($T = 21.5$, $p < .001$): motorcyclists were detected more often (56%) than cyclists (43%). A significant effect of distance was observed ($T = 0$, $p < .001$), with a higher detection rate when the vulnerable user was near (72%) than far (33%). Target excentricity also had a significant effect ($T = 0$, $p < .001$) indicating a higher detection rate when the target was located in the center of the image (69%) than when it was off-centered (37%).

Motorcycle detection

A significant effect of car DRL was found ($T = 24$, $p < .05$), corresponding to higher motorcycle detection rates in condition DRL-off than in DRL-on (66% vs. 60%) (see Figure 1).

There was also a significant effect of distance ($T = 0$, $p < .001$), with near motorcycles being better detected than distant ones (82% vs. 43%) (see Figure 2, left panel). The analysis also revealed a significant effect of excentricity ($T = 0$, $p < .001$) with centrally located motorcycles better detected than off-centered ones (80% vs. 46%) (see Figure 2, right panel).

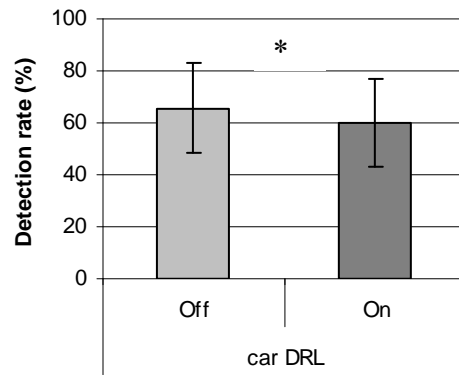


Figure 1. Means and standard deviations of the motorcycle detection rate, according to whether car DRLs were on or off (* $p < .05$)

The analysis of the car DRL effects according to the distance and excentricity variables yielded a significant difference in the far condition ($T = 20, p < .05$), with motorcycles being detected better in the DRL-off condition than in the DRL-on condition (47% vs. 40%). There was also a significant difference in the central condition ($T = 19, p < .05$), again, with the negative impact of car DRLs on the motorcycle detection rate (76% vs. 83%).

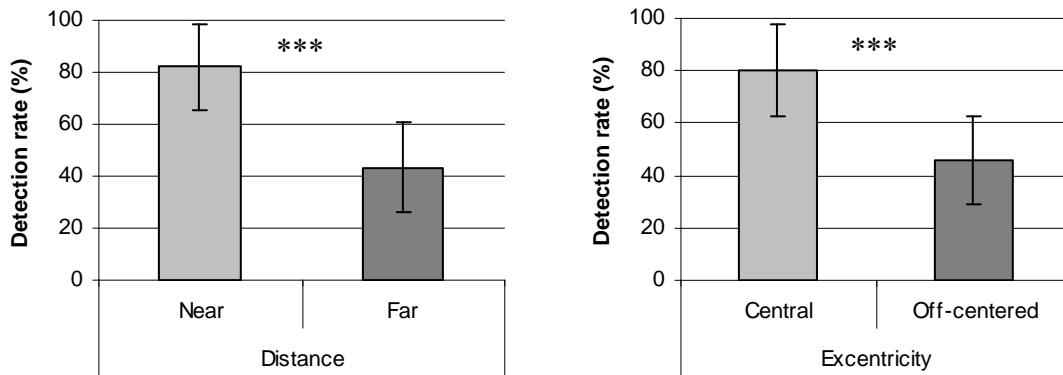


Figure 2. Means and standard deviations of the motorcycle detection rate, according to distance (left) and excentricity (right) (*) $p < .0001$)**

DISCUSSION AND CONCLUSIONS

The present study indicated a detrimental effect of car DRLs on the perception of all kinds of vulnerable road users: overall, the detection rate decreased by 7 percentage points when the cars' head lights were turned on. These findings highlight that more attention should be paid to motorcyclists and other vulnerable road users when introducing car DRLs.

The findings also indicate that motorcycles were better detected than bicycles in general. This was probably due to their greater conspicuity owing to their slightly bigger size and the presence of their headlights that were easy to see. Furthermore, the experiment replicated previous findings on the influence of target distance and excentricity on detection performance (e.g., Engel, 1971). Motorcycle distance determined its angular size, which is known to be an important conspicuity-

influencing feature. The effect of excentricity was observed because no or only small eye movements were required to see centrally located targets whereas detecting off-centered targets needed larger eye movements and more time.

The study demonstrated a clear-cut decline in the ability to perceive motorcycles in a car DRL environment compared to conditions in which the cars' headlights were unlit. The car DRL effect was particularly strong when the motorcycle was far away, and when it was located in the center of the visual scene. The negative effect of car DRLs at greater distances suggests that the DRLs generated competing light patterns in conditions where the motorcycles were hard to see because of their small angular size. At shorter distances, where the angular size of the motorcycle and thus its inherent conspicuity were greater, car DRLs had little or no impact. More surprisingly, the adverse effect of car DRLs was observed even when the motorcycles were located in the central part of the visual field, which is a favorable condition for target detection. It would seem that in these conditions, it was specifically motorcycle identification that was hampered by car DRLs because both motorcycles and cars had their daytime lights on. In this case, the poorer detection of motorcycles could be due to the fact that they have lost their visual "signature" as the sole users of DRLs.

With regard to motorcyclist safety, the present findings suggest that motorcycle sensory conspicuity has again become a major issue in car DRL environments. An important question for future research concerns the improvement of motorcycle conspicuity through their headlight ergonomics. The goal of such research should be to find a new visual signature for motorcycles that would make them easier to detect and identify. A number of studies in this area are already in progress in Europe, Israel and Japan. Yellow headlights (Pinto and Cavallo, 2011), lighted helmets (Gershon and Shinar, 2010) and triangle headlights ("face design", Marayuma and Tsutsumi, 2009) have been proven to provide conspicuity improvements for motorcycles. Another way of enhancing conspicuity is to change the visual features of motorcycling gear (helmets, jackets, vests), although these measures have been found less effective than headlight-centered designs (Olson et al., 1981).

Further research should extend the studied conditions in order to confirm the present findings based on photographs. It can be assumed that dynamic stimuli will not change the overall picture as long as short viewing times are considered, because the angular motion of oncoming motorcycles would be too small to be seen or analyzed. It would seem worthwhile, however, to conduct experiments in real situations (for instance on a track) to study more realistic luminance and contrast levels and to gain insight in the roles played by these factors.

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REFERENCES

- ACEM (2009). In-depth investigations of accidents involving powered two wheelers (MAIDS). Retrieved August, 28, 2010, from <http://www.maids-study.eu/pdf/MAIDS2.pdf>.
- Brenac, T., Clabaux, N., Perrin, C., & Van Elslande, P. (2006). Motorcyclist conspicuity-related accidents in urban areas: A speed problem? *Advances in Transportation Studies*, 8, 23-29.
- Brendicke, R., Forke, E., & Schäfer, D. (1994). Auswirkungen einer allgemeinen Tageslichtpflicht auf die Sicherheit motorisierter Zweiräder. 6. Fachtagung 'Motorrad'. *VDI Berichte 1159*, Düsseldorf, Germany, 283-318.
- Brooks, A.M., Chiang, D.P., Smith, T.A., Zellner, J.W., Peters, J.P., & Compagne, J. (2005). A driving simulator methodology for evaluating enhanced motorcycle conspicuity. *Proceedings of the 19th International Technical Conference on the Enhanced Safety of Vehicles*, Washington, DC, Paper No. 05-0041-O.
- Brouwer, R.F.T., Jansen, W.H., Theeuwes, J., Duistermaat, M., & Alferdinck, J.W.A.M. (2004). *Do other road users suffer from the presence of cars that have their daytime running lights on?* (Research Report). Soesterberg, the Netherlands: TNO.
- Cobb, J., 1992. *Daytime conspicuity lights*. (Research Report). Crowthorne, Berkshire: Transport Research Laboratory (TRL).
- Crundall, D., Humphrey, K., & Clarke, D. (2008). Perception and appraisal of approaching motorcycles at junctions. *Transportation Research Part F: Traffic Psychology and Behaviour* 11 (3), 159-167.
- Engel, F.L. (1971). Visual conspicuity, directed attention and retinal locus. *Vision Research*, 11 (6), 563-575.
- Gershon, P., & Shinar, D., 2010. Increasing PTW's detectability by using phi-phenomenon. *Proceedings of the International Conference on Safety and Mobility of Vulnerable Road Users: Pedestrians, Motorcyclists, and Bicyclists*, Jerusalem, Israel.
- Hancock, P.A., Wulf, G., Thom, D., & Fassnacht, P., 1990. Driver workload during differing driving maneuvers. *Accident Analysis and Prevention*, 22 (3), 281-290.
- Hurt, H.H.J., Ouellet, J.V., & Thom, D.R. (1981). *Motorcycle accident cause factors and identification of countermeasures, volume 1*. (NHTSA Report). Washington DC: U.S. Department of Transportation.
- Maruyama, K. & Tsutsumi, Y. (2009). Study of face design lighting system design for enhanced detection rate of motorcycles. *Proceedings of the 21st International Technical Conference On the Enhanced Safety of Vehicles*, Stuttgart, Germany, Paper No. 09-406.
- Olson, P.L., Halstead-Nussloch, R., & Sivak, M. (1981). The effect of improvements in motorcycle/motorcyclist conspicuity on driver behavior. *Human Factors*, 23 (2), 237-248.
- Pinto, M., & Cavallo, V. (2011). Influence of headlight design on sensory conspicuity of powered two-wheelers. *Proceedings of the 6th International Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design*, Lake Tahoe, CA, U.S.
- Van Elslande, P., & Jaffard, M. (2010). Typical human errors in traffic accidents involving powered two-wheelers. *Proceedings of the 27th International Congress of Applied Psychology*, Melbourne, Australia, 1363-1364.
- Wulf, G., Hancock, P.A., & Rahimi, M. (1989). Motorcycle conspicuity: An evaluation and synthesis of influential factors. *Journal of Safety Research*, 20 (4), 153-176.