DRIVER PERCEPTION OF PEDESTRIAN CONSPICUOUSNESS UNDER STANDARD HEADLIGHT ILLUMINATION

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A driver must perceive objects in the roadway early to avoid accidents. Pedestrians are the most vulnerable of all roadway users, and they must completely avoid accidents to escape injury or death. How conspicuous pedestrians should be at night is explored in this study. Brightness and area are related to subjective driver interpretations of pedestrian conspicuousness. The performance of various reflective surfaces illuminated by the present standard headlight system is compared to the brightness and area requirements found for each level of conspicuousness. The area available for pedestrian visibility enhancement is determined by silhouette area analysis. Applicable reflective treatments are proposed as safety countermeasures, and other potential contributing factors are discussed.

•THE PEDESTRIAN accident problem and the need for more effective countermeasures to reduce pedestrian injuries and fatalities are well documented. In 1973 there were 10,500 pedestrian fatalities, accounting for nearly 20 percent of the total highway death figure (1). A breakdown of statistics into daytime and night categories is quite revealing. During the daytime periods in 1973 there were 4,800 pedestrian fatalities or about 46 percent of the total, and at night there were 5,700 fatalities or 54 percent of the total. One could conclude from this that night is slightly more dangerous than day. However, if one further analyzes these figures based on exposure to risk, a different picture emerges. In 1973 the number of vehicle miles driven at night was only 44 percent of that driven in the daytime. Therefore, if one surmises that an accident involving a pedestrian and a motor vehicle resulting in a pedestrian fatality is strictly a function of vehicle travel, then only 2,112 fatalities should have occurred at night. The actual total is 2.7 times greater than this. If one takes pedestrian exposure into account, a still higher ratio of actual total to expected fatalities emerges. Pedestrian travel rate or exposure is much harder to accurately assess than motor vehicle travel. A study by Cameron (2) shows pedestrian volume at night to be less than 15 percent of pedestrian travel in the daytime. This is for an urban environment; rural pedestrian volume might be even lower. If one assumes that night vehicle miles are, even more conservatively, only 25 percent of those driven in the daytime, then the predicted number of night fatalities would be 528. The 25 percent assumption represents the combined effect of motor vehicle and pedestrian travel rates. The actual observed figure of 5,700 nighttime fatalities is nearly 11 times higher than what one would expect. Nearly 5,200 of the 5,700 fatal night accidents are due to conditions that are absent during the day. It is evident that the night environment is dramatically more dangerous for the pedestrian than the daytime environment is.

The obvious difference between day and night is lack of visibility and visual cues at night that the driver uses during the day. Alcohol and fatigue and their interaction with vision and perception also are involved. Because the visibility factors are obvious and much research has been done in this field, perhaps a tendency exists to think that there is little room for new effective safety countermeasures. But research is being carried

Publication of this paper sponsored by Committee on Pedestrians.

out on new forward lighting systems for vehicles, and these new systems have been the subject of several papers at recent Transportation Research Board meetings. Schwab and Hemion (3) point out, however, that vehicle headlight design is a compromise between providing adequate illumination of the road ahead and avoiding glare to oncoming drivers. Low beams that avoid glare do not provide enough illumination to drive safely, yet low beams are used in over 60 percent of all night driving in low-volume rural areas; this increases to 90 percent at higher volumes (14).

Some research in roadway lighting indicates that improved visibility at night can help reduce accidents (4, 5). Adequate funding to light substantial portions of roads and streets with fixed lighting always has been limited. With energy in short supply, it becomes less attractive. Alternatives that more efficiently use light available to the motorist need to be explored. One alternative is judicious use of reflectorization, especially for the pedestrian, to achieve greater efficiency in the use of available light and improve visibility. This can be done now with existing technology; further technical breakthroughs are not necessary.

Richards (6) has made an extensive compilation of the pertinent literature related to night vision and visibility of road objects at night. A distinction should be made at this point between human vision capabilities and deficiencies and object visibility. Burg (7) studied the relationships between static visual acuity, dynamic visual acuity, other measures of vision, and the driving records of 17,500 drivers. Although certain measures of vision, such as dynamic visual acuity, were useful in predicting accident involvement, correlation was relatively low because many factors other than human eye capabilities and deficiencies are involved. Even a young driver with 20/20 eyesight, for example, does not detect a pedestrian in dark clothing at night until he or she is dangerously close (15). Target visibility and not driver vision is crucial under these circumstances. Bergsman (8) points out that there are 4 problem areas in pedestrian safety. Three concern very young and very old people and alcohol abusers. The fourth, an environmental problem rather than one concerned with people, is darkness and its attendant poor visibility.

Much of the research on visibility is concerned with the limits where objects first can be detected or where signs first can be read. These threshold values can be readily determined by straightforward experimental procedure. Very little research has been concerned with higher than threshold values that are needed to alert an otherwise complacent, distracted, or inattentive driver that an object or person is in his or her path that needs immediate consideration. deBoer (9) indicates that, although visibility distance (a threshold measure) is a very important criterion, ease of seeing within that visibility distance is of great importance. He indicates that values 3 to 10 times higher than threshold should be considered for ease of seeing. An early study by Breckenridge and Douglas (10) has been interpreted to show that values that are 100 to 1,000 times higher than threshold may be needed to command attention. Thus we hypothesize that the level of conspicuousness of a road target for easy visibility and attention getting is considerably different from threshold detection values.

This study tries to relate the measured photometric and area properties of certain light targets under dark ambient conditions to the subjective responses of human observers. In addition, various retroreflective materials were measured photometrically under standard low-beam illumination at 550 ft (167.64 m) so that a comparison with light targets could be made. Further analysis of the adult and child pedestrian silhouettes sets upper limits for the target and reflective areas.

PROBLEM

Avoiding a collision with an object on the roadway involves not only detecting an object when one is actively seeking its presence but also being able to detect and recognize the nature of the object when one does not expect its presence. Detection, recognition, and attention are separate dimensions of the problem. This study explores detection and attention in a simulated roadway condition under dark, static conditions. It does not deal with dynamic conditions involving vehicle and target movement that would include estimation of distance and closing rates. Nor does it deal with the problem of recognizing a pedestrian from all other possible objects encountered on the roadway. The contributions of movement and recognition cues can be very important but must be the subject of other research. The 2 variables studied in this experiment were target brightness and area, which are basic to detection and attention.

Many experimental possibilities exist that can link the photometric and geometric properties of visual targets to observer reaction, particularly with the suprathreshold reactions characterized as easily visible and attention commanding. One procedure might be to place targets of various areas and brightness in random position and sequence along a roadway and measure detection distances and errors by observers in vehicles traveling the course. Because of equipment and time limitations this could be carried out more easily after simpler preliminary research was conducted with targets of randomly varying brightness and area displayed to observers at a fixed distance. The distance chosen was 550 ft (167.64 m), corresponding to minimum stopping sight distance under wet conditions at 55 miles/h (88.5 km/h) (11, 12). The observers sat behind standard headlights set on low beam in dark surroundings to approximate the mesoptic adaptation of the eye in night driving. The targets were internally illuminated light sources that could be masked to reveal various areas. Light sources were chosen instead of reflective targets to allow easier small luminance adjustments and to avoid any extraneous variables that might be introduced if different reflective materials were used. In a separate part of the experiment, the photometric responses of a number of actual reflective materials were measured under standard head-lamp illumination. These responses can be related to the light source values by means of photometric and area data.

The observers were asked to rate each target as visible, easily visible, or attention getting. The data response sheet filled in by each observer was structured so that gradations within each of the 3 categories could be indicated by the position of the mark. A large number of area and brightness combinations covering wide ranges were presented randomly to each observer. The presentation of any given combination could not be anticipated, and the observer thus was forced to make a fresh evaluation of each target. Part of this study design rests on the fact that observers make mental comparisons with targets previously observed so that a hierarchy of responses is created.

Even though the important elements of motion, shape, and color were not included and road conditions were simulated for the test, we believe that basic relationships between targets at suprathreshold levels and subjective response can be established with this method.

SIMULATED ROADWAY DESIGN

A corridor in a large, dark warehouse was used as the test site. A headlight stand mounted with standard head lamps was positioned at an end of the corridor (Figure 1). The corridor was striped with a reflective white edge line 4 in. (10.16 cm) wide and a reflective white skip line that simulated lane dividers and also was 4 in. (10.16 cm) wide. The road was 11 ft (3.35 m) wide from edge to center and 550 ft (167.64 m) from head lamps to view box. The front surface of the view box was centered in the simulated roadway and angled at 4 deg from the perpendicular of the center line between the head lamps to avoid any specular glare. The center point of the target was 42 in. (106.68 cm) from the floor. The head lamps were properly mounted to simulate a car in the center of the designated lane. The headlights were used to adjust the observers' eyes to the mesoptic range of adaptation to simulate normal night driving. Five chairs for the observers were placed behind the head-lamp stand to position observers at proper eye height. A telephotometer was placed at driver's eye position to record the luminance of the view box. A variable transformer was located near the readout of the telephotometer. An extension cord linked the available transformer to the view box to provide control of the luminance of the view-box target surface.

APPARATUS

Variable Transformer

A 60-A rheostatic variable transformer with 250-V capacity and 600 ft (201.17 m) of No. 10 wire extension cord was used.

Photometric Instrumentation

A Gamma Scientific Model 2000 telephotometer was used. This instrument is well suited for this experiment because it has a transistorized photomultiplier and electrometer amplifier, 2-in.-diameter (5.08-cm-diameter) objective, measurement span from 0.001 to 35,000 ft-L (0.0034 to 11,900 cd/m^2), color correction, internal standardization, and calibration. Five acceptance angles are available with this instrument. The 1.67-deg sensing-probe acceptance angle for all suprathreshold conditions was used and provided proper sensitivity within the conditions of the study. The instrument has a bipolar, 3-digit display with 100 percent overrange (Max Count 1999) and automatic polarity indication that will blank on overload.

View Box and Illuminated Targets

The view box consisted of twelve 200-W light bulbs equally spaced in a 3-sided housing with an inner surface painted flat white (Figure 2). The front, or face, consisted of 2 pieces of 0.125-in. (3.18-mm) clear acrylic panels both of which were sandblasted. The outer panel was positioned parallel to the inner panel at a distance of 18 in. (45.72 cm). The outer panel was the target surface viewed by the observer. Variable area was provided by the outer metal shroud, which had removable panels. Target sizes and their visual angles were as follows:

1. 1 by 1 in. (2.54 by 2.54 cm) > 0.8 deg,
2. 4 by 4 in. (10.16 by 10.16 cm) = 0.55 deg,
3. 8 by 8 in. (20.32 by 20.32 cm) = 1.11 deg,
4. 24 by 24 in. (60.96 by 60.96 cm) = 3.33 deg, and
5. 24 by 72 in. (60.96 by 182.88 cm) = 10.55 deg.

Inserting panels produced the first 3 target sizes. Removing all panels produced the 4th target size. Removing the shroud produced the 5th target size.

Head Lamps

The head lamps used were a standard set of GE6014 type 2 lamps, designed for the 2-beam system, and were properly aimed according to SAE Standard J599C. The voltage to the head lamps was maintained at the normal automotive operating level of 12.7 V. No lights other than the view-box target lights were on in the warehouse. These conditions simulated night driving conditions in a dark, rural area. The pavement surface 60-deg gloss measurement averaged 14 and the percent reflectance averaged 10.

PROCEDURE

Threshold Determination

Participants indicated by a switch light when the target was barely visible. First, the

Figure 1. Simulated roadway conditions.

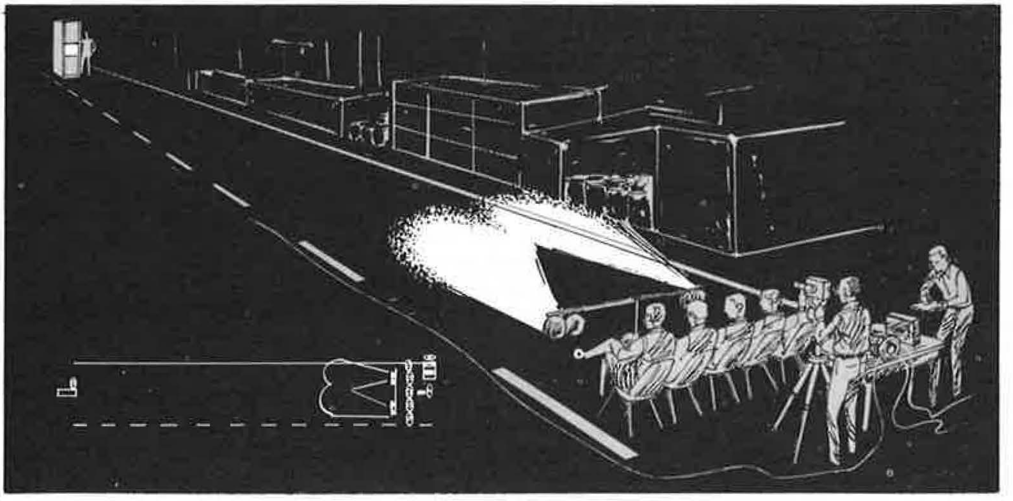
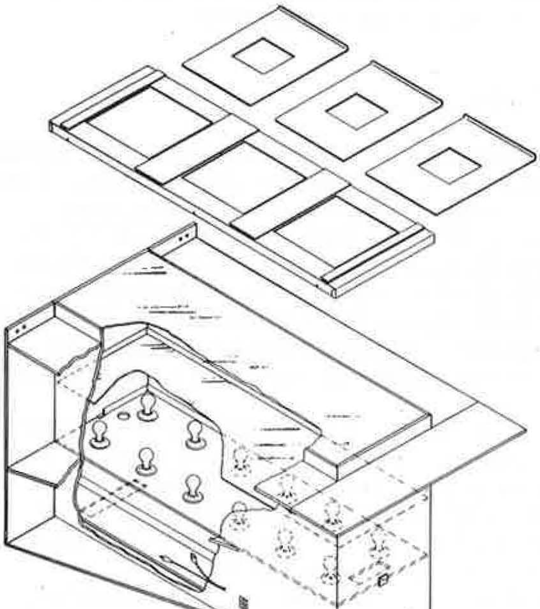


Figure 2. View-box design and illuminated targets.



target was bright enough so that the participants could specifically locate it. Then it was blacked out. The surface was illuminated gradually until all had responded and the operator had recorded the data. This procedure was carried out for each of the 5 areas starting with the 24- by 72-in. (60.96- by 182.88-cm) target and proceeding down to the 1- by 1-in. (2.54- by 2.54-cm) target.

Suprathreshold Determination

The observers were told to imagine that they were driving an automobile under normal night driving conditions. They were to respond to each target situation while imagining that they were traveling at 55 mph (88.5 km/h) on the roadway ahead of them. Responses for each of the conditions were marked on the chart to indicate when they considered the target to be either visible, easily visible, or attention getting. They were to mark each response on a graduated scale to indicate how strongly they felt about the condition. The observers indicated their immediate response after glancing up at the target. They were told not to stare or concentrate on the target and to look away from the target after they made their observation to retain proper adaptation. After the participants recorded their responses, they signaled with their indicator switch lights. The total time for the suprathreshold experiment averaged 33 to 45 min. Thirty-five people participated in the experiment as observers. Teams of 3, 4, or 5 people at a time were used. Each viewer's eyes were tested for visual acuity and depth perception. The average corrected visual acuity was 20/20. Vision and age data are given in Table 1. Average age was 32 years, and all volunteers were licensed drivers.

DEFINITIONS OF TARGET CONSPICUITY LEVELS

The 3 levels of conspicuousness were defined for the observers before the test. Visible meant that the driver could see the target but could miss it in a driving situation. Seeing the target requires at least a slight amount of effort. Existing visual distractions, pavement surface, and lane lines might cause a driver to miss it at 550 ft (167.64 m). Easily visible meant that the driver could see the target easily despite existing visual distractions if he or she looked directly at it but might miss it if he or she looked elsewhere on the roadway. Seeing the target did not require concentrated effort. The target was viewed as comfortably visible and not glaring. Attention getting meant that the target was not only easily visible but bright enough to attract attention even if the driver was not looking directly at the target.

The data were divided into 15 relative values: (a) 1 to 5 for visible, (b) 6 to 10 for easily visible, and (c) 11 to 15 for attention getting. A value of 1 represented the lowest subjective estimate of visibility and 15 represented the highest. Ten different luminances were chosen for each of the 5 different area conditions. The target size and luminance were randomly varied. An additional 4 situations were added to the first part of the design to attempt to condition the viewer on what to expect.

Average response of the viewers was tabulated for each condition. A multiple regression analysis was performed on the data to determine the relationship between the response of the observer and the combination of luminance and target area. Equations were developed that accounted for 94 percent of the averaged responses of the observers. Analysis of the comparison of the predicted value from the equation with the data did not exhibit a pattern that would suggest data drift such as one that might be due to fatigue.

RESULTS

All of the test results could be depicted on a single graph. Figure 3 shows the average responses of the observers as a function of target area and brightness. Figure 4 shows an extension of the curves developed to lower levels to include nonretroreflective black, gray, and white targets.

Table 1. Age and visual factors of participants.

Participant	Age (years)	Far Acuity Both Eyes	Far Acuity Right Eye	Far Acuity Left Eye	Near Acuity Both Eyes	Near Acuity Right Eye	Near Acuity Left Eye	Depth Perception
1	40	20/17	20/18	20/17	15/15	15/20	15/15	OK
2	49	20/18	20/18	20/20	15/15	15/15	15/15	OK
3	38	20/17	20/20	20/17	15/20	15/20	15/15	OK
4	26	20/20	20/20	20/25	15/15	15/15	15/15	OK
5	38	20/17	20/17	20/17	15/15	15/15	15/15	OK
6	31	20/20	20/22	20/22	15/15	15/20	15/15	OK
7	40	20/17	20/17	20/17	15/15	15/15	15/15	OK
8	43	20/17	20/17	20/17	15/15	15/15	15/15	OK
9	21	20/18	20/20	20/18	15/15	15/15	15/15	OK
10	54	20/20	20/20	20/20	15/15	15/15	15/15	OK
11	48	20/20	20/25	20/22	15/25	15/25	15/25	OK
12	21	20/22	20/29	20/22	15/15	15/15	15/15	OK
13	27	20/17	20/17	20/17	15/15	15/15	15/15	OK
14	26	20/22	20/22	20/29	15/15	15/15	15/15	OK
15	21	20/17	20/17	20/17	15/15	15/15	15/15	OK
16	26	20/18	20/18	20/17	15/15	15/15	15/15	OK
17	22	20/22	20/20	20/22	15/15	15/15	15/15	OK
18	22	20/25	20/22	20/20	15/15	15/15	15/15	OK
19	16	20/33	20/33	20/29	15/15	15/15	15/15	OK
20	37	20/25	20/22	20/29	15/15	15/15	15/15	OK
21	20	20/17	20/17	20/17	15/15	15/15	15/15	OK
22	45	20/22	20/20	20/200	15/15	15/15	15/60	OK
23	26	20/18	20/18	20/18	15/15	15/15	15/15	OK
24	29	20/20	20/18	20/20	15/15	15/15	15/15	OK
25	31	20/22	20/22	20/25	15/15	15/20	15/15	Marginal
26	24	20/20	20/20	20/22	15/15	15/20	15/15	OK
27	35	20/20	20/20	20/18	15/15	15/15	15/15	OK
28	36	20/17	20/18	20/18	15/15	15/15	15/15	OK
29	35	20/17	20/18	20/20	15/15	15/15	15/15	OK
30	30	20/18	20/20	20/18	15/15	15/15	15/15	OK
31	61	20/20	20/20	20/22	15/20	15/20	15/15	OK
32	26	20/22	20/22	20/25	15/15	15/15	15/15	OK
33	18	20/17	20/20	20/18	15/15	15/15	15/15	OK
34	28	20/17	20/17	20/17	15/15	15/15	15/15	OK
35	37	20/25	20/25	20/25	15/15	15/15	15/15	OK

Figure 3. Average graded response of observers as a function of area and luminance.

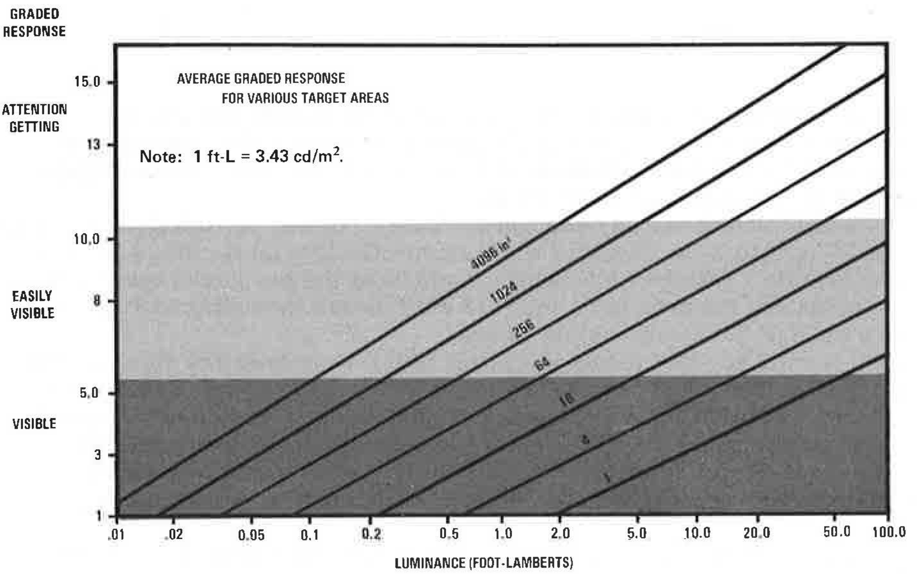


Figure 4. Average graded response extended to low-luminance targets.

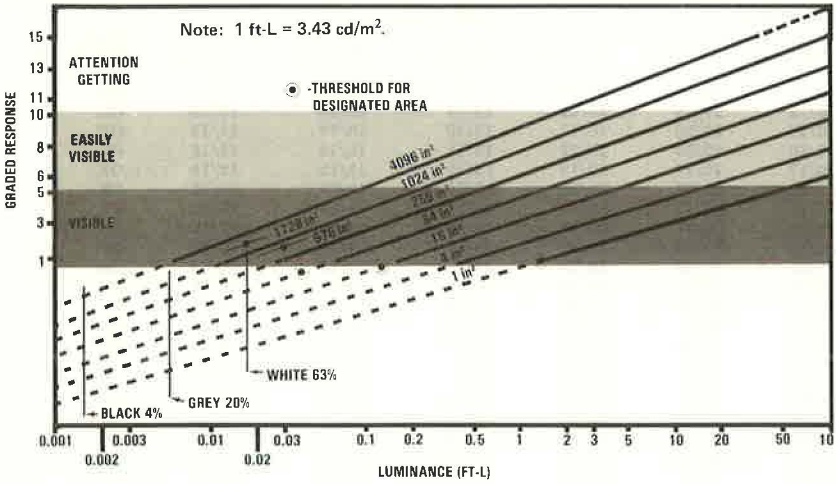


Table 2. Luminous intensity and luminance for retroflective materials using standard low-beam head lamps at 550 ft (167.64 m).

Material	Luminous Intensity (candle/ft-c/ft²)[a]	Luminance (ft-L)[b]
L-S-300A reflectivity-5 sheeting	65	3.4
L-S-300A reflectivity-1 sheeting	110	5.8
White retroreflective fabric	100	5.4
High-performance retroreflective sheeting	260	13.7
Prismatic retroreflective sheeting	1200	63.3

Note: 1 candle/ft-c/ft² = 1 cd/lx/m². 1 ft-L = 3.43 cd/m².
[a]At a -4-deg entering angle and 0.2-deg observation angle. [b]At 12.7 V.

DISCUSSION

Figure 3 shows the derived relationships between target luminance and subject response for different target areas. For certain luminance values, the response can vary from just visible to attention getting as area is increased. For a given response, greater brightness is needed for smaller areas.

Using Figure 3 and Table 2 values, one can evaluate a number of reflective material applications. A 16-in.² (10.3-cm²) band of white retroreflective fabric would be predicted to have an observer rating of 5.5, which would be at the low end of the easily visible range. Increasing the area to 64 in.² (413 cm²) moves the rating to 7.5, which would be in the middle of the easily visible range.

A white, class A reflector that meets minimum Motor Vehicle Safety Standard 108 and SAE J594 requirements would have a 6 rating, which would be just in the easily visible range. A red, class A reflector would have a 4 rating. The effect of color was not considered in this study, so actual observer response rating remains doubtful. Studies (12) have shown red to be more noticeable than white at equal intensities, so one could postulate that a response between 4 and 6 would be given a red, class A reflector.

The advance warning triangle, as specified in Motor Vehicle Safety Standard 125, when viewed head on at a 0.2-deg observation angle, receives an observer rating of nearly 8. However, at a 30-deg angle to traffic, as a result of road curvature, misalignment, or both, the same advance warning triangle receives a rating of 4.5, which would be visible but not easily visible or attention getting. The slow-moving-vehicle emblem manufactured under present standards would be rated about 4.

The area available for reflectorizing a pedestrian is limited. A silhouette analysis is as follows (0 deg is front view; 1 ft = 0.305 m; 1 in.^{2} = 6.45 cm^2):

		View (in.^{2})				
Subject	Height (ft)	0 deg	45 deg	90 deg	135 deg	180 deg
Adult	5.86	981	750	675	838	956
Child	3.98	506	462	375	456	494

[This analysis was carried out in a manner similar to that described by Woltman and Austin (14) in their analysis of motorcycle silhouettes.] Because these are rather small areas, high luminance is required to achieve ratings of 11 or higher. Objects with much larger areas, such as road signs, more easily achieve ratings in the attention-getting region. A 36-in. (91.4-cm) octagonal stop sign would be rated at 10, and a 10- by 20-ft (3.05- by 6.1-m) green-ground-mount guide sign might be rated at 13.5 based on luminance values of high-performance retroreflective sheeting. As we have indicated before, the effect of color has not been taken into account.

When various areas and luminances of light targets and reflective devices are plotted, observer response is influenced mostly by the total light returned. Confining a given amount of light in a small area is somewhat more efficient than spreading it out (within the range of areas observed in this study), but smaller areas are limited in the amount of total light that can be generated. This is especially true for retroreflectors, the attainable luminance of which is limited. A more feasible, direct way to increase total light is by increasing area. This can have the added advantage of providing identifiable shapes and recognition cues (rather than point sources) if it is judiciously done.

At the lower end of the scale, average threshold readings are plotted for various areas. A curve fitted to these points is a straight line that almost coincides with an observer rating of 1. If the measured luminances for white, gray, and black clothing (63, 20, and 4 percent reflectances respectively) are plotted (Figure 4), they fall below threshold except for the full area of an adult in white from the front, which is just barely over threshold. Thus an adult dressed entirely in white clothing would be just barely discerned at 550 ft (167.64 m). All other clothing combinations would be below threshold.

The following indicates how the varying head-lamp light output, which results from varying voltages in an automobile, affects light return from a representative retro-reflector (1 ft-L = 3.43 cd/m^2):

Operating Voltage	Luminance (ft-L)	Operating Voltage	Luminance (ft-L)
12.7	3.4	12.0	2.8
12.4	3.1	11.5	2.4

The previous discussion was based on the 12.7-V conditions. Lower voltages would shift all data to the lower direction on the observer response scale.

Use of high beams or shorter viewing distances would probably move the curves in the direction of higher observer response. However, these conditions would be far from universal because low beams are used much of the time, and the full stopping sight distance may be needed frequently, especially when driver inattention and lack of expectancy prevail. Lack of expectancy probably plays a major role in pedestrian accidents on expressways.

Use of target motion (pedestrian's moving arms and legs or movement of bicycle pedals), recognizable shape, and color also might move the data curves in the direction of higher response. These factors should be further explored and, if effective, be used in the visual protection of pedestrians, bicyclists, and motorcyclists. In addition to mere detection, recognition of an object on the roadway is quite important so that the driver can make correct decisions and proper avoidance maneuvers in time. Area shapes provide not only recognition but also a frame of reference by which speed and distance can be judged.

Other factors exist that might move these curves toward lower observer response. Some of these could be tinted and dirty windshields, misaimed headlights, rain, snow, fog, road curvature, and effects of alcohol. Hazlett and Allen's study (15) on the effect of alcohol on the driver's ability to perceive a pedestrian at blood alcohol levels of 0.06 to 0.10 showed a dangerous loss of detection capability unless reflectorization was added. Even small amounts of reflectorization [material 11 in.^{2} (71 cm^2) of 50 candles/ft-c/ft^2 (50 cd/lx/m^2)] enabled the driver at blood alcohol levels of 0.06 to 0.10 to perceive the pedestrian sooner than a sober driver could perceive a pedestrian dressed in all-white clothing.

The combined effects of the various counterbalancing factors described above have not been quantified. If the positive and negative effects offset each other to some extent and the curves presented here represent typical driving condition responses, one can conclude that a pedestrian dressed in any normal clothing cannot be seen adequately on the roadway. To make matters worse, most pedestrians think they are easily seen by approaching motorists because they appear to be bathed in light. The study done by Allen et al. (16) shows that pedestrians' estimates of their own visibility are dangerously high.

The results of this study agree with those of the Breckenridge and Douglas (10) study that stated that attention getting is different from threshold values. The data (Figure 4) did show that factors 100 to 1,000 times threshold were appropriate. It is probably not necessary to use this degree of visibility enhancement to substantially improve pedestrian visibility at night. If an observer response level equal to the class A reflector at head-on angles were established, it could be met with 16 in.^{2} (103 cm^2) of white retroreflective fabric. If an observer response level equal to that of the advance warning triangle at head-on angles were established, it could be met with 128 in.^{2} (826 cm^2) of white retroreflective fabric, which would be equivalent to a piece 12 by 10.7 in. (30.5 by 27.2 cm).

Probably more important than ensuring extremely high values of reflectorization would be ensuring that, regardless of angle of orientation, the pedestrian is visible to the motorist. Providing a high degree of visibility from one direction such as from the front or back but failing to provide it at other angles does not sufficiently protect the pedestrian.

SUMMARY AND CONCLUSIONS

This experiment was conducted to establish some standard viewer responses under 1 set of conditions—viewing illuminated targets at 550 ft (167.64 m) under dark ambient light as target area and brightness were varied. The viewer responses to the targets lighted with standard low head lamps then were related to reflective materials having various reflectance values.

The set of curves developed showing relationships of target area, brightness, and subjective response enable the selection of reflective treatments appropriate to the visual enhancement desired. Apart from threshold values, there appears to be no sharp cutoff point but rather a continual improvement in target conspicuousness as the total amount of light returned to the viewer increases. Because of practical limitation in retroreflector brightness and design, we find the most feasible way to increase total light is through increased reflective area.

Good visibility and early perception of the pedestrian by the driver play an important role in accident prevention both day and night, but especially at night. Because the energy exchange is so unequal in a collision between a vehicle and a pedestrian and because the pedestrian is so vulnerable to a variety of impacts, accidents must be completely avoided. Accident data analysis indicates that if drivers could see and react to pedestrians at night as well as they do during the day, many lives would be saved. The observer response index developed in this research hopefully will be a step toward achieving needed conspicuousness for the pedestrian. Additional research is needed on this important subject, but, more importantly, immediate action and implementation are needed to begin reducing pedestrian deaths and injuries.

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