

DETECTION AND RECOGNITION OF PEDESTRIANS AT NIGHT

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Background

There is, as yet, no definitive study which quantifies the extent of the pedestrian accident problem accounted for by the poor visibility of the pedestrian at night. However, for substantial numbers of nighttime pedestrian accidents, "inconspicuity" is strongly suggested as a major contributing factor. Moreover, it appears that enhancing the conspicuity of the relatively small (with respect to other elements of the traffic environment) pedestrian visual stimulus represents a counter-measure with great potential for accident reduction.

In a study of the causative factors in rural and suburban pedestrian accidents (1) two of the accident types identified might be characterized as nighttime events. The "Walking Along the Roadway" type (11.6% of the study sample) had 55% of its occurrences after dark. This type involves a pedestrian walking in the roadway either with or against traffic. The type called "Hitchhiking," although of lower incidence (1.5% of the study sample), was almost totally an after dark phenomenon (87% after dark). It was also characterized by an absence of roadway lighting in almost half (43.5%) of the studied cases.

Another way to estimate the nighttime pedestrian accident problem is to examine the relative accident risk day and night. This was done by Austin, Klassen and Vanstrum (2) when analyzing pedestrian fatality figures from 1973. When pedestrian exposure and vehicle miles were considered for the nighttime driving situation, the authors calculated the expected number of nighttime fatalities to be 10 percent of the daytime number. In fact, the actual nighttime number was 119 percent of the daytime figure. They concluded that the "night environment is dramatically more dangerous for the pedestrian than the daytime environment is."

The reasons for this apparently large difference in fatality figures are likely to include poor pedestrian visibility as well as the effects of alcohol and fatigue in both drivers and pedestrians. For example, a recent study of the role of alcohol in pedestrian injuries and fatalities (3) found that almost 70 percent of adult (age 14 and older) pedestrian accidents that occurred between 8:00 p.m. and 4:00 a.m. involved a pedestrian whose BAC was .10% or higher. Certainly alcohol involvement cannot be ignored as a casual element in nighttime adult pedestrian crashes.

One approach to correcting a pedestrian's poor visibility at night is to enhance his target value with retroreflective material. This type of material reflects light, such as the illumination from an automobile headlight, directly back to its source. The driver, who is close to the source, sees a much brighter image than could be seen with ordinary diffuse reflecting materials.

Many studies have shown the enhanced visibility that results from the use of retroreflective materials at night.

Hazlett and Allen, in a study of visibility associated with intoxication (4), found a decreasing ability of drivers with increasing blood alcohol concentration (BAC) to detect simulated pedestrians. The study showed that a small amount of reflectorization on a pedestrian increased detectability even by drivers with high BAC's.

Hazlett, Courtney, Stockley and Allen studies various geometric patterns of retroreflectorization on motorcycle helmets (5). In the road test portion of the study, observers riding in an automobile with headlights on low beams detected highly reflectorized shapes mounted on a helmet at an average of 800 feet. This compared with a normal white helmet being detected at only 243 feet and showed the clear superiority of reflectorization.

Based on these and other studies not necessarily associated with pedestrians, there appears to be a potential safety benefit to the addition of retroreflective material to pedestrians at night. Moreover, if there is enhanced conspicuity as a consequence of adding retroreflectorization, it should be measurable in terms of detection and/or recognition of pedestrian targets at night. In this context, detection distance is the range (in feet) at which a subject (driver) determines that a target is in his visual field, and recognition is the range at which the subject unequivocally can identify the target as a pedestrian.

In order to examine the effects of various retroreflective treatments on the detection and recognition of pedestrians at night, two controlled field experiments were conducted by Dunlap and Associates, Inc., with funds provided by the 3M Company.

The first of these studies (6) examined the relative detection and recognition distances for point sources (2" by 2"), stripes (1" by 24") and full figure treatments at varying levels of reflectivity and retroreflectivity (luminance). All trials were run on a totally dark course (Lime Rock Raceway in Lime Rock, Connecticut). Detection and recognition distances were measured directly through on-board instrumentation in the test vehicle activated by the experimental subjects as they drove the course at a constant speed.

The second study (7) employed a similar procedure to examine 16 different garments on a dark course. These garments represented a range of configurations including:

- a. child jacket (size 8),
- b. medium jacket (size 14),
- c. large jacket (size 44),
- d. full figure coveralls (large), and
- e. trousers (large).

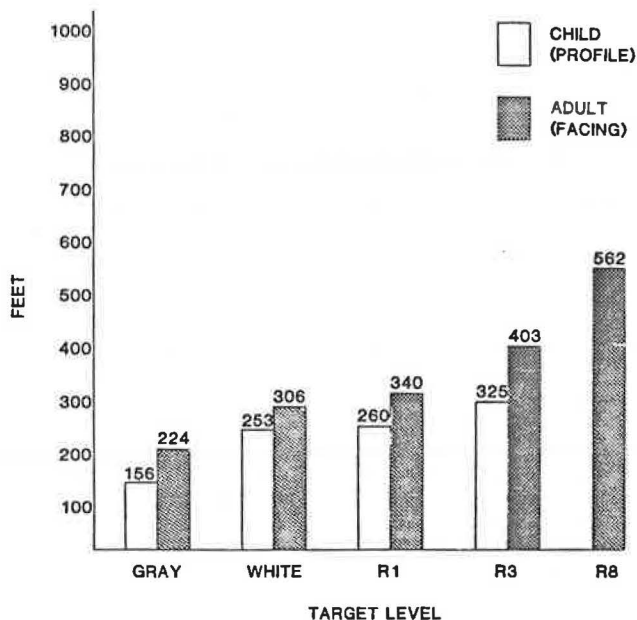
Three levels of retroreflectorization (1, 3 and 8 cpl) as well as white and neutral gray were tested, although not every garment was tested at each target level. (cpl=candles per lumen or candlepower per footcandle per ft.² These levels were designated R1, R3 and R8 in the studies.) In addition, all four of the child jackets (gray, white, R, R3 and R8) were tested in a "typical" suburban environment with ambient lighting from street lamps and potential glare from oncoming vehicles. Only recognition distance was measured for the suburban course while both detection and recognition distances were taken on the dark course (run at an airport after it closed at night).

Some of the data from these two experiments are presented below to aid in the derivation of some basic principles for maximizing the effectiveness of retroreflective conspicuity enhancement of

pedestrians at night. In examining these data, one should keep in mind the following:

1. All data were collected in test cars with new, properly aimed headlamps on low beam;
2. All subjects had normal vision without correction;
3. Subjects knew their task was one of target detection and identification. Although distractor stimuli were included in every test run and the targets were located irregularly along the course, the measured distances should be considered somewhat long when compared with the detection and identification performance which could be expected from unselected persons driving normally. This aspect of the studies should also add confidence to the comparisons between test stimuli; since subjects were alert and tested under uniform conditions, differences in the data across target configurations should be due only to target differences;
4. Within the first study, six subjects (male) were tested on each target stimulus three times (on three separate nights). In the second, 10 male and 11 female subjects were tested on each target stimulus once. Thus, all the reported data are based on nearly equal numbers of observations. For each stimulus condition, the standard deviations across observations varied from less than 100 feet to about 200 feet. (Smaller values were found in the earlier study and for target stimuli with smaller means across both studies.) As a general yardstick, differences in the means of two target stimuli of 100 feet or more may be considered statistically significant ($p < 0.05$). All effects described below, however, were tested specifically and found to be statistically significant;
5. Data for the child sized jackets were collected with the target in profile stimulating a child about to dart into the street on a path perpendicular to the vehicle. This is the most typical child accident situation (e.g., 8). All other targets were oriented facing the oncoming vehicle with arms at sides; and
6. All targets were stationary.

FIGURE 1: Suburban course mean recognition distances, jacket targets (7).



Selected Data

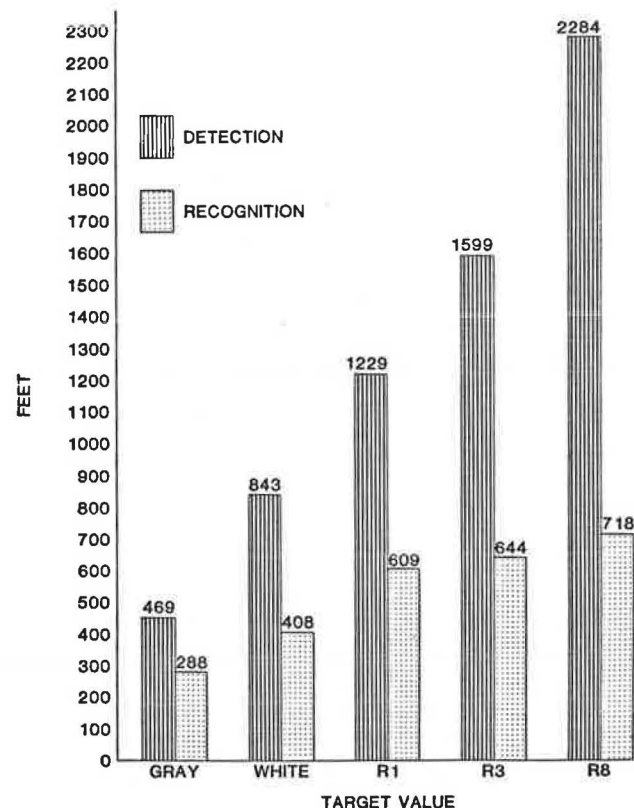
Figure 1 shows the mean recognition distances for the nine targets tested in the suburban setting. Two target shapes--a child figure in profile to the subjects and an adult figure facing toward the subjects--were tested wearing gray pants and jackets of several levels of reflectivity and retro-reflectivity. For the same target brightness levels, the larger adult figures were recognized consistently about 70 feet farther away than the smaller child targets. For the same size targets, adjacent luminance levels were also significantly different, with the brighter targets recognized farther away than white ones, but not significantly so.)

The same pattern was found across most other tested conditions. Figure 2 shows the average detection and recognition distances for the five full figure targets tested in the first study on the Lime Rock Raceway. Detection distances increased significantly with each brightness increment, from 469 feet for the all-gray figure to 2,284 feet for the figure with R8 long-sleeve jacket and trousers.

Recognition distances also increased consistently with increasing target brightness. (Only the recognition difference between the R1 and the R3 targets failed to reach significance at the .05 level.) The R8 target was recognized as a pedestrian at two and one-half times the distance for the gray target (718 feet vs. 288 feet) and 75% farther than the white target (408 feet).

While increased detection distances with increased brightness was the rule across all tested conditions, the same was not always true for

FIGURE 2: Dark course mean detection and recognition distances, full figure targets (6).



recognition. Figure 3 shows the data for the stripe targets used in the first study--gray figures with a 1" stripe running horizontally across the chest and arms. Data for the all-gray figure are included for comparison. The stripe targets were detected farther away than the gray target, and brighter-stripe targets were detected farther away than less bright ones. In fact, the stripe targets were detected about as far away as the full figure targets of the same luminance level. Recognition distances, however, showed no corresponding shift. For the stripe targets as a whole, recognition was slightly (but significantly) worse than for the all-gray target.

Nearly identical findings were seen for the "point source" targets, which had white, R1 or R3 square spots (2" by 2") on the chest of an otherwise gray figure. Again, the data (not shown) suggest that the single bright area may actually interfere with identification of the whole figure (reduced recognition distance).

To further investigate this finding, other less-than-full-figure targets were tested in the dark course segment of the second study. Figure 4 shows mean detection distances for 13 targets. (Three other targets--of medium size with white, R1 and R3 jackets--were tested as well. Their data were nearly identical to the data for the similar large-jacket targets and have been omitted from the Figure.)

At any target luminance level, the full figure targets showed the longest detection distances, followed by the targets with gray jackets and brighter trousers, then the adult targets with bright jackets and gray trousers, and finally, the child (profile) targets with bright jackets and

gray trousers. Targets with higher luminance levels were detected farther away than (similar) targets with lower luminance levels.

The corresponding recognition data appear in Figure 5. They show the same basic pattern. Within luminance levels, targets were recognized in the order, from farthest to nearest, or full figure, trousers, jacket and child jacket in profile. For all these target shapes, recognition was better for targets with higher luminance

FIGURE 4: Dark course mean detection distances (7).

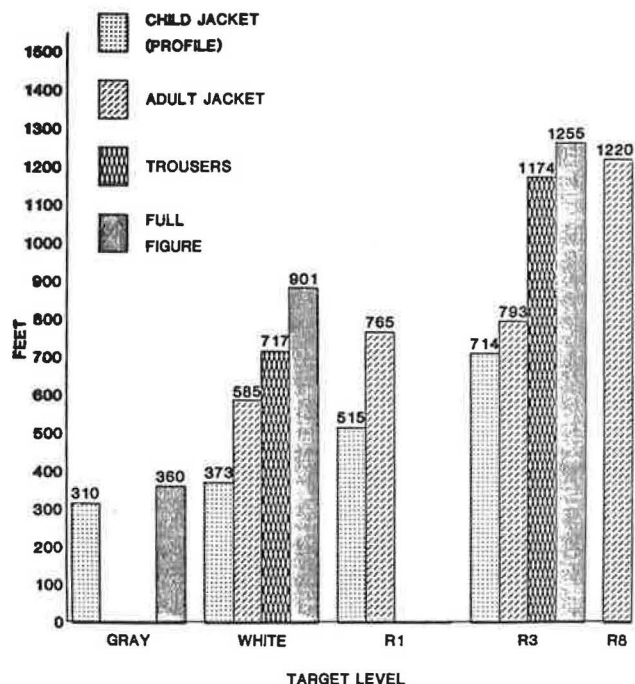


FIGURE 3: Dark course mean detection and recognition distances, stripe targets (6).

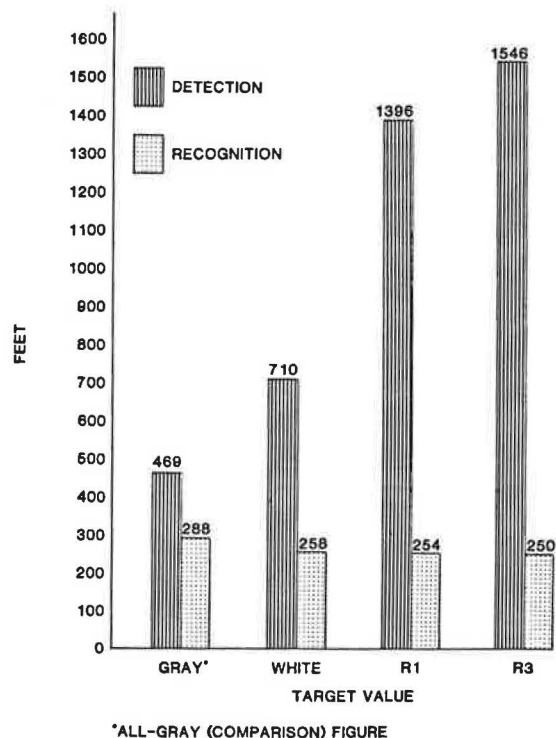
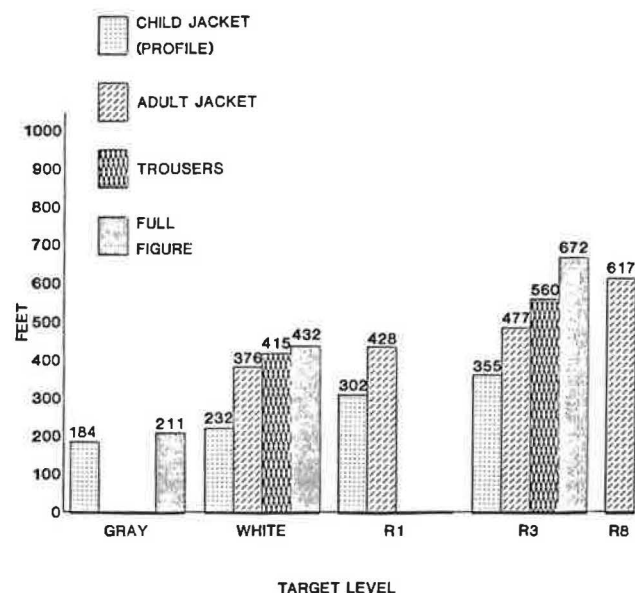


FIGURE 5: Dark course mean recognition distances (7).



levels. The jacket targets, and perhaps even more the trouser targets, had brightness patterns which did not interfere with subjects identifying the target as part of a pedestrian. The target with R3 trousers and a gray jacket, for example, was identified 200 feet farther away than a similar all-gray target was even detected (560 feet vs. 360 feet), a distance at which the gray top of the figure may not have been visible to most of the subjects even though they had already fixated on the lower half of the figure.

The exact detection and recognition distances varied for the same targets between the two studies and between the dark and suburban test courses of the second study. The patterns of results remained consistent, however. Targets detected or recognized farther away when tested under other conditions. This is graphed in Figure 6, for the nine targets tested under both courses of the second study. The values fall very close to a straight line; the correlation between means across test conditions for the nine common targets was .973.

Conclusions

The data presented above clearly indicate that retroreflective treatments on pedestrians can increase the distance at which they are detected and recognized. Thus, it is a reasonable extension of these results to postulate a safety benefit from the widespread use of appropriately designed retroreflective garments at night. However, it must be remembered that all subjects in the reported experiments were alerted, had normal vision and were neither fatigued nor intoxicated when the data were collected. Therefore, care must be exercised in extending these findings, particularly the extent of improvement in detection and recognition, to the entire population of drivers.

Until additional research can be conducted to refine even further the optimal design for a

retroreflective countermeasure for pedestrians, the foregoing findings can be utilized to begin to enumerate several basic principles.

First, to improve detection, one should use bright target materials. Consistently, these studies showed that each increment in target brightness tested produced a corresponding increase in detection distance. In these studies, brightness was a more important influence on detection than was the total target area, even though the targets ranged in size from a minimum of four square inches to a maximum of several square feet.

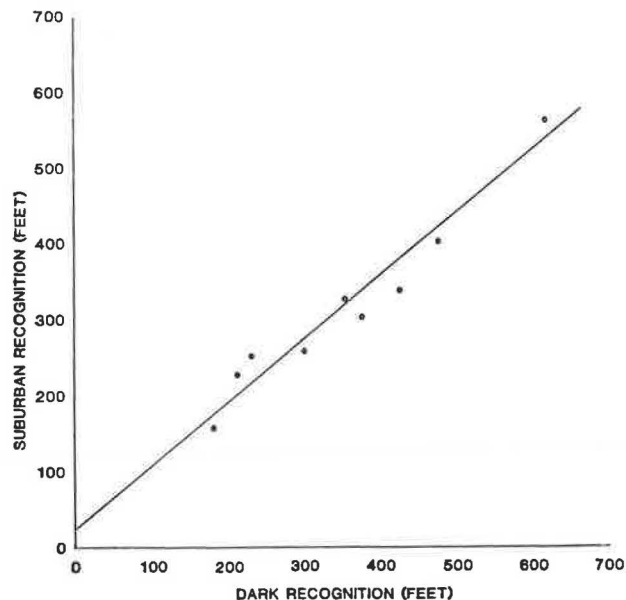
Second, identification of the targets as pedestrians requires more than mere early detection. Anthropomorphism of the target shape greatly aids recognition. In these studies, shapes which are commonly associated with "people" led to effective identification even though the shapes only partly reproduced the human form. Retroreflective jackets seemed to produce a significant improvement in recognition. Retroreflective trousers were significantly better than jackets, and the combination of the two was better than either alone. Shapes which did not represent human figures, articles of clothing or other visual forms associated with the human figure--spots and stripes--did not enhance and may actually inhibit recognition of the pedestrian figures. Hence, for improved safety, it would appear best to outline the body as completely as possible with the brightest material available.

Finally, the excellent prediction of suburban course results from dark course findings is of interest. It means that the relative effectiveness of new pedestrian conspicuity enhancers can be assessed under totally dark field test conditions, which are easier to establish and control for experimental purposes. Thus, the further refinement of the design of retroreflective treatments for pedestrians should not be significantly hampered by test and evaluation costs.

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FIGURE 6: Comparison of dark course and suburban course mean recognition distances (7).



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