Visibility of Bicycle Headlamps, Tail lamps and Retroreflective Markings in Real Road Conditions: Results of a Pilot Study

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1 INTRODUCTION

In 2015, 818 bicyclists died while riding on roads in the United States. Although they compose of less than two percent of total roadway fatalities, only about one percent of trips are taken on bicycles, making cyclist deaths overrepresented among traffic fatalities [1]. In 2012, of crashes occurring during the day, 68% of cyclists had no safety equipment or conspicuity markings, like reflective clothing and lighting. Of those occurring at night, 81% had no safety equipment or conspicuity markings [2]. If cyclists were more conspicuous, they would be more visible to drivers, potentially reducing cyclist deaths. The effect would likely be more pronounced at night, when visibility is lower than during the day. Further, the evaluation of bicycle visibility treatments have traditionally been conducted in closed test-tracks or via accident analyses. Evaluation of such treatments in real road conditions has never been reported and such an evaluation could result in developing more valid-recommendations to increase bicyclist conspicuity.

This pilot study had two goals. The first goal was to check the feasibility of the evaluation of several commercially available bicycle conspicuity treatments in real road conditions during both night and day. The second goal was to evaluate the visibility of the above mentioned treatments at day and night. Such an evaluation in a naturalistic setting will help in providing high-validity recommendations for increasing bicyclist conspicuity.

2 METHODS

Twenty-four participants of two age groups (18 to 34 years, and 65 years and older) participated in the study. The participant sample had equal number of male and female participants. The age groups provided a wide range of driving experiences and visual capabilities. The study was conducted in downtown Blacksburg, Virginia and on the Virginia Tech campus. Because visibility treatments can be seen only from certain directions, two different approaches were chosen. Experimenter bicyclists approached the participant vehicle from two directions: (1) oncoming, (2) passing. The two approach directions gave researchers discrete opportunities to evaluate various headlamps, tail lamps, and biomotion markings (see Table 1).

Table 1. Independent variables and their levels.

Independent Variable	Values
Age (two levels)	Younger (18-25), Older (65+)
Headlamp (HL)* (seven conditions)	Steady Low Intensity (100 lumens (lm)), Steady Medium Intensity (350 lm), Steady High Intensity (700 lm), Flashing Slow (0.9 Hz), Flashing Moderate (3.4 Hz), Flashing Fast (6.67 Hz), No Headlamp (Standard Reflectors)
Tail Lamp (TL)* (three conditions)	On, Off (Standard Reflectors), Flashing
Retroreflective Markings (RR)* (four conditions)	Vest, Biomotion, Vest and Biomotion, No Markings (Standard Reflectors)

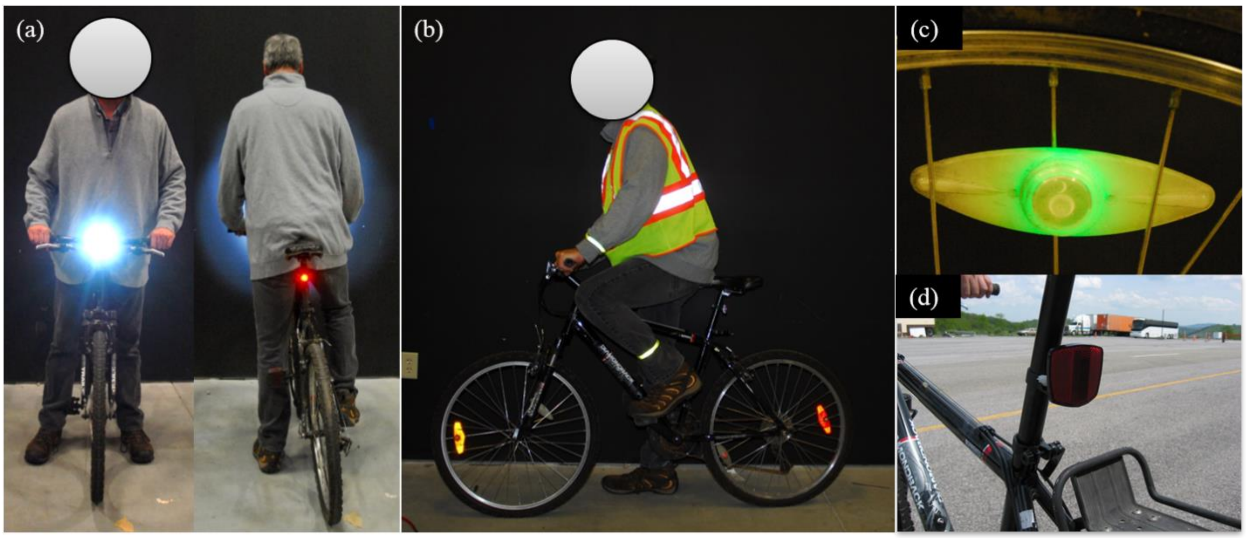

Figure 1. Bicycle visibility treatments used in the study. (a) Confederate experimenter with head lamp and tail lamp. (b) Confederate researcher wearing a retroreflective vest and biomotion bands. (c) Spoke light. (d) Standard rear reflector.

Experimenters were issued bicycles, positioned at various points on the roadway, and assigned visibility treatments. Another group of experimenters rode in the vehicle with the participants, guiding them through the test route while simultaneously coordinating the position of the experimenter bicyclists with respect to the vehicles, and then recorded participant responses. Detection distance was used as the dependent variable. It is the distance at which the participant driver was able to detect the bicyclist. To measure this variable, both the test vehicle and bicyclist were equipped with GPS receivers and the coordinates at the instant of detection was used to calculate the detection distance.

Four separate linear mixed models analyses was used to assess effect of bicycle visibility enhancement systems on driver visual performance (one for each orientation and time of day). The level of significance was $p < 0.05$ for all statistical tests. Where relevant, post hoc analyses (pairwise comparisons) were performed using Tukey's honest significant difference (HSD).

3 RESULTS

In the oncoming directions, the main effect of bicycle visibility enhancement was significant at night. Mean detection distances for each of bicycle visibility enhancement conditions in the oncoming orientation are shown in Figure 2.

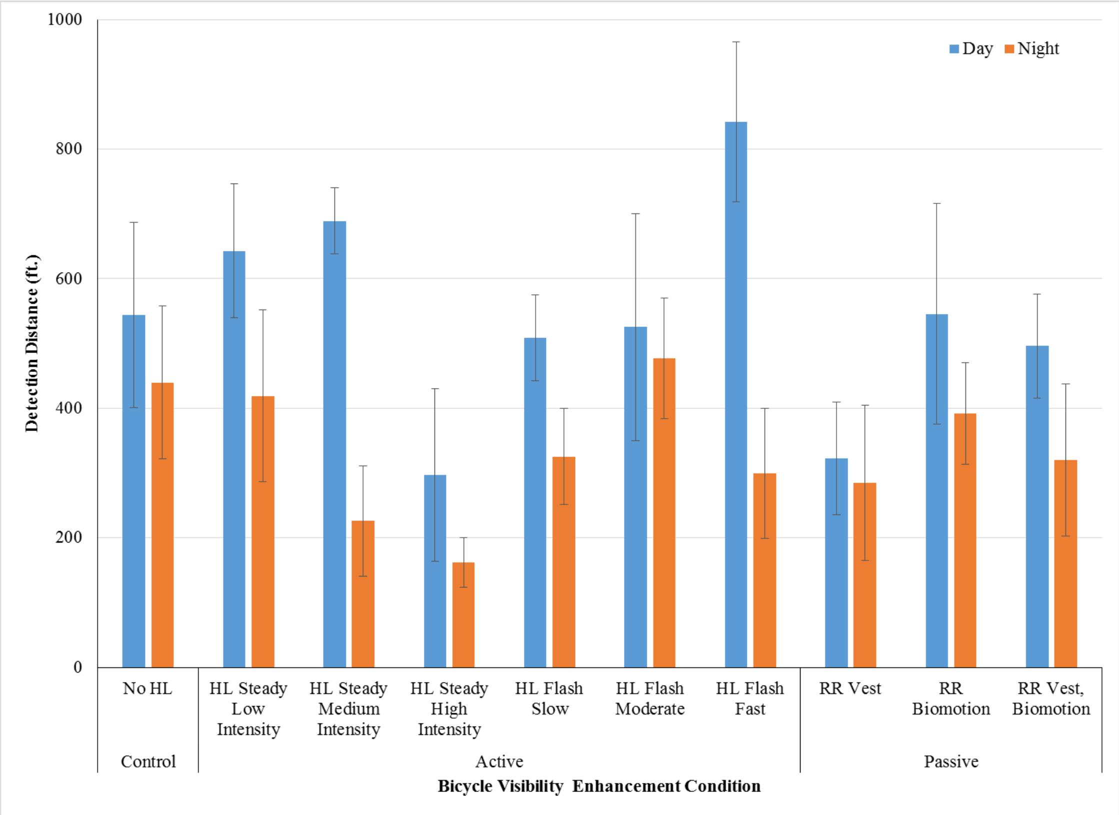

Figure 2. Mean detection distances per visibility treatment at day and night in oncoming orientation. Error bars reflect standard errors.

In the passing orientation, the effect of the bicycle visibility enhancement on detection distance was not significant during both night and day.

4 CONCLUSIONS

Usable data from this pilot study indicated that an evaluation of the bicycle conspicuity treatments in real road conditions was possible and lessons learned from this study could help in designing a more comprehensive study. Results also showed that active visibility treatments such as bicycle mounted lights make bicyclists more conspicuous than passive systems, like retroreflective vests and biomotion bands. Flashing headlamps and tail lamps were the most conspicuous treatments during both day and night. This study also found that biomotion markers alone do not significantly increase bicyclist conspicuity in visually complex natural environments. Finally it is recommended that the bicyclists should use a combination of both active and passive treatments to increase their conspicuity at day and night.

REFERENCES

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