Detecting Cyclists at Night: visibility effects of reflector placement and different lighting conditions

Paul. E. Hemeren, Mikael Johannesson, Mikael Lebram and Fredrik Eriksson

School of Informatics
University of Skövde
Box 408, 541 28, Sweden
email: paul.hemeren@his.se; mikael.johannesson@his.se; mikael.lebram@his.se; fredrik.eriksson@his.se

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1 INTRODUCTION

The use of visual aids can increase the ability of drivers to detect cyclists at night and reduce the seriousness of injuries if a crash occurs [1]. The use of reflectors placed on critical parts of the human body have been shown to increase cyclist conspicuity at night [2]. Drivers detect cyclists with reflective clothing that enhances the movement of the human body (biomotion) at considerably longer distances than a reflective vest, which is a very often used piece of clothing by cyclists who want to be detected in darkness. Recent research [3] has also shown that driver eye movements are quicker to fixate on cyclists who are wearing the biomotion reflector clothing than the reflective vest.

The explanation of the effect of the biomotion-patterned reflector placement stems from the sensitivity of human vision to the movement of other humans. This has been demonstrated in a wealth of research, which was promulgated by Gunnar Johansson [4]. Human vision can detect the movement and portrayed actions as points of light attached to the joints of a human body in a little as 300 milliseconds. This sensitivity can be exploited by placing reflective material on the joints of human body so that visual conspicuity is increased for cyclists and other vulnerable road users.

Our research demonstrates the effectiveness of different patterns of reflectors worn by cyclists on the distance it takes drivers to detect the cyclists in different places in an existing city environment. This research was carried out in a driving simulator in order to include more naturalistic testing conditions and to achieve a relatively high level of experimental control. As a complement to our previous research [5], we aimed to determine the distance at which drivers would detect cyclists dressed in different patterns of reflective clothing, i.e., biomotion, standard vest, and no reflective material at all on the cyclist, which is the minimum legal requirement.

2 METHODS

2.1 Participants

Twenty-four participants (19 males, mean age 29) were recruited from the student population at the University of Skövde and from the circle of acquaintances of the experimenters. All participants had a valid driving license, but driving experience/frequency varied, from once a month to daily. All participants signed consent forms, and the experiment was conducted according to Swedish law and ethical guidelines.

2.2 Design and Procedure

Based on our previous research, three patterns of reflective clothing were used (Fig. 1): *biomotion*, *vest* and the minimum legal requirement (*legal*), in which no reflector material was worn by the cyclists. The reflective material used in the *biomotion* and *vest* conditions was 3M™ Scotchlite™ Reflective Material 8910 Silver Fabric. The vest was a common item purchased at a local store. In order to maintain focus on placement and not on other material, the reflective material on the vest was replaced with the same reflective material used for the biomotion clothing. Importantly for comparison, the amount of visible reflective material in these two conditions was approximately the same. The reflective strips on the vest were much wider than the strips in the *biomotion* condition.

A 4.6 kilometer long route which included central areas of the city of Skövde was selected for the video recording of cyclists dressed in the different reflective clothing conditions. Twelve positions were also selected

Figure 1: Reflective clothing patterns from left to right: biomotion, vest and legal minimum.

along the route for placement of cyclists. The positions were selected to include well-lit areas with street lights and other light sources for commercial areas, no street lights and positions where the visibility of cyclists was partially obstructed by making a turn or by bushes along the road. The bicycles were placed in stationary training stands so that distance measures could be reliably made while cyclists pedaled. Each clothing condition was video recorded at each position for a total of thirty-six conditions. The spacing of the positions along the route was unevenly spaced in order to reduce expectancy effects about the presence of a cyclist.

A GoPro video camera was placed on the windshield of a car, and all forty-eight conditions (including the no-cyclist-present condition) were recorded at a speed of forty km/h. The cyclists were recorded as the car approached from behind. Only the backside of the cyclists was visible. The car headlights were set to bright to compensate for the reduced visual quality of the video recordings. The recordings were then edited to produce driving routes that contained counter-balanced orders of clothing condition and route position.

The experiment was conducted in the driving simulator at the University of Skövde. The participants were instructed to drive the car and maintain a speed of 50 km/h as the primary task. The gas pedal of the car was used to increase the speed of the recorded film to give the impression of acceleration. The steering wheel could also be used to create changes in the image on the screen to create a feeling of control similar to a fully functional simulator environment. The secondary task was to honk the horn as soon as a cyclist was detected.

Each participant drove the route two times, which resulted in viewing each clothing condition six times for a total of 18 observations per participant. Since it was not practically feasible for each participant to view each clothing condition at each position, because of likely practice effects, the conditions were evenly divided among two groups of participants. The starting point along the route for each participant was randomly determined.

3 RESULTS

There were twelve possible correctly detected cyclists for each of the thirty-six conditions due to the necessary balancing of conditions and to reduce practice effects. The detection results for each condition showed that drivers were generally accurate at detecting cyclists with the exception of two positions along the route where detection accuracy for the *legal* condition (no reflective material) was 0 and 3 out of twelve. The detection accuracy for the vest condition for these two positions was also low, 4 and 6 respectively, while the biomotion condition resulted in perfect detection in all twelve trials.

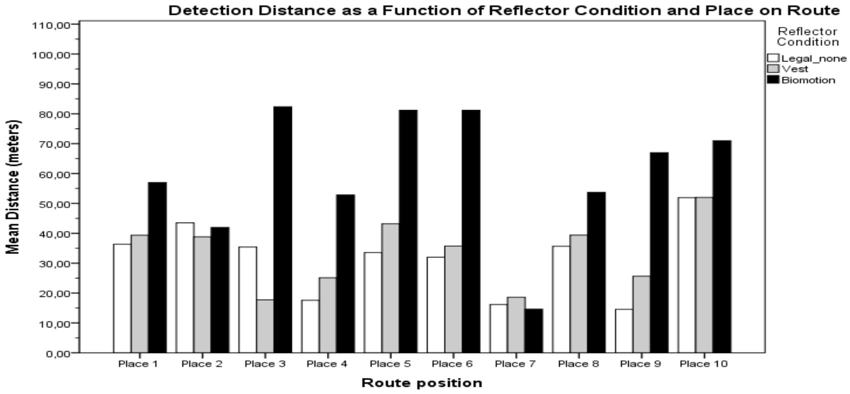

Figure 2: Distance detection in meters as function of reflector condition and place on route.

The data for the distance at which cyclists were detected were entered into a between-groups ANOVA with position as a random factor. Given the design of the experiment, this was the most conservative statistical analysis compared to a repeated measures ANOVA. The means for detection distance as a function of clothing condition and route position are presented in Figure 2. The pattern of results across the different positions/places shows that the *biomotion* pattern of reflector placement (mean 60.28, black bars) is detected at much greater distances than *legal* (mean 31.67) or *vest* (mean 33.56). The exceptions to this occur when the visibility of cyclists is obstructed (Place 7). The main effect of reflector placement was significant, $F(2,18) = 16.91$, $p < 0.001$. Pairwise comparisons between the conditions for reflector placement show significant differences between the *legal* and *biomotion* conditions, $t(227) = 10.46$, $p < 0.001$, and between the *vest* and *biomotion* conditions, $t(227) = 9.62$, $p < 0.001$. The main effect of position was also significant, $F(9,18) = 2.69$, $p < 0.001$. The interaction effect showed that the effect of the different reflector conditions varied as a function of position along the route, $F(18, 309) = 9.16$, $p < 0.001$.

4 CONCLUSIONS

The clothing that supports biomotion perception is superior to the *legal* and *vest* conditions. The surprising result here is the lack of any significant difference between *legal* and *vest*. This indicates that cyclists should wear reflective clothing that can trigger driver attention by placing reflective material on the joints of the human body.

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