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Final Report

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CONSPICUITY FOR PEDESTRIANS AND BICYCLISTS: DEFINITION OF THE PROBLEM, DEVELOPMENT AND TEST OF COUNTERMEASURES

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16. Abstract

A field experiment was conducted to determine the extent of conspicuity enhancement provided pedestrians and bicyclists at night by various commercially available retroreflective materials and lights. The conspicuous materials were designed to be worn or carried by the pedestrians and bicyclists.

Detection and recognition distances for the various experimental and baseline conditions were determined using subjects driving instrumented vehicles over a predetermined course on a real-world roadway system. Field experimenters were used to model the conspicuity-enhancing materials employing natural motion associated with walking and bicycling.

The detection and recognition data collected for the experimental treatment are compared to respective baseline or untreated conditions and are interpreted in terms of various indices of "sufficient conspicuity."

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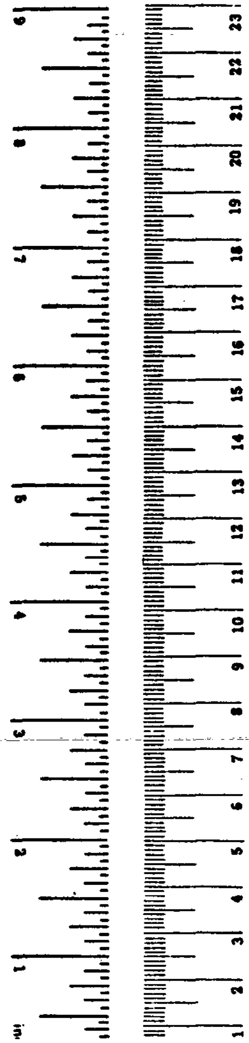
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

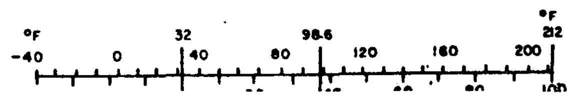
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286,



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

TECHNICAL SUMMARY

CONTRACTOR	CONTRACT NUMBER
Dunlap and Associates East, Inc. 17 Washington Street Norwalk CT 06854	DTNH22-80-C-07052
REPORT TITLE Conspicuity for Pedestrians and Bicyclists: Definition of the Problem, Development and Test of Countermeasures	REPORT DATE April 1984

REPORT AUTHOR(S)
Richard D. Blomberg, Allen Hale and David F. Preusser, Ph.D.

This study was designed to identify and test countermeasures to improve the conspicuity of pedestrians and bicyclists. The field study, reported on in this final report was preceded by three principal analytical steps. A comprehensive examination of the role of conspicuity, or lack thereof, in collisions between motor vehicles and pedestrians/bicyclists was conducted coincident with the development of an operational definition of conspicuity. Existing accident data bases for bicycle/motor vehicle accidents (Cross and Fisher, 1977) and rural and suburban pedestrian crashes (Knoblauch, 1977) were re-analyzed to identify targets for countermeasure development. This analysis led to the selection of two accident types upon which to focus the countermeasure development, selection and testing processes.

These accident types were "Type 25--Walking Along the Roadway" for pedestrians (Knoblauch, 1977) and "Type 13--Motorist Overtaking, Bicyclist Not Observed" (Cross and Fisher, 1977). Both principally involve a motorist at night on a rural/suburban, two-lane road overtaking and striking a pedestrian/bicyclist along the side of the roadway. Although in many cases a substantial and unobstructed line of sight is available, the pedestrian or bicyclist is not seen until it is too late to avoid a collision. The telling features of this situation are darkness and dark clothing of the pedestrians and bicyclists. Clearly, effective enhancement of pedestrian and bicyclist conspicuity in this traffic situation has the potential to reduce substantially the risks to these individuals.

While these accident types were selected as the focus for test efforts, other conspicuity-related situations were also identified as important but could not be addressed in the test phase with available resources. These included the situation of pedestrians and bicyclists who were not visible because a motorist's view was obstructed and the case of "camouflaged" pedestrians and, especially, bicyclists who, though theoretically visible in daylight or twilight conditions, were simply not detected by the motorist.

A second preliminary step in the study was to perform an extensive literature review to provide background for both the development of countermeasures and the establishment of field test protocols. The results of this review indicated that there was virtually no information available on consumer attitudes towards conspicuity countermeasures. The literature also suggested that a controlled field test in which measurements were made with alerted subjects rather than an unobtrusive test in free-flowing traffic would

(Continue on additional pages)

"PREPARED FOR THE DEPARTMENT OF TRANSPORTATION, NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION UNDER CONTRACT NO.: DTNH22-80-C-07052. THE OPINIONS, FINDINGS, AND CONCLUSIONS EXPRESSED IN THIS PUBLICATION ARE THOSE OF THE AUTHORS AND NOT NECESSARILY THOSE OF THE NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION."

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July 1974

be likely to provide the best information to meet the objectives of this study. Detailed descriptions of the reviewed literature were separately published as part of this study (Hale and Zeidler, 1984).

A third preliminary step was undertaken to attempt to overcome the absence of "market" data on conspicuity-enhancing products. This step, conducted in cooperation with the American Society for Testing and Materials (ASTM) Committee F-22 on "High Visibility Materials for Individual Safety," involved a mailed survey of ASTM members. Responses from 2,864 ASTM members and their friends were collected and indicated a generally positive attitude towards the acquisition and use of conspicuity countermeasures costing up to $10.00. Above that price, interest diminished rapidly. Hence, the selection of countermeasures for testing gave first consideration to commercially available products which could likely be mass produced and sold for $10.00 or less. Although this sample was likely older and more technically oriented than the typical accident-involved pedestrian or bicyclist, the results were unique and therefore of value to the present effort.

The basic orientation of the field study was to assess the relative benefits of various active (lights) and passive (retroreflective) materials to increase the nighttime conspicuity of pedestrians and bicyclists. Based on the results of preliminary steps and to maximize the generalizability of results to the real-world traffic environment, the following experimental procedures were employed:

- o An operational highway environment with characteristics similar to the accident types being studied was secured and utilized for data collection.

- o Data were collected from alerted subjects driving instrumented vehicles using low beam headlights. The primary measures were "detection" and "recognition" distances for pedestrian and bicyclist targets with and without conspicuity-enhancing treatments.

- o Live models ("field experimenters") were used to display the pedestrian and bicyclist conspicuity enhancing treatments along with the motion associated with walking and pedaling in order to add realism.

The field study was conducted on a section of the naturalistic (two lane with traffic control devices) roadway system of the Camp Atterbury U.S. Army Reserve Forces Training Area near Columbus, Indiana on the nights of October 2, 3 and 4, 1983. Due to military requirements and for the safety benefit of all study participants, vehicles other than the instrumented cars, were excluded from the experimental course.

The experimental conditions tested for pedestrians were:

P1 Baseline Pedestrian--wearing an extra large, white tee shirt over outer clothing and blue jeans and walking in place (limb movement/only, no translational movement).

P2 Dangle Tags--baseline pedestrian wearing two 2-1/8 inch retro-reflective disks suspended from strings attached near the waist level.

P3 Flashlight--baseline pedestrian holding and swinging while walking a common two D-cell flashlight in the right hand.

P4 Jogger's Vest--baseline pedestrian wearing a combination retroreflective and fluorescent vest.

P5 Rings--baseline pedestrian wearing a retroreflective headband, two retroreflective wristbands, a retroreflective belt and retroreflective anklebands.

The experimental conditions tested for bicyclists were:

B1 Baseline Bicyclist--wearing a white tee shirt and blue jeans astride and pedaling a ten speed bicycle (with CPSC required reflectors) mounted on a bicycle stand. This permitted a pedaling motion to occur and the rear wheel to rotate without the bicycle changing position on the roadway.

B2 Spokes and Crank--baseline bicyclist plus the addition of retroreflective strips on the sides of the bicycle cranks and retroreflective tubes on the spokes of the rear wheel.

B3 Leg Lamp--baseline bicyclist wearing a small light (two 1.5 volt C-cells) attached to the left ankle. A red lens faced rearward and a clear lens forward.

B4 Fanny Bumper and Anklebands--baseline bicyclist wearing a 12 inch equilateral fluorescent triangle over his posterior. The triangle or "Fanny Bumper" had a one inch border of retroreflective material. The bicyclist also wore retroreflective anklebands.

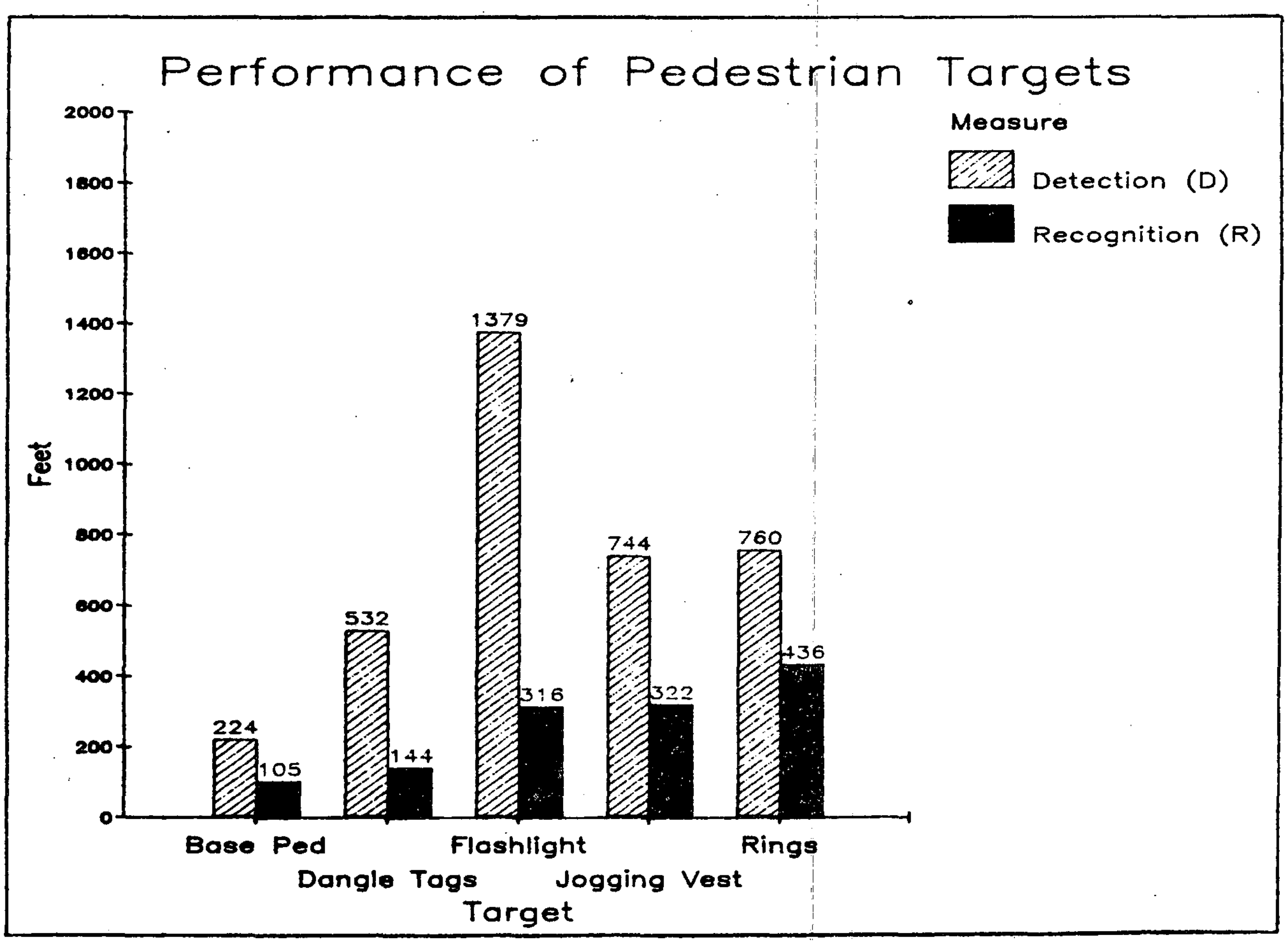
Each of these targets was selected after a thorough review along several dimensions such as previous use in a large-scale safety program, postulated or actual consumer acceptance or representativeness of the types of commercially available products. Since there was a limit on the number of treatments which could be tested in the chosen full factorial design, a significant amount of subjective judgment was needed to arrive at the final set.

To minimize any effects due to location on the test course at which a treatment was placed, each of the nine treatments enumerated above was relocated after having been seen by four subjects. Thus, each of the nine "movable" targets (five pedestrian and four bicycle) was seen by four subjects in each of nine locations. In addition, nine distractor targets were deployed at fixed locations including: two warning triangles, a strobe, a construction barricade with flashing light, a pedestrian in dark clothes and a similarly attired pedestrian with the addition of four retroreflective "Hot Dots," a riderless bicycle with a flashing amber "Belt Beacon" attached, a riderless bicycle with a retroreflective arrow attached and an array of traffic cones capped with retroreflective sleeves.

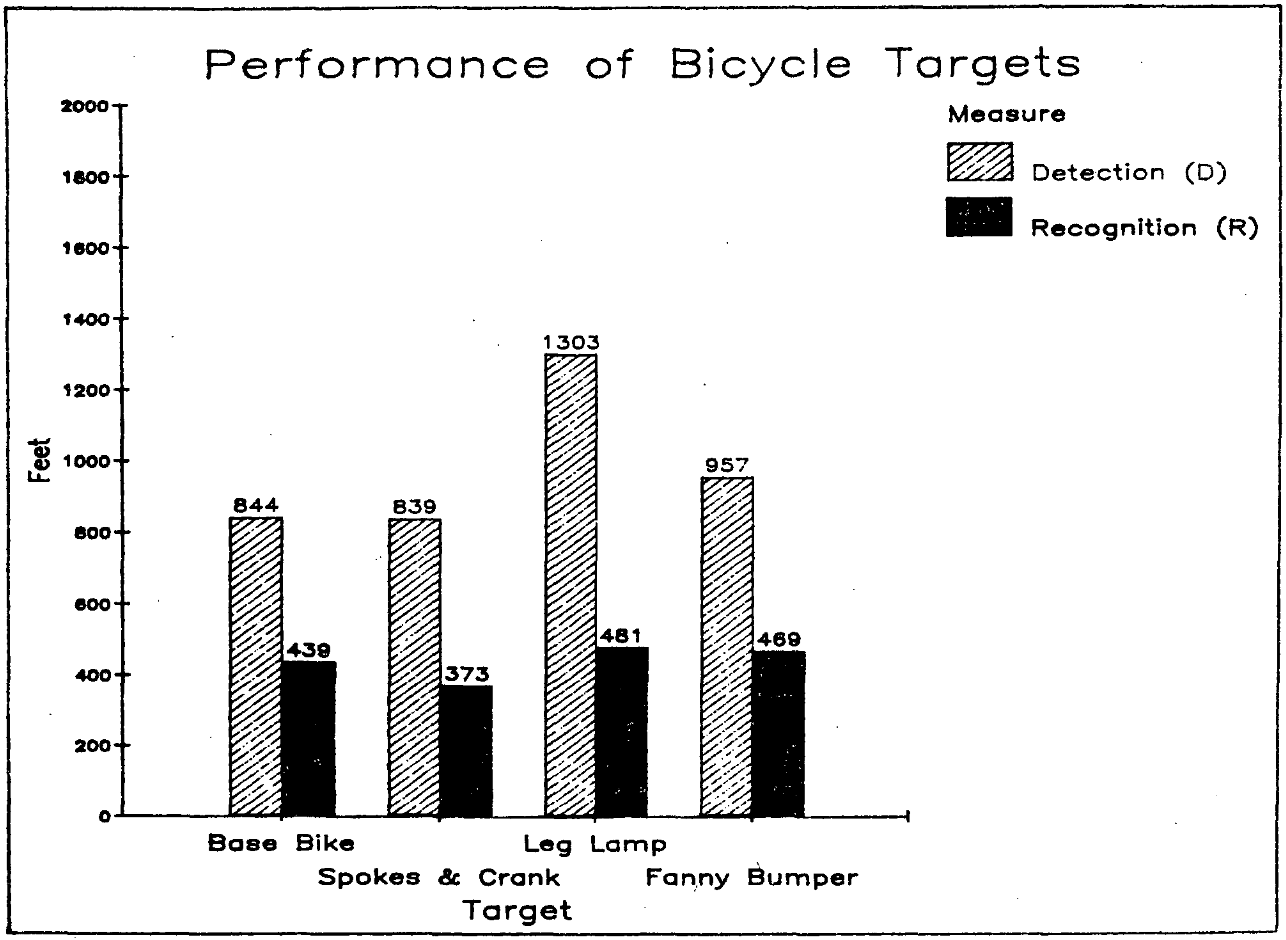
Subjects and field experimenters were Indiana University graduate students (School of Optometry). A total of 36 subjects were used, with 12 subjects being run on each of the three nights of experimentation. Subjects drove the 8-½ mile course (about 20 to 25 minutes driving time) at Camp Atterbury in an instrumented car which permitted the recording of announced detection and recognition distances for all targets observed (experimental and distractor). Pedestrian targets were located near the edge of the roadway facing traffic and walking in place (except for the fixed targets which faced traffic and posed as hitchhikers). Bicyclist targets were located near the edge of the roadway, facing in the direction of the adjacent traffic flow. Bicyclists pedaled the bicycle mounted on a bicycle stand.

Beyond the principal data collected during the experimental runs, namely target detection and recognition distances, in situ photometric measurements were made of the targets and the background illumination at target locations. Moreover, reactions and comments were obtained from subjects via a questionnaire following their experimental runs.

The Figure below shows the mean detection and recognition distance values for the five movable pedestrian targets.



Similar data for the four bicyclist targets is shown below.



Principal among the results were the following:

- On average, the Flashlight (1,379.22 feet) was detected over 600 feet farther away than the next best pedestrian target, Rings (759.56 feet). The average baseline pedestrian detection distance was 223.83 feet.

- On average, the Leg Lamp (1,302.69 feet) was detected over 300 feet farther away than the next best bicyclist target, the Fanny Bumper (956.61 feet) and was superior on all measures to all other bicyclist conditions. The average baseline bicyclist detection distance was 844.06 feet.

The study results led to the derivation of several recommendations for specific, frequently encountered use situations. It should be noted that none of these recommendations cover pedestrians walking with traffic, which is almost always illegal in all states, or bicyclists riding facing traffic, which also is universally prohibited. Even though these situations are frequently associated with accidents, there is no justification for tacitly condoning them by suggesting conspicuity-enhancing countermeasures for use while walking with traffic or bicycling against it.

Specific recommendations for use derived were:

- White clothing should not be used as a conspicuity enhancer. If a pedestrian or bicyclist is unexpectedly caught on the roadway during darkness, deploying white, e.g., by removing a dark jacket to reveal a white shirt, would likely be beneficial. However, the preponderance of evidence suggests that white alone is not sufficient to promote an acceptable level of safety. Safety campaigns should certainly <u>not</u> promote the use of white clothing as a countermeasure but, rather, should concentrate on retroreflective and active treatments for nighttime use and fluorescent materials for daytime applications.

- Motorists should carry a flashlight or other active light source in their vehicles in case of a breakdown or accident. The flashlight would also be helpful in performing repairs at night. In addition, some retroreflective treatment should also be carried. Based on the findings of Ulmer, Leaf and Blomberg (1982), care should be exercised to insure that this treatment returns a strong signal from the side of a kneeling or standing pedestrian, an aspect often presented by a motorist changing a tire.

- Pedestrians who must undertake a purposeful nighttime trip should carry a flashlight or other light source and wear anthropometric shaped retroreflective materials like the Rings treatment.

- If someone must bicycle at night, an active source, such as the Leg Lamp, supplemented by at least the standard CPSC reflectors should be used. In addition, consideration should be given by those who ride regularly at night such as bicycle commuters to purchasing one of the available high intensity bicycle lighting systems. The belt beacon type of flashing light, tested herein as a fixed target, would also appear to be a reasonable choice for both pedestrians and bicyclists.

- Joggers who are willing to risk running at night should wear a vest with two horizontal stripes of bright, retroreflective material in addition to carrying a flashlight or other active light source. This configuration of a vest, as tested in this study, seems to be sufficiently common to have created a target signature as indicated by post-trial subject debriefings. Adding retroreflective trim visible to the front of running shoes or, in fact, any footwear, although not tested in this study, also seems advisable. It places the material low to the ground where headlights can easily strike it and should achieve additional attention-getting value from the normal foot motion.

FOREWORD

This report is the final product of Contract No. DTNH22-80-C-07052 between the National Highway Traffic Safety Administration and Dunlap and Associates East, Inc. The effort entitled "Conspicuity for Pedestrians and Bicyclists: Definition of the Problem, Development and Test of Countermeasures," began in September 1980 and ended in November 1983. The objectives of this study were to analyze existing pedestrian and bicyclist accident data bases to estimate the extent and nature of the problem attributable to conspicuity. This information was to be utilized to formulate remedial measures which could be rigorously tested in the final stage of the effort.

This report concentrates on the field test portion of the study although the entire study chronology and intermediate results relevant to the design or conduct of the field test are presented. An additional report entitled "Review of the Literature and Programs for Pedestrian and Bicyclist Conspicuity" (Hale and Zeidler, 1984) was also a product of this study.

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ACKNOWLEDGMENTS

Valuable assistance has been provided by various individuals and agencies in the planning and conduct of this study. Dr. Marvin M. Levy, Contract Technical Manager, of the National Highway Traffic Safety Administration, was a primary source of technical consultation in developing and meeting useful goals for this research. Essential support to the planning and conduct of the field study was provided by the individuals listed below:

- Dr. Merrill J. Allen, Professor of the Indiana University School of Optometry. Dr. Allen devoted considerable time and effort to the screening and recruitment of subjects and field experimenters, the measurement of conspicuity treatment luminance and target location background illumination, and the coordination of study site arrangements and experimental protocol.

- Mr. Jacque Kubley, Graphics Laboratory Director of the Indiana University School of Optometry. Mr. Kubley performed the very difficult job of locating and relocating experimental targets on the driving course. Mr. Kubley also smoothly coordinated the transportation of subjects, field experimenters and catered meals between the Indiana University campus and the field study site.

- Colonel Arthur L. Goldman, Post Commander and CSM Engelking of the Atterbury Reserve Forces Training Area who kindly consented to the field study being conducted at "Camp Atterbury" and generously made numerous facilities available to project staff and study participants.

- Mr. Jerry Cravens, Superintendent of the Indiana Department of Highways (Bloomington Sub-District). Mr. Cravens provided numerous traffic control devices which were used in the field study.

- Mr. Wade Miller, Sales Director of Nu-Metrics Instrumentation. Mr. Miller devoted personal attention to the prompt delivery of the K-5000 Distance Measuring and P-5000 Printer Units, provided timely check-out of the equipment and training for the project staff. The equipment worked flawlessly.

Finally, the authors wish to express their sincere appreciation for the professional manner in which the students of the Indiana School of Optometry conducted themselves as subjects and field experimenters under circumstances which were demanding at times. Their performance during the cool and rainy conditions of the third night of experimentation was particularly commendable.

I. INTRODUCTION

A. Contractual Background

The National Highway Traffic Safety Administration (NHTSA) has sponsored research to identify causal factors and countermeasures for pedestrian and bicyclist traffic accidents since the early 1970's. Training programs have been developed to improve the search and detection behavior of young pedestrians, a behavioral deficiency identified as a leading contributor to pedestrian accidents. In the statement of work for this contract (DTNH22-80-C-07052, p. 1), it was stated that "To one degree or another conspicuity has also emerged as a contributing factor in the pedestrian and bicycle accident areas. In the rural pedestrian accident area, approximately 16 percent of the accidents involved poor visibility as a potential causal factor (Knoblauch, 1977). Poor visibility also was found to be a predisposing factor in approximately three percent of the urban pedestrian accidents studied (Snyder and Knoblauch, 1971). In the bicyclist/motor vehicle accident area, degraded visibility has been noted as a contributory factor in ten percent of the nonfatal and 35 percent of the fatal accidents studied (Cross and Fisher, 1977)."

In attacking the problem of "inconspicuity" for pedestrians and bicyclists, a structured, incremental approach has been adopted. First it was necessary to examine all relevant accident data bases to determine the extent of the inconspicuity problem and the specific situations and mechanisms involved. Parallel with this effort was the development of an operational concept of conspicuity which could provide an empirical basis for assessing conspicuity-enhancing materials. From this point, general concepts for countermeasures were developed to enhance the visibility or conspicuity of pedestrians and bicyclists. Supporting such an initial conceptualization was a comprehensive review of the latest world-wide scientific and technical literature bearing on the subjects of human visual perception, information processing and conspicuity. Moreover, foreign and domestic governmental and private programs to promote enhanced pedestrian and bicyclist conspicuity were identified and described and available conspicuity-enhancing materials and devices were collected, analyzed and catalogued. Finally, a survey conducted of public awareness of the conspicuity problem for pedestrians and bicyclists and acceptance of various conspicuity-enhancing measures in terms of perceived effectiveness, cost and convenience was undertaken as an important final developmental step in the process of selecting specific conspicuity-enhancing countermeasures for field testing.

The aforementioned developmental steps were carried out and documented during the course of this contract. They are summarized below as background to the effort described in detail in this report.

1. Operational Definition of Conspicuity and Accident Analysis

As a foundation for a provisional operational definition of conspicuity, a model of the "Motorist Sensory-Evaluative-Motor Process for Collision Avoidance" was postulated. The operational definition of conspicuity proposed was anchored to a quantifiable, although conservative, concept of sight stopping distance (SSD). SSD is defined as the sum of the distance a vehicle travels after the driver sights an object but before braking and the distance it travels after braking until it stops (ITE, 1976). The core of the conspicuity definition proposed that any conspicuity treatment "... shall be considered sufficiently conspicuous when it affords the pedestrian, regardless of orientation to the paths of approaching traffic, a pre-recognition distance by a passenger vehicle motorist (using low-beam lights at night), which is equal to or greater than the stopping sight distance for the maximum safe speed for the roadway in question." Pre-recognition distance was defined as the distance at which the object is perceived to be animate (not necessarily specifically a pedestrian or bicyclist) and mobile or capable of motion.

In examining the role of inconspicuity in pedestrian and bicyclist accident records, the following three types of inconspicuity were identified:

- Type I--The Invisible Object

  This embodies all those situations where a pedestrian or bicyclist is unobstructed within the visual field, and would otherwise be visible during "normal" daylight, but is now rendered invisible (subthreshold) by low light (twilight), no light (nighttime), precipitation, or glare from the sky or pavement. Nighttime is the principal offending condition.

- Type II Inconspicuity--The Obstructed Object

  In this case the pedestrian or bicyclist is located within the normal, forward visual field of the motorist. Whereas the pedestrian or bicyclist in Type I is subthreshold, the individual in Type II is suprathreshold, typically during the daytime. The pathway of the bicyclist or pedestrian is usually at a right angle to that of the approaching motorist, and in this case, obstructions (typically parked, standing or moving vehicles; buildings, walls, fences; vegetation--trees, hedges, shrubs) dangerously foreshorten the views which pedestrians, bicyclists and motorists may have of one another.

- Type III Inconspicuity--The Visible Object Not Seen

  This case basically describes the situation where a suprathreshold (typically daytime or twilight) pedestrian or bicyclist does not stand out sufficiently from the visual background to be seen when the driver looks. Additionally, this category often includes the situation of a motorist experiencing high attention demand (e.g., negotiating a turn at a busy intersection) and not seeing a bicyclist or pedestrian in the visual periphery.

From an overall view of the accident data, it was estimated that approximately 10 to 30 percent of all pedestrian and 31 to 42 percent of all bicyclist accidents involved inconspicuity as a contributing factor. These estimates were necessarily broad and somewhat subjective since the available data bases had not been structured to obtain detailed information on the role of conspicuity in the studied accidents.

In attempting to narrow the field of accident types for countermeasure development and testing in a cost-effective manner, it was decided to focus on pedestrian and bicyclist accident types involving an available but lost opportunity (due to inconspicuity) for motorists, to detect pedestrians and bicyclists. The classic situation occurs at night with the motorist and pedestrian and/or bicyclist on parallel courses for some time on a non-intersecting road segment before the collision occurs. Accident types such as the following define the focus of the present study towards counteracting Type I Inconspicuity for pedestrians and bicyclists:

- <u>Pedestrian (Rural/Suburban Pedestrian Accident Data Base--Knoblauch, 1977)</u>

  - Type 25, "Walking Along the Roadway"

    It represents 11.6 percent (largest percentage) of all rural/suburban pedestrian accidents studied. It involves a pedestrian walking along a two-lane roadway in a residential, country location. Over half (55 percent) of this type occurred after dark.

- <u>Bicyclist (Bicyclist Accident Data Base--Cross and Fisher, 1977)</u>

  - Type 13, "Motorist Overtaking: Bicyclist Not Observed"

    It represents 4.0 percent of the non-fatal accidents studied and <u>24.6 percent (largest percentage)</u> of the fatal accidents studied. <u>In most cases (60 percent)</u>, it involves a bicyclist on a narrow roadway with two traffic lanes and no useable shoulder or sidewalk. It is the only bicycle type for which nighttime accidents are more frequent than daytime crashes with 63 percent of the non-fatal and 71 percent of the fatal crashes occurring at night.

The salient and disturbing factor in these accident types is the available sight distance (thus preview time) between a motorist and pedestrian or bicyclist which is compromised by twilight or darkness. Improving the target value of pedestrians and bicyclists through appropriate conspicuity enhancement should increase the distances at which motorists detect and recognize pedestrians and bicyclists and thus counteract the deadly "cloaking" effects of darkness and twilight.

Countermeasures for inconspicuity Types II and III were not tested in the present study. Type II inconspicuity, although estimated to represent between two percent and 13 percent of all pedestrian accidents and eight to 12 percent of bicyclist crashes, was not addressed in the test phase of this effort. In general, the problems or visual obstructions were considered best addressed by removing the obstacles, e.g., parked cars, than by adding extensions to the pedestrian or bicyclist to enable them to be seen in spite of the visual screen. Also, Type II inconspicuity is largely a daytime problem and available resources did not permit testing both daytime and nighttime conspicuity-enhancing approaches.

Type III inconspicuity, involving a camouflaged pedestrian or bicyclist, is also primarily a daylight or twilight problem and hence was not included in the test phase of the effort reported herein. It is largely a non-urban pedestrian problem and likely accounts for well under five percent of all pedestrian crashes. It is, however, a major factor in bicyclist accidents and is implicated in between 16 and 21 percent of all bicyclist/motor vehicle accidents. Both Type II and Type III inconspicuity problems are worthy of further research of the kind reported in the remainder of this report if additional resources become available.

2. Literature Review and Materials Collection

A comprehensive review of world-wide literature was undertaken of selected countermeasures and experimental protocols. Topics covered included:

- Operational concepts of conspicuity
- Basic driver visual capabilities
  - Visual/psychomotor behavior
  - Foveal versus peripheral vision
  - Scanning behavior
  - Flashing and intermittent signals
  - Colored lights
  - Object size, luminance, shape and contrast
  - Object motion
  - Information processing and signal detection
- Factors affecting driver vision
  - Driver-based
    - General
    - Alcohol and drugs
    - Glare
  - Vehicle-based
    - Headlamps
    - Windshields
  - Traffic environment-based
- Conspicuity-enhancing approaches
  - Pedestrians
  - Bicycles and Bicyclists
  - Bicycles and Motorcycles
  - Motor Vehicles
  - Miscellaneous Vehicles (aircraft, trains)
  - Traffic control device active (lights) and passive (retroreflective, fluorescent)

The various classes of conspicuity enhancing materials of practical significance for bicyclists and pedestrians were identified and their applications discussed. The results of this literature review have been published separately

(Hale and Zeidler, 1984) in the form of an annotated bibliography. The review itself suggested the need for a "realistic" experiment with subjects engaged in an actual driving task. It also provided insights concerning the types of conspicuity-enhancing approaches which had been tried previously and/or were considered to have the greatest countermeasure potential.

3. Survey on High Visibility Materials for Pedestrians and Bicyclists

The selection of countermeasures for testing had to consider the knowledge, attitudes and desires of the potential users of high visibility materials. Simply, any countermeasure is only of value if it is used. A survey was considered the best vehicle to obtain the desired information, but contractual restrictions made a survey of the general public impossible. However, the American Society for Testing and Materials (ASTM) through its committee F22 on High Visibility Materials for Individual Safety was also interested in the same information and agreed to survey the ASTM membership and share the results with this project. Although this sample was likely older and more technically oriented than the typical accident-involved pedestrian or bicyclist, the results were unique and therefore of value to the present effort.

Responses by 2,864 members of the ASTM and their friends to the survey questionnaire on various subjects concerning the visibility of pedestrians and bicyclists were analyzed. The questionnaire sought information in categories important to the selection and development of conspicuity-enhancing countermeasures. The basic categories were:

- Awareness and understanding of the overall pedestrian/bicyclist visibility problem
- Estimated respondent exposure time as a pedestrian and bicyclist
- Present respondent use of general clothing items and accessories
- Willingness (perceived convenience) to use high visibility materials
- Respondent present and future use of high visibility materials
- Willingness to pay (acceptable costs) for high visibility materials

The three tasks described above, collectively, represent the foundation upon which the field study reported herein was based.

B. Objectives of the Field Study

In consideration of the decision to focus research efforts on the identification, development and evaluation of methods to improve the nighttime visibility of pedestrians and bicyclists along the roadway, the following specific objectives emerged for the field study reported herein:

- Identify a set of both active and passive conspicuity-enhancing treatments for the targeted nighttime pedestrian and bicyclist accident types which were responsive to the factors of user convenience and cost acceptance identified in the consumer survey and represented a reasonable number of alternatives which could be accommodated by a well controlled experimental design for the field study.

- o Assess the relative performance of the selected treatments by collecting driver perceptual data (detection and recognition distances) using "live" subjects as drivers of actual vehicles in real-world, highway setting/lighting conditions with "live" experimenters modeling the experimental treatments. In essence, this objective was to determine which treatments improve conspicuity with as much validity as possible to facilitate the generalizability of test results to the real world traffic environment.

C. Organization of the Report

This report is organized into four additional sections. Section II presents the major considerations leading up to the experimental design and selection of specific conspicuity-enhancing treatments for field testing. In Section III the methods employed in gathering in situ photometric data on the treatments and target location background illumination are described. Additionally, the specific design of the field study and methods for collecting the driver perceptual data are described. Section IV presents the major results and findings of the field study which are interpreted with respect to various criteria of effectiveness. In Section V, the results of the study are discussed in terms of the possible improvement in safety afforded pedestrians and bicyclists using conspicuity-enhancing materials tested in this study.

Appendices are included showing the results of the photometric measurements taken (Appendix A), the results of debriefing questionnaires given to experimental subjects (Appendix J), sample conspicuity-related laws and ordinances (Appendix K) and various forms and exhibits supporting the text of this report (Appendices B-I).

II. FIELD TEST DESIGN CONSIDERATIONS

A. General Considerations

After considering a number of potentially useful approaches to the conduct of the field study for this contract, the decision was made to conduct an assessment of the safety performance of a variety of active and passive conspicuity enhancing treatments designed for pedestrians and bicyclists during nighttime and twilight. "Active" treatments refer to self-luminous materials such as steady or flashing incandescent/fluorescent lights, strobes or chemiluminescent wands. "Passive" treatments, on the other hand, are energized by incident radiation, such as retroreflective and fluorescent materials. While an experiment which studied thé effects of systematic variation of such attributes as brightness, effective area, location, motion, etc. for a given treatment on detectability and/or recognizability would be of value, it was not seen as the most useful approach to the problem of pedestrian and bicyclist conspicuity enhancement at this time. Moreover, any development and testing of unique, prototype treatments, while interesting, did not seem to have the desired utility. Despite the apparent under-utilization of conspicuity enhancing materials by pedestrians and bicyclists, numerous and diverse materials are currently commercially available, especially for joggers/runners and bicyclists. Most of these products employ research-proven conspicuity-enhancing principles to good advantage. Moreover, the presence of these products in the marketplace (in many cases for several years) may be presumed to indicate acceptance and potential use of these products currently by pedestrians and bicyclists. For these reasons, it was decided to structure the present study as an empirical assessment of a selection of commercially available products, singly or in combination, all of which were judged to have substantial potential effectiveness for enhancing pedestrian and bicyclist conspicuity.

Of considerable importance was the desirability of acquiring directly measured, perceptually-based driver responses for the conspicuity treatments, rather than driver response data inferred from observed motor vehicle performance. In some studies of conspicuous materials, effectiveness of these materials has been inferred from passing vehicle performance parameters such as lateral placement from the conspicuity-treated object along the road and the speed at which the vehicle approaches and/or passes the treated object. Specifically it has been asserted that the farther from a treated object a vehicle passes and the slower it does that, the safer. While in some cases these interpretations may be true, an absence of these indications does not necessarily mean that driver awareness and readiness to respond have not been improved. Enhanced conspicuity resulting in drivers seeing and identifying objects sooner may well have been achieved without this improved awareness necessarily showing up as reduced speed or passing an object with a wider clearance. Clearly there are many circumstances where a wider than normal clearance distance is not possible due to the width and/or geometry of the roadway system (e.g., narrow two lanes or an upcoming curve). Similarly, a relatively low initial approach speed of 25 to 30 mph would not necessarily have to be reduced after sighting a conspicuity enhanced roadside object to achieve a cautious approach and passing.

Examination of a number of measured vehicle lateral placements and approach speeds vis a vis objects with and without conspicuity treatments during free flow of traffic has the benefit of capturing motorists driving normally and ostensibly unaware of an experiment in progress. However, undesirable shortcomings were seen to be the following:

- o Ignorance of driver state/condition, i.e.:
  - physical impairments (fatigue, alcohol, drugs, poor vision)
  - distractions (loud audio, interpersonal difficulty);
- o Ignorance of what the driver was seeing, when and where;
- o Unreliability of lateral placement and speed as measures of conspicuity.

A previous study utilizing this approach (Ulmer, Leaf and Blomberg, 1982) had tended to indicate that the method would not discriminate among the types of conspicuity-enhancing treatments being considered for test during this study.

In view of the foregoing a perceptually-based or "inside looking out" approach for structuring the experiment was deemed more valuable. Specifically, determining the average distance at which treated and untreated pedestrians and bicyclists are detected and recognized by subjects driving vehicles with low beam headlights at night over an actual roadway system became major objectives for the field study.

While this form of experiment suffers to some extent from the fact that participating subjects are aware of their participation in a "visibility" experiment, there are numerous advantages of this approach over the free flow of traffic experiment, i.e.:

- o A pre-selected driving course whose traffic flows can be controlled for test participant safety purposes and experimental control can be utilized.
- o Selection and control of subjects to avoid effects of visual pathology, drugs, alcohol or fatigue can be undertaken.
- o Selection and standardization of the body style and headlight illumination systems of experimental vehicles is possible.

It was also felt that the undesirable aspects of the potential "Hawthorne effect" created by subject awareness of participating in an experiment could be minimized. Specifically, carefully conceived instructions to create the proper set for reporting and identifying roadside targets, plus the use of "distractor" targets, plus a realistic and demanding driving task could yield detection and recognition distances on experimental targets that were quite realistic.

The choice of a controlled experiment did not necessarily constrain the subject population employed or the parameters of the driving task, e.g., speed, presence of oncoming glare. However, available resources did not permit a full factorial treatment of even two levels of subject type, e.g., young versus old, or driving task. Hence, a homogeneous subject population (described below) was employed and the driving task was not intentionally varied.

Another desirable design objective for this study was to employ live human experimenters to display the conspicuity treatments. This feature allows pedestrian and bicyclist motion to enter into the conspicuity treatment presentation which has been lacking in some experiments dealing with pedestrian and bicyclist conspicuity. Target motion is a natural attribute of the pedestrian-vehicle encounters for the accident types of principal concern (Type 25--Walking Along the Roadway, Type 13--Motorist Overtaking: Bicyclist Not Observed--see Knoblauch, 1977 and Cross and Fisher, 1977). In both cases the pedestrian and bicyclist are usually in motion when encountered by an overtaking motorist because they are enroute to a planned destination. It seems only fitting that the natural locomotion of pedestrians and bicyclists should be translated into the design and application of conspicuity enhancing materials.

B. Selection of Pedestrian and Bicyclist Treatments

The treatments ultimately selected for assessment in the field test were identified after several utility-oriented criteria. These considerations are discussed and the final set of conspicuity-enhancing treatments are described below. It must be noted that the treatment selection process was not a rigorous rating of multiple criteria but, rather, an application of subjective judgments guided by a general specification of desirable characteristics for a conspicuity countermeasure.

Wherever possible, treatments were selected which embodied one or more of the following desirable characteristics.

1. Research and Program Based Predicted Effectiveness

The literature review highlighted various features of visual stimuli which enhance conspicuity such as:

- Brightness contrast
- Periodicity (flashing/intermittent signals)
- Movement
- Color Contrast

The first three aspects apply especially to the nighttime situation with the relative effectiveness following the order of listing. Color contrast is relatively more effective as a conspicuity-enhancer in the daytime.

Conspicuity features when considered in the deployment of conspicuity-enhancing materials, particularly retroreflective materials at night, generated several deployment strategies, namely:

- Placing retroreflective materials as close to the ground as possible to return the maximum available reflectance from low headlight beams which predominate at night.

- Placing retroreflective materials on the extremities of appendages to capitalize on user-generated motion to increase detectability and recognizability.

- Delineating or outlining the human form with materials to increase recognizability.

Preliminary efforts also involved a collection of available conspicuity-enhancing materials. Basic types of materials suitable for use on the person or a bicycle were itemized. In addition, both domestic and foreign government-sponsored programs to distribute and encourage the use of conspicuous materials by pedestrians were examined. Consequently any large scale distribution of conspicuous materials, such as the pedestrian dangle tags/pendant reflectors distributed in Scandanavia and Great Britain in the late 1970's and early 1980's and the federally financed (in part) "Hot Dot" pedestrian retroreflector programs carried out by approximately 24 states during the 1970's naturally received attention as far as suggesting particular materials for assessment.

2. <u>Current/Pending Statutory Requirements</u>

In recent years with the growing numbers of walkers and joggers on the highway during twilight and evening hours, legislation is pending or has been enacted which requires pedestrians to display retroreflective material or lights when on the highway during hours of poor illumination. For instance, the traffic code of the State of Delaware (Title 21, §4148) has the following requirements:

> §4148. Carrying of Lights or Reflector Device by Pedestrians; Penalty.
> (a) No pedestrian shall walk upon any roadway or shoulders of any roadway of this State that is used for motor or vehicle traffic, beyond the corporate limits of any city or town without carrying a lighted lantern, lighted flashlight or other similar light or reflector type device during the period of time from one-half hour after sunset to one-half hour before sunrise and at any other time when there is not sufficient light to render clearly visible any person or vehicle on the highway.
> (b) Whoever violates subsection (a), shall for the first offense be fined not less than $2 nor more than $25. For each subsequent like offense within one year, he shall be fined not less than $10 nor more than $25.

Similar requirements have been enacted as ordinances in such municipalities as Ottawa Hills, Ohio; Montclair, New Jersey and Charlotte, North Carolina (see Appendix K). Hence legal requirements for <u>both</u> active (lights) and/or passive (retroreflective) materials to be used <u>at night</u> by pedestrians were strong considerations for selection of candidate test materials.

3. Market Availability

Selection of conspicuous materials from those which are currently or about to be available on the marketplace was seen as a desirable feature. Numerous hypotheses for the basic design and/or implementation of active and passive conspicuous materials have been conceived and even pilot tested by the project staff. Some of these ideas have demonstrated considerable apparent effectiveness. However, several of the designs/implementations were unique and not commercially available. Therefore, testing such designs among a limited test set was not deemed to be of maximum benefit to the public. Extrapolation of test results to "analogous" commercially available products could be tenuous. Therefore, since the range of commercially available active and passive pedestrian and bicyclist conspicuity-enhancing products, embodying proven conspicuity principles was considerable, it was decided to restrict selection of candidate conspicuity treatments to commercially available items.

4. Usability and Durability

Judgements as to the usability and durability of candidate treatments were made by the project staff. Within the overall cost envelope for given products, a reasonable expected lifetime of six months to one year was generally considered necessary for inclusion. Overall ease of storage and use of the product were also considered as important consumer acceptance factors strongly affecting the likelihood of actual use of the materials.

5. Design for Personal Use

When considering conspicuity-enhancing materials for pedestrians, clearly only items which may be conveniently used on the person of the pedestrian are really appropriate. To consider any bulky contrivance which would have to be carried or propelled by a pedestrian would not be appropriate. On the other hand, a bicyclist rides a bicycle which is itself a platform for conspicuous materials. Many systems of retroreflectors (e.g, those mandated by the Consumer Product Safety Commission--CPSC) and lights exist for bicycles. Fewer conspicuous materials are designed for bicyclists, per se. However, when an "untreated" bicyclist leaves his bicycle in the highway situation and thus becomes a pedestrian, this individual would be unprotected if conspicuous materials only resided on the bicycle. For all of these reasons it was decided to select and test conspicuous materials that were primarily designed for personal use--that is on the body of the pedestrian or bicyclist.

6. Significant Current or Previous Use

Any conspicuous materials which are currently marketed or distributed in substantial numbers and/or are used to a noticeable degree on the highways qualified for selection consideration. Examples of such materials would include retroreflective headbands, armbands/wristbands, belts, anklebands; retroreflective and fluorescent jogger's vests; dangle tags; hand-held, clipped-on or strapped-on light sources; retroreflectively and/or fluorescently trimmed athletic suits and footwear, etc.

7. Cost

The results of the ASTM survey provided guidance as to consumer tolerance for cost. Of those individuals willing to pay something for a high visibility accessory (n=2,538 out of a total of 2,864 responding) 1,845 or 72.7 percent were willing to pay up to ten dollars for that item. The appeal of cost categories over ten dollars dropped precipitously. This figure was thus considered as a "guideline," but not necessarily a firm ceiling for consumer cost tolerances in selecting treatments for testing.

8. U.S. Origin of Manufacture

All items selected for testing were of U.S. manufacture thus increasing the likelihood of a timely and adequate supply should consumer interest and demand increase in the near future.

C. Pedestrian and Bicyclist Treatments

1. Final Considerations

As previously mentioned, principally "personal" conspicuity treatments were considered for field testing. Such items are designed to be worn or carried on the person of the pedestrian or bicyclist. Accessories were considered as items designed to be "put on" and used with any clothing and taken off after there is no longer a need for conspicuous enhancement. This feature was seen as providing maximum flexibility in use and maximum useful lifetime for the materials than otherwise would be obtained if, for example, retroreflective trim were permanently integrated into a garment. In the latter situation, the user must wear the particular garment that has the retroreflective trim to receive its conspicuity benefit. The garment may not always be appropriate to the weather conditions (e.g., temperature, precipitation) or style requirements. In addition, being integral to a garment subjects the retroreflective trim materials to the additional wear and deterioration induced by necessary cleaning cycles for the garments. Hence the accessory concept was a primary selection strategy. It should be noted, however, that the results of several of the accessory conspicuity treatments tested could be generalized to the situation where such treatments were integrated in a garment.

2. Experimental Treatments

What follows is a standardized description of each of the "experimental" pedestrian and bicyclist treatments selected for testing. All treatments are designed for nighttime conspicuity enhancement principally. Some treatments are or could be effective in the daytime or twilight as well because of the presence of fluorescent colors. It is important to emphasize that the chosen treatments were selected as the set of materials which would provide the most useful information resulting from the test. They were not selected to represent the entire range of criterion values as that would have been impossible given the limitation on the number of treatments which could be tested. In particular, there are several very expensive treatments available, e.g., high intensity bicycle lighting systems, which likely would perform better than any tested treatment but which were excluded from the test because their high cost severely limits the universaility of their application.

The informational categories presented for each selected treatment include:

- o Treatment Number/Name (as used in the balance of this report)
- o Physical and Functional Description
- o Typical Photometric Intensity (as supplied by the manufacturer)
- o Source of the Tested Materials
- o Estimated Retail Cost

Five pedestrian treatments or conditions are described in Tables 1 through 5 and they are called:

- o P1 Baseline Condition
- o P2 Dangle Tags
- o P3 Flashlight
- o P4 Jogger's Vest
- o P5 Rings

Four bicyclist treatments or conditions are described in Tables 6 through 9 as follows:

- o B1 Baseline Condition
- o B2 Crank and Spokes
- o B3 Leg Lamp
- o B4 Fanny Bumper and Ankle Bands

D. Distractor Stimuli

Several distractor stimuli were employed in the experiment. These items were placed in identical, fixed locations for all experimental trials and not moved from location to location as were the experimental treatments. In total, eight different signal sources were used at nine fixed locations (one, the triangle, was used twice) and these were:

- o Strobe--Honeywell Strobolight (three inch by two inch white translucent lens on a six inch by two inch body powered by two C-cells). The flashing light was affixed to a STOP sign stanchion about three feet above the roadway.

- o Barricade--Standard Type I--Highway Barricade and Warning Light (seven inch diameter amber flashing light with retroreflective ring on a three foot long, three foot high amber and white diagonally, retroreflectively striped wooden barricade.

Table 1. P1 Pedestrian Baseline Condition

Note 1: This baseline or untreated pedestrian condition constituted a control or comparison condition for the "experimental" conspicuity treatments. All treatments to be described subsequently were thus added to this baseline configuration which is described below.

Physical and Functional Description:

Experimenters displaying this condition wore new, white, extra large, short-sleeved tee shirts over their outer clothing and blue jeans. Footwear was unspecified. Rather than using all dark attire for the control condition, as has been traditional in many reflectorization studies, the compromise described was used. It was felt that this combination would more realistically approach the blend of brightness materials typically employed by most pedestrians on the roadway--thus providing a realistic control condition with which to compare the experimental treatments.

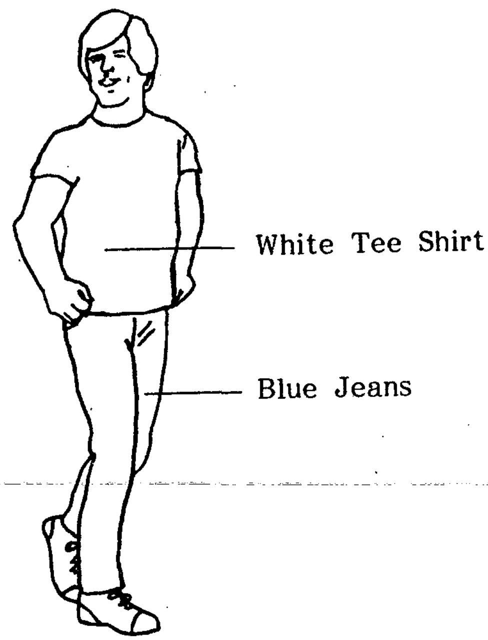


Table 2. P2 Dangle Tags

Physical and Functional Description*:

Two transparent double-sided 2-1/8 inch diameter, rigid, circular prismatic reflectors, suspended by 12 inch strings and fastened on either side of the bottom edge of the tee shirt by the supplied safety pins were used. The optics and construction of these pendant reflectors are basically the same as for rigid reflectors used on vehicles and bicycles, with approximately 121 injection molded acrylic cube corner reflectors to the square inch on the reflecting surface. The pendant reflectors were free to dangle from the strings provided and thus easily rotate when perturbed by the wind or pedestrian ambulation. The rotation of the pendant reflector and concomittant rotation of the primary retroreflective axis of the reflector caused a bright "twinkling" or "flashing" white reflected signal to be returned to the eyes of a driver whose vehicle's headlights struck the reflectors.

Typical Photometric Intensity:

Approximately 27.0 CIL**

Source of Test Materials:

Reflectors of the Americas, Inc.
Nine Byre Lane
Wallingford PA 19086

Arvid Safety Products, Inc.
733 East Eighth Street
P.O. Box 1809
Traverse City MI 49685

Approximate Retail Cost:

Between 50¢ and $1.00 per reflector.

*See Note 1 on page 14.
**CIL refers to "coefficient of luminous intensity" which is the ratio of total light intensity of the reflector to the incident illumination falling on it. CIL is expressed in either candela/lux or candela/footcandle. CIL units are generally used to quantify the luminous intensity of small rigid reflectors such as motor vehicle/bicycle reflectors and dangle tags. The CIL value shown is manufacturer-supplied and typically obtained in an optical laboratory setting with a 0.2° observation angle and a -4° entrance angle.

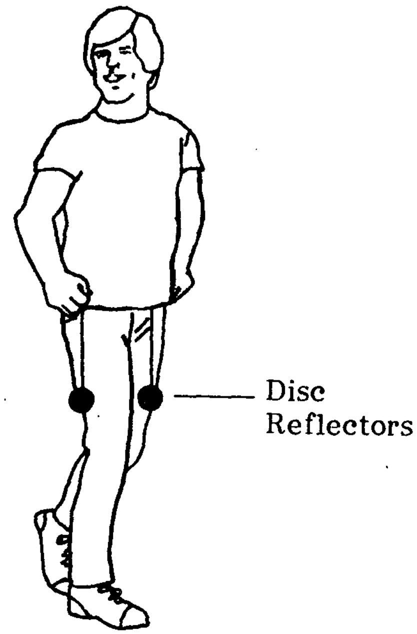


Table 3. *P3 Flashlight*

Physical and Functional Description:*

A common hand-held cylindrical flashlight was used. The exterior shell of the light was of red plastic construction with a 1-½ inch diameter lens and a ¼ inch wide translucent red housing. The overall length of the flashlight was 7-¼ inches and the diameter of the battery receptacle was 1-¼ inches. The flashlight was powered by two 1.5 volt alkaline D-cell batteries.

The deployment strategy involved the pedestrian holding the light in the right hand in a relaxed, normal fashion. This resulted in the face of the lens pointing at the pavement when the arm was at rest at the side of the body, with the longitudinal axis of the flashlight being offset about 20° forward of the axis of the forearm. When the pedestrian was walking or simulating that activity, the pedestrian allowed both arms to swing in the natural counterbalancing fashion which is typical of a walking pedestrian. This natural arm motion imparted to the flashlight created an alternating red (light transmitted through the translucent red housing) and white (light beam transmitted through the lens) light signal to anyone approaching the pedestrian. This was the signal seen by subjects in the study.

Typical Photometric Intensity:

Unavailable

Source of Test Materials:

Eveready (Union Carbide)
Danbury CT 06817

This is a standard type of two-D cell hand-held flashlight which is manufactured by many firms and is widely distributed in hardware and department stores nationwide.

Approximate Retail Cost:

Between $1.00 and $3.00 including conventional carbon, D-cell batteries.

*See Note 1 on page 14.

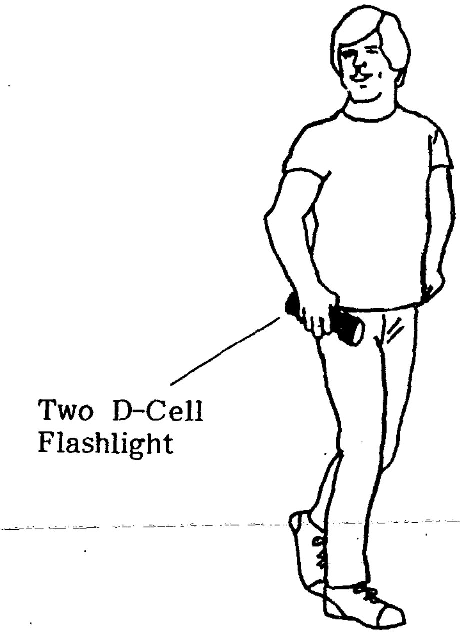


Table 4. P4 Jogger's Vest

Physical and Functional Description:*

Marketed as a "jogger's vest," this fluorescent and retroreflective vest is widely used as such. It also may serve as conspicuity enhancement for any pedestrian or bicyclist (principally daytime or twilight for the bicyclist because of the fluorescent material--the retroreflective components would be too highly placed above the roadway and inappropriately angled to be effective for bicyclists). The vest measured approximately 20-½ inches from the shoulder to the bottom and approximately 13 inches wide. The vest was constructed of fluorescent red-orange mesh material, with the front and back panels secured to one another by straps with velcro fasteners. In addition, two strips of 1-½ inch, lime-yellow fluorescent/retroreflective Reflexite** sheeting were sewn across the entire width of the vest. The top of the first strip was approximately 3-½ inches from the bottom of the vest and the top of the second strip approximately 9-½ inches from the bottom of the vest. The lime-yellow, fluorescent/retroreflective tape strips present a vivid color contrast with the red-orange fluorescent mesh and also retroreflect at night. When the vest is used at night by a jogger, a noticeable up and down action is imparted to the retroreflective return of the horizontal strips by the jogging motion.

Typical Photometric Intensity:

Approximately 165 CPL*** for the lime-yellow Reflexite fluorescent/retroreflective sheeting.

Source of Test Materials:

Jog-A-Lite, Inc.
Box 125
Silver Lake NH 03875

Approximate Retail Cost:

$13.00 to $15.00

*See Note 1 on page 14.
**"Reflexite" is a tradename of the Reflexite Corporation; P.O. Box 1628, New Britain CT 06051.
***CPL refers to "coefficient of retroreflection" whch is the ratio of the reflective luminance (intensity per unit area) of the retroreflector to the incident light illumination falling on it. CPL is expressed in either candela/lux/meter^2 or candela/footcandle/foot^2. This measurement approximates the "candles per lumen" measurement for smaller entrance angles and, therefore, is abbreviated commonly as CPL. CPL units are generally used to define large extended reflective areas and measure reflective sheeting. The CPL value shown is manufacturer-supplied and typically obtained in an optical laboratory setting, with a 0.2° observation angle and a -4° entrance angle.

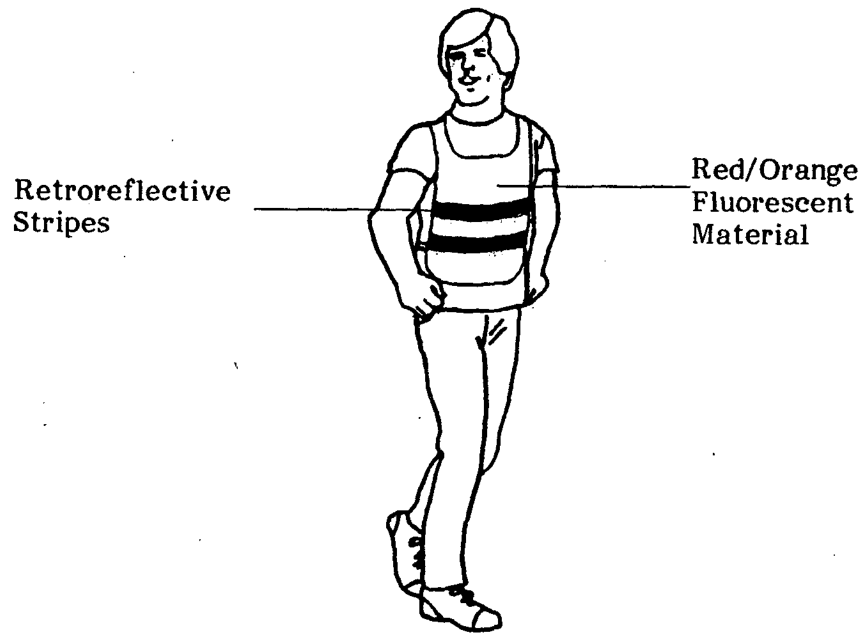


Table 5. P5 Rings

Physical and Functional Description:*

This treatment consists of six bands of retroreflective sheeting applied to the body in the following ways:

- o One Headband
- o Two Wristbands
- o One Belt
- o Two Anklebands

The headband, wristbands and anklebands were made of 1-½ inch wide Scotchlite 8910** retroreflective sheeting affixed to a terrycloth backing and joined by velcro fasteners. The belt was made of 1-½ inch wide, white (clear) Reflexite sheeting fastened by a double snap belt buckle. The objective in configuring these materials was to retroreflectively outline the human form and highlight the natural motion of the appendages during walking or running.

Typical Photometric Intensity:

For the Scotchlite 8910 sheeting approximately 450 CPL; for the white (clear) Reflexite sheeting approximately 250 CPL.

Source of Test Materials:

For the headband, wristbands and anklebands:
Light Gear (Edith Sullivan)
51 Osgood Street
Methuen MA 01844

For the belt:
Caution Industries
P.O. Box 329
Freehold NJ 07728

Approximate Retail Cost:

Approximately $10.00 for the set of headband, wristbands and anklebands; and about $8.00 for the belt.

*See Note 1 on page 14.
**"Scotchlite" is a tradename of the 3M Company; Safety and Security Systems Divison; St. Paul MN 55144.

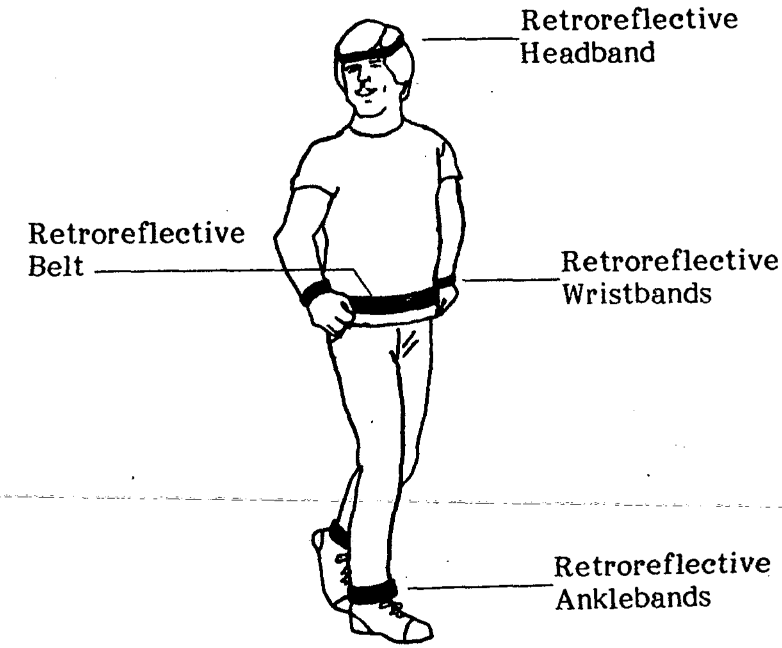


Table 6. B1 Bicyclist Baseline Condition

Note 2: The baseline or untreated bicyclist condition constituted a control or comparison condition for the "experimental" conspicuity treatments. All treatments to be described subsequently were thus added to this baseline configuration which is described below.

Physical and Functional Description:

An experimenter displaying this condition wore a new, white, short sleeved tee-shirt and blue jeans. Footwear was unspecified. The experimenter was positioned atop a 26 inch wheel, ten speed bicycle whose rear wheel was elevated approximately two inches above the road surface due to its mounting on a bicycle stand. The bicycle stand enabled the bicycle to be stabilized in a fixed location near the roadway and pedaled by the experimenter--thus permitting a naturalistic pedalling motion without changing the location of a bicyclist relative to the roadway and approaching motorist. This bicycle (as well as the three other "treatment" bicycles) was equipped with Consumer Products Safety Commission (CPSC) recommended bicycle reflectors consisting of the following:

- One red rear reflector mounted just under the seat
- One clear (white) front reflector mounted just under the front handlebars
- Four amber pedal reflectors affixed to the two outside surfaces of each pedal

Spoke or lateral facing reflectors were not employed.

Typical Photometric Intensity:

N/A

Source of Test Materials:

The standardized CPSC reflectors for each bicycle were supplied by:

Amerace Corporation
7542 North Natchez Avenue
Nile IL 60648

Approximate Retail Cost:

N/A

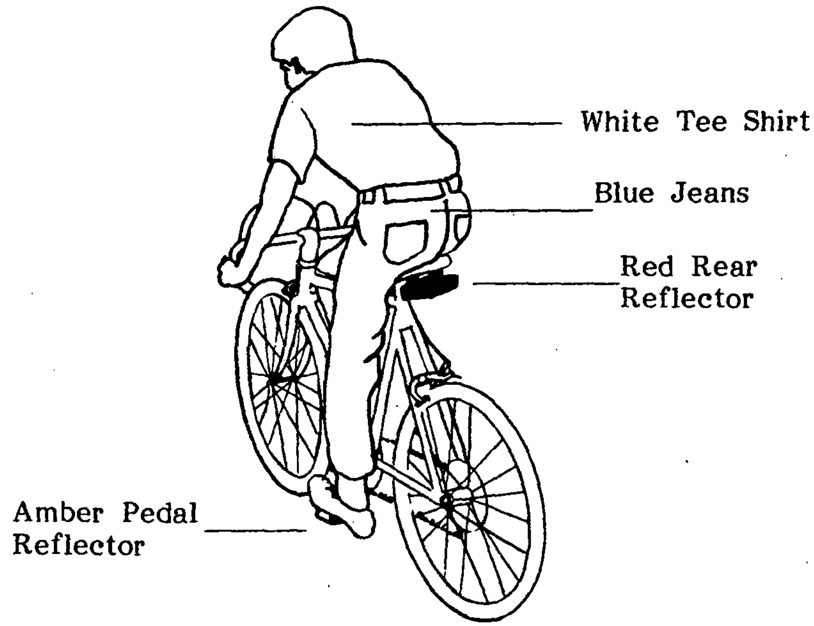


Table 7. B2 Spokes and Crank

Physical and Functional Description*:

The overall design objective for this treatment was to enhance the retroreflective potential of the bicycle with particular emphasis on highlighting the inherent components of bicycle motion. Specifically, retroreflectors were added to bicycle cranks and spokes of the rear wheel. The crank reflectors consisted of Reflexite amber-colored, microprismatic, polycarbonate, adhesive strips 4-7/16 inches by 15/16 of an inch affixed to the front and back surface of each crank. When in motion, the combination of the amber crank and pedal reflectors appeared as a large retroreflective crank turning in space. The spoke reflectors consisted of eight 3 inch by ¼ inch slit retroreflective tubes affixed to the spokes close to the hub. Four reflectors were affixed in an orthogonal pattern to the spokes on one side of the rear wheel and four on the other side. Scotchlite 8710, glass bead retroreflective sheeting was laminated to the cyclinidrical reflectors which reflected a silver color.

Typical Photometric Intensity:

For the Reflexite polycarbonate strips, approximately 600 CPL; for the Scotchlite 8710 sheeting, approximately 425 CPL.

Source of Test Materials:

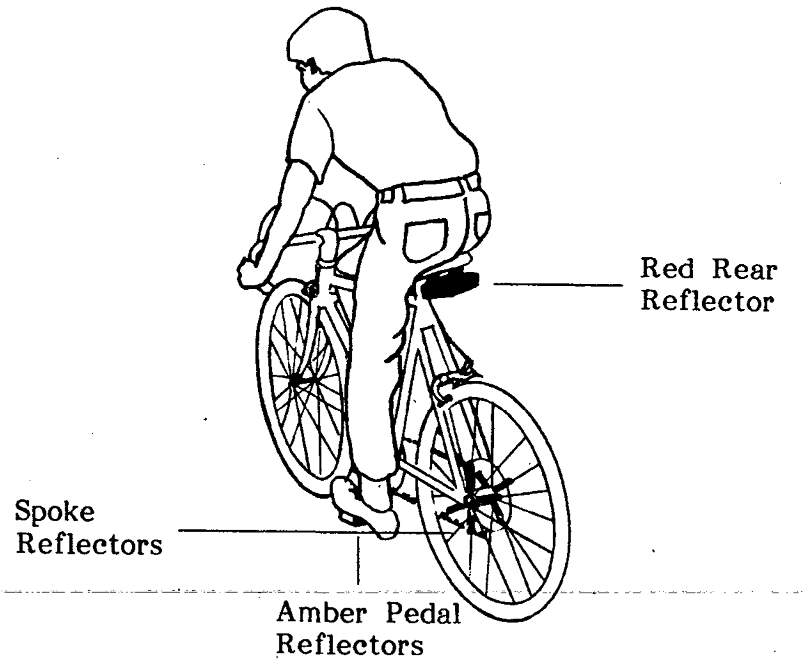
For the Polycarbonate Crank Reflectors:
Reflexite Corporation
P.O. Box 1628
New Britain CT 06051

For the spoke reflectors:
Jagnetti, Inc.
P.O. Box 1014
Ceres CA 95307

Approximate Retail Cost:

For the polycarbonate strips, about 50¢ per reflector. For a package of eight spoke reflectors, marketed as the "Glow Wheel" about $3.95 or 50¢ per reflector.

*See Note 2 on page 20.



n.b. Crank Reflectors not visible in this depiction.

Table 8. B3 Leg Lamp

Physical and Functional Description:*

Marketed under the name of "Road Runner Safety Lite," this steady burn light measures approximately two inches by 3-3/4 inches by 1-¼ inches and was designed to be either strapped on the leg or arm. Loaded with two 1.5 volt C-cells, the light weighed approximately six ounces. A one inch by 1-¼ inch red and clear (crystal) lens face in opposite directions. The light was strapped to the left (outside) ankle of the bicyclist during all test conditions, to capitalize on the attention-getting feature of the up and down pedalling motion. The clear lens faced forward and the red lens rearward.

Typical Photometric Intensity:

Data unavailable from manufacturer.

Source of Test Materials:

Wonder Corporation of America
22 Elizabeth Street
Norwalk CT 06856

Approximate Retail Cost:

About $5.99, including two C-cell batteries.

*See Note 2 on page 20.

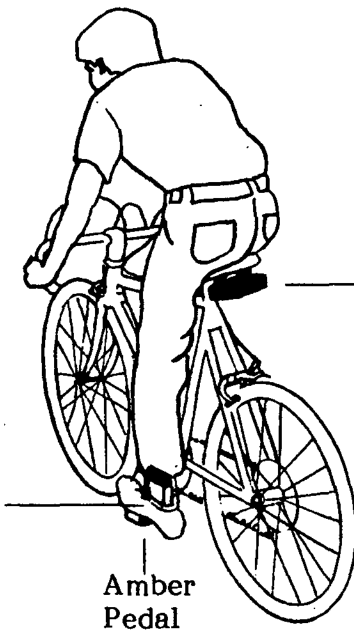


Table 9. B4 Fanny Bumper and Anklebands

Physical and Functional Description:

The overall design objective for this treatment was to enhance the retroreflective potential of the bicyclist. "Fanny Bumper" is a tradename for a retroreflective/fluorescent triangular device constituting part of this treatment. The interior of the equilateral triangle, measuring approximately 12 inches on a side, consisted of a red/orange fluorescent material. The triangle was bordered by a one inch strip of white (clear) Reflexite prismatic retroreflective sheeting. The Fanny Bumper had two cords attached which permitted it to be tied around the waist and positioned over the posterior of the seated bicyclist. In addition to the Fanny Bumper, 1-½ inch white Reflexite ankle bands were velcro fastened to both ankles of the bicyclist. The retroreflective anklebands were intended not only to highlight the pedaling motion provided by the pedal reflectors, but to serve the useful purpose of gathering trouser/slack material close to the ankle.

Typical Photometric Intensity:

Approximately 250 CPL for the white (clear) Reflexite retroreflective sheeting used for both the Fanny Bumper and anklebands.

Source Availability:

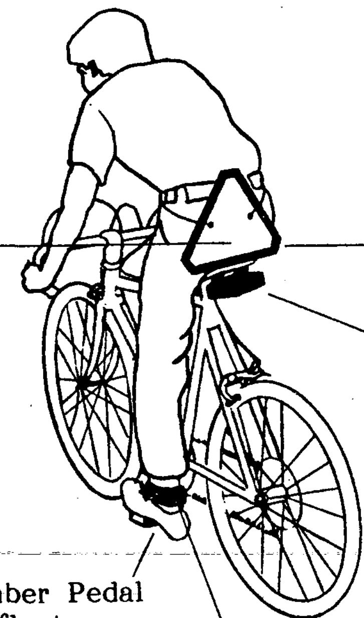
For the Fanny Bumper:
F.B. Action
c/o R. Seebode
824 South Remington Road
Columbus OH 43209

For the anklebands:
Jog-A-Lite, Inc.
Box 125
Silver Lake NH 03875

Approximate Retail Cost:

For the Fanny Bumper about $4.50; for the two legbands about $4.50.

*See Note 2 on page 20.



- o Hot Dots--A pedestrian in dark clothes (i.e., blue jeans and dark blue sweatshirt) with a three inch sided diamond pattern of red/orange fluorescent and retroreflective "hot dots" (11/16 inch diameter) on the mid-frontal area of the pedestrian's chest.

- o Belt Beacon--A baseline bicycle (no riders) equipped with the standard array of CPSC rigid reflectors plus a 2-5/8 inch diameter, single faced, amber flashing taillight called a "Belt Beacon." The light was attached immediately below the bicycle seat facing rearward and powered by a single nine volt battery.

- o Triangle--A fluorescent red/orange and red retroreflective warning triangle meeting Federal Motor Vehicle Safety Standard 125--(equilateral; 17 inch by two inch on a side) in two different presentation locations.

- o Dark Ped--A pedestrian in dark clothes (i.e., blue jeans and dark sweat shirt).

- o Arrow--A baseline bicycle (no rider) equipped with the standard array of CPSC rigid retroreflectors previously described plus a 1-7/8 inch by 10-1/2 inch white Reflexite retroreflective arrow, hinged to the left arm of the rear bicycle fork. The retroreflective arrow is distributed by the American Automobile Association as the "Bike Safety Arrow."

- o Cones--An array of three 30 inch high traffic cones with 6 inch high white Reflexite retroreflective cone caps.

E. The Field Test Site

1. Selection Considerations

Several attributes of the field test setting were considered to be very important to establishing a high level of face validity necessary for generalizing the results of the study to the U.S. traffic environment at large. First, any field test site selected had to provide a realistic traffic environment with paved roads, typical pavement markings such as centerlines and stop lines, appropriate traffic control devices (e.g., stop signs, speed limit signs, advisory signs, traffic lights) and conventional roadway appurtenances such as street lights and fire hydrants. Driver performance in any simulated roadway environment such as road lanes demarked by traffic cones in a parking lot would not suffice. Second the site selected had to provide a controlled environment in which all the experimental conditions and treatments could be arranged with adequate safety for subjects and experimenters. The need for the restriction of freely flowing traffic with all the possibilities of alcohol or fatigue-impaired drivers was paramount as all experimental treatments for this study involved live experimenters displaying the treatments on or near the roadway.

In addition, the roadway setting had to offer sufficient sight distances for the number of experimental treatments to be tested (over 1,000 feet where possible) over a total course distance which would not require excessive run times, i.e., in excess of one half hour. Overall length and geometry of the course had to be such that CB radio communications would be possible to coordinate subjects and experimenters. Moreover, a varied ambient illumination setting from basically dark to varying levels of street illumination was desirable to provide a range of operating conditions in which to assess the experimental treatments.

2. <u>Potential Sites Considered</u>

Several sites other than the one ultimately chosen were initially considered. For example, a nearby, grand prix racing track was considered and rejected because there were not a sufficient number of track segments affording adequate sight distances for the treatments. Moreover, the roadway setting was not particularly representative of the highway environment. Another setting evaluated was a 16 mile stretch of essentially straight, flat limited access highway which was initially thought to be under control of a state park authority which could restrict the free flow of traffic at night. When it was learned that not only traffic control was not possible but this was a prime roadway for the frequent transits of drinking drivers during the evening hours, this site was abandoned.

Attempts to locate unopened or abandoned sections of interstate roadway systems yielded no promising candidates. Investigations into military camp/reservation roadway systems were mostly unproductive until the roadway system at Camp Atterbury near Columbus, Indiana was located. Other sites were basically rejected due to unimproved or atypical roadway systems lacking sufficient sight distances for testing the treatments.

3. <u>Characteristics of the Selected Field Test Site</u>

Camp Atterbury is a U.S. Army Reserve Forces Training Area which presently is only significantly populated with personnel on weekends. On weekdays and nights only security and administrative personnel are present. Public access to and from the Atterbury roadway system, shown in Figure 1, was controlled by security personnel at the main gate. Security personnel also patrolled the roadway system in vehicles from time to time.

Camp Atterbury roads were basically two-lane, blacktop paved with unimproved shoulders. One stretch of the roadway system selected for the experimental course (about one-third of a mile) was graded but unpaved. On wider stretches of roadway, a centerline was apparent. Intersections were basically orthogonal and controlled by standard octagonal stop signs. Speed limit (25 mph) signs were frequently displayed. In various parts of the experimental course actually driven by subjects, the following background lighting factors were present at night:

- Overhead street lights (sodium vapor) and motor pool lighting arrays.
- Interior room lights emanating from various buildings near the road.
- Red retroreflective vehicle reflectors singly and in various groupings mounted on military vehicles parked in yards near the roadway.
- Substantial segments of basically dark roadways.

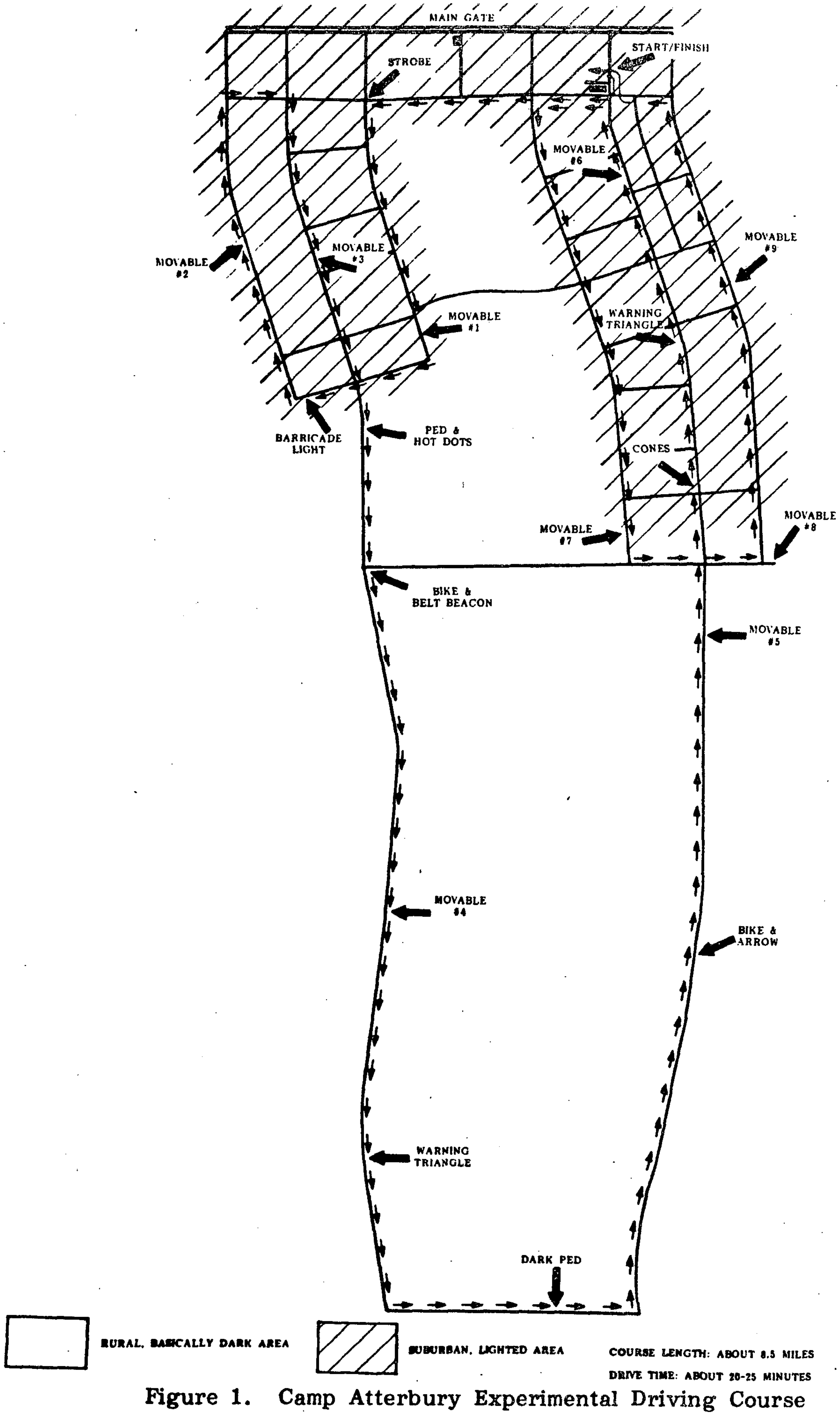


Figure 1. Camp Atterbury Experimental Driving Course

Integrating the salient site characteristics, the overall "character" of the Camp Atterbury roadway system was judged to be rural-suburban, which is consonant with the setting for the focal accident types for this study discussed in Section I.

The final assessment factor for determining the suitability of the Camp Atterbury roadway system for experimental purposes was to determine that sufficient sight distances existed within a reasonable overall driving distance (and time) for each trial to accommodate the type and number of treatments planned for presentation. The topography of the entire Atterbury roadway system was basically flat (as is characteristic of this general area of the country), having few significant rises, depressions or curves to limit available sight distances. When the roadway segments to be driven were eventually laid out, candidate treatment locations were spotted based on an estimate of adequate sight distance.

Sight distance measurements were made using the Nu-Metrics distance measuring equipment described in Section III.B.4.a. A driver and an observer passenger in the distance measuring car approached a 6 foot 2 inch pedestrian visual target stationed at each prospective treatment location from a distance at which the pedestrian was not visible. Depending on the time of day, the pedestrian was either wearing a red/orange fluorescent headband and ankle bands or a headlamp and ankle lamp to aid observer detection. The measuring car closed on the pedestrian target and when the pedestrian's head was first visible the distance was recorded. When the full figure of the pedestrian was revealed, that distance was recorded. This procedure was reversed to verify the distances already recorded. The average sight distance recorded for fixed target locations was 1,675 feet (range of 1,232 to 2,617 feet) for head only and 1,327 feet (range of 426 to 2,132 feet) for full figure. The average sight distance recorded at movable target locations, where the experimental treatments were displayed, was 1,895 feet (range of 1,364 to 3,313 feet) for the head only and 1,616 feet (range of 798 to 3,278 feet) for the full figure.

Final determination of movable experimental treatment locations took into account not only adequate sight distance but the spacing of treatments over elapsed run time so as to preclude subjects acquiring a "response set" for target detections. This resulted in the mix of fixed targets and movable targets shown in Figure 1. Together these yielded a manageable run time of 25 to 30 minutes to cover the approximately 8-½ mile course.

There were two conditions unique to this site which were not totally controllable. The first related to camp security. Periodically a security vehicle would patrol the roadways at day and night. Despite reasonable attempts to control patrol activity at night during experimental runs, patrol vehicles occasionally encountered experimental cars on trial runs. The contribution of headlight glare during these five or six encounters, was considered insignificant for the results of this study. The second factor was indigeneous wildlife and cattle. Frequently at night, deer would be encountered on parts of the roadway system, running beside an experimental car or crossing its pathway. In the southern and middle areas of the course which consisted of open grassland, cattle would migrate and graze freely at night. It was also not uncommon to find a cow loitering in the middle of the roadway. Rabbits and other small animals could be found anywhere on the course. Subjects were advised of these animal hazards before each experimental run and no unfortunate encounters ever materialized. These random distractor situations, if anything, may have provided more realism to the results by diverting driver attention and thereby pushing the recorded detection and recognition distance more towards those that would be achieved by unalerted drivers in a freely flowing traffic situation.

III. METHOD

This section discusses the various procedures employed in the conduct of this field study. These procedures include a photometric assessment of the various pedestrian and bicyclist treatments used in the study and the background lighting conditions of each location where treatments were located. The basic design of the study is presented along with descriptions of the various equipment and procedures employed to collect the perceptual data. The procedures employed during the three nights of experimentation are also described.

A. Acquisition of Photometric Data

The procedures followed and results obtained for the photometric measurement of target luminance and target location background illumination are presented in Appendix A.

B. Design of the Field Study

1. Basic Design

Considering human, material and financial resources available, and the need for reasonable control of potential biases, the following principal design constraints evolved:

- A varied order of presentation of experimental treatments to subjects would be necessary to control for potential "order effects."
- A varied order of presentation of experimental treatments to subjects would be necessary to control for potential location effects," as illumination conditions and other physical environmental features varied among treatment locations.
- Three nights of trials were a logistically feasible span of time in which use of the Camp Atterbury roadway system would be unimpeded by weekly military operations.
- The number of subjects should be as large as possible.

In consideration of these factors, the experimental design shown in Table 10 was developed. In essence, the design employed provides for a randomized order of presentation of experimental treatments and the opportunity for every experimental treatment to be seen by four subjects at every location where treatments were located (nine in all). This meant that a given order of treatments, or set-up, was changed after a group of four subjects had driven the course. This design thus provided a measure of control for order and location effects.

Table 10. Basic Design of the Experiment

Movable Target Location No.*	Target Set-up** NIGHT #1			NIGHT #2			NIGHT #3		
	1	2	3	4	5	6	7	8	9
1	P4	B3	P2	P3	P5	B1	B4	P1	B2
2	B2	P4	B3	P2	P3	P5	B1	B4	P1
3	P5	B2	P4	P1	P2	P3	B3	B1	B4
4	P3	P5	B2	B4	P1	P2	P4	B3	B1
5	B1	P3	P5	B2	B4	P1	P2	P4	B3
6	P1	B1	P3	B3	B2	B4	P5	P2	P4
7	B4	P1	B1	P4	B3	B2	P3	P5	P2
8	P2	B4	P1	B1	P4	B3	B2	P3	P5
9	B3	P2	B4	P5	B1	P4	P1	B2	P3

Experimental Treatment Legend:

P1	Pedestrian Baseline Condition	B1	Bicyclist Baseline Condition
P2	Dangle Tags	B2	Spokes and Crank
P3	Flashlight	B3	Leg Lamp
P4	Jogger's Vest	B4	Fannybumper and Anklebands
P5	Rings		

*See Figure 1.
**A total of four different subjects drove the Atterbury course with experimental (movable) targets in a given set-up order. Thus, four subjects saw set-up order number 1, four subjects saw set-up order number 2, etc.

2. Subjects and Field Experimenters

Subjects employed were Indiana University School of Optometry graduate students (save one who was a music student) ranging in age from 20 to 33 years, with the average age being 25 years. Of interest, for the Type 25 "Walking Along the Roadway" pedestrian accident type, 52 percent of the involved drivers were 18 to 35 years and 27 percent were 15 to 19 years of age (Knoblauch, 1977). For Type 13--"Motorist Overtaking..." bicycle accident, 49 percent of the involved drivers were 16 to 35 years of age (Cross and Fisher, 1977). Eleven (31 percent) of the 36 subjects used were female and 25 (69 percent) were male. In the accident data for both accident types, approximately 21 percent of the drivers were female and 67 percent were male. The average number of years of subject driving experience ranged from four to 16, with the average being 8.75 years. All subjects had their vision tested at the Indiana University School of Optometry. All subjects had at least 20/20 acuity (spectacles allowed), with no discernible visual field, night vision or color vision problems. All subjects possessed valid drivers' licenses.

Field experimenters who served as pedestrian or bicyclist models to display the experimental treatments were drawn from the same population as the subjects. In some cases, subjects also served as field experimenters but only after they had completed their runs as subjects. In other cases, field experimenters were recruited and served only as field experimenters. All attempts were made to keep the cadre of field experimenters as standardized as possible throughout the experiment, having only one person display a given treatment throughout the trials. However, exigencies dictated that changes in personnel be made. When necessary, replacements for a given field experimenter were selected to be as similar as possible in height and body build to the person being replaced.

Individuals, whether serving as subjects or field experimenters were paid $50.00 for each night they worked.

3. Experimental Vehicles

Two virtually identical vehicles were employed for recording the driver-determined detection and recognition distances for each target on the course. One vehicle was a 1983 Oldsmobile Cutlass Ciera and the other was a 1983 Buick Century. Both vehicles had fuel-injected, four cylinder engines, automatic transmission, power steering and brakes, and cruise control. The cruise control system presented a convenient point for coupling for the onboard distance measuring equipment but was otherwise not used in the trials.

The low beam headlamps in each vehicle were replaced with new sealed beam headlamps and realigned in a Bloomington, Indiana service station. Quartz-halogen headlamps could have been used as replacements, and their output is considerably greater than sealed beam headlamps. Even though quartz-halogen headlamps will likely become the universal headlamp in use by the end of the decade, well over half of the vehicles presently in service are still operating with sealed beam headlamps. Thus, with respect to the type of headlamp employed, the detection and recognition distance results obtained in this study tend somewhat toward the conservative.

4. Instrumentation

The principal instrumentation employed in the experiment was distance measuring, communications and audio recording equipment.

a. Distance Measuring Equipment

Each experimental car was equipped with a Nu-Metrics* K-5000, solid state, distance measuring device. A Nu-Metrics P-5000 printer was also used in each car to print out the record of elapsed detection and recognition distances stored in the K-5000 memory after the completion of a subject's run on the course. The devices operated on the current supplied by the 12 volt DC automobile electrical systems.

In essence, the K-5000 is a sophisticated counter and storage device within the confines of a 2.5 inch high, 8.125 inch long, 6.25 inch deep, 1.9 lb. enclosure. Programmed elapsed distances are displayed in a .320 inch high LED numerical display readout. A numerical keyboard and several function keys control the distance measuring device. A special transmission sensor is connected to one of the speedometer cable connectors in the cruise control unit. The disconnected speedometer cable is then reattached to the sensor. Regular pulses from the rotation of the speedometer cable translate into numerical output on the K-5000. When a K-5000 equipped car measures a known calibration distance on level pavement (1000 foot distance is recommended), a "calibration number" is displayed which can be "entered" into the unit's memory. The incorporation of the calibration number into memory enables the recording of true distance (in feet) between events designated on the K-5000 (i.e., actual locations traveled to on the roadway by the K-5000 equipped car).

The procedure followed at the beginning of each run driven by a subject was for the experimenter, located in the passenger's seat, to "zero" the K-5000 at the start point. Subsequent to the car moving along the course, elapsed distance was continuously displayed on the numerical readout. Each time a subject announced a detection of a roadside object, a unique "detection" two-digit code was entered on the K-5000 keyboard causing the elapsed number of feet traveled at this point and sequence number of the target to be entered into the K-5000 memory. Whenever a detected object was announced as recognized by the subject, a unique "recognition" two-digit code was entered on the K-5000 keyboard causing the elapsed distance at this point and sequence number of the target to be entered into memory. Finally, when the experimental car passed the location of the object in question, the experimenter entered a unique two-digit code and the elapsed distance at the object in question was recorded. This pattern was followed for all objects detected and recognized throughout the experimental run. When the run was completed, the final distance (course length) was entered into the K-5000. The procedure after a run was to transfer the contents of the K-5000 memory onto the paper tape printout of the P-5000 printer. A hard copy record of all detection, recognition and object location distances was thus provided in the order

*Nu-Metrics Instrumentation
Division of Pentron Industries, Inc.
Box 800
Connellsville, PA 15425

corresponding to the known order of treatment locations. A computer program was devised and implemented to convert the total elapsed distances into detection and recognition distances from each respective object location. Procedures were also employed for accommodating false or corrected detections or recognitions. The complete set of Nu-Metrics' procedures employed may be found in Appendix B.

b. Communications Equipment

A four-watt Citizen Band (CB) radio was installed in each of the two experimental cars to coordinate any essential communications with the field study base station at the start point. This communication link was necessary to control the movement and separation of the experimental cars on the course in the event of any contingencies or difficulties and to consult with the principal experimenters on matters relating to experimental protocol.

In addition, all field experimenters modeling the pedestrian and bicyclist treatments were provided with four-watt hand-held CB units, all controlled to the same channel but a different channel from the one used by the cars. This enabled the field experimenters to stay in contact with one another and to be self-alerting at the approach and passing of the experimental cars on the course. This communications network also provided a sense of well-being for field experimenters located in dark, remote areas of the course. Moreover, it ensured the bicyclist and pedestrian treatments were properly oriented and in motion before the approach of the experimental cars. Finally, this communication network was also anchored at the study base station to enable the reporting of any difficulties encountered by the field experimenters of a personal nature or with the treatments being displayed.

c. Audio Recording System

To create a record of the acoustical environment within each experimental vehicle during a trial run, particularly comments made by either the principal experimenter or subject, an audio cassette tape recorder was installed in each vehicle with a microphone attached to the dashboard. Prior to a run a blank C-60 tape was loaded into the recorder and a tape recording was made of the entire trial run which was retrieved and annotated at the conclusion of the run.

5. Basic Nightly Situations and Procedures

a. General

The study was conducted over the three nights of October 2, 3 and 4, 1983 with 12 subjects being run each night. All three nights were moonless and the temperature ranged from the mid-forties to the mid-fifties, Farenheit. The first two nights were clear. On the third night, intermittent rain showers were experienced. While consideration was giving to cancelling experimental runs for this night, the decision was eventually made to go ahead subject to the following provisos:

- The progress of an experimental run would be halted if the intensity of rainfall resulted in water sheeting on the windshield, to an extent which appeared to obscure visibility.

- o The progress of an experimental run would be halted if the intensity of rainfall caused any field experimenter sufficient discomfort or caused an unnatural or faulty display of the treatment.

On the third night field experimenters were equipped with black, collapsible umbrellas which were used during periods of moderate rainfall. Care was taken by field experimenter to hold the umbrellas so as not to obscure any displayed treatment.

The estimated perceptual impact of conducting trials during the encountered wet or rainy conditions was not so much a direct interference with detection of targets due to water particles in the air or on the windshield, but more the creation of distractive light sources due to reflections from puddles and wet pavement surfaces. In other cases, retroreflective materials whose reflective elements are not sealed off from contact with water droplets, could have suffered a degradation of reflective intensity of up to 30 percent. Overall, the impact of collecting data on the night of October 4, 1983 was judged to be not significant statistically (see Section IV) but did seem to somewhat reduce initial detection distances while leaving recognition distances unaffected.

On a given night of experimentation, the subjects and field experimenters arrived by school bus from the Indiana University (I.U.) campus at the Camp Atterbury base station about 6:30 P.M. The school bus remained on site throughout the experimental trials and returned all students to the I.U. campus at the conclusion of an evening's experimentation. While on the site, the school bus served as the base station CB communications center, having excellent radio contact with all experimental vehicles and field experimenters.

The building used as the base station was a "mess hall" with ample seating and table facilities as well as a kitchen and rest room. Several interior rooms existed which permitted simultaneous, isolated briefings of subjects and field experimenters to expedite the experimental protocol.

When the students arrived, they were given the following forms for signing, and the contents of each form were briefly reviewed by a principal experimenter:

- o Project Description and Statement of Informed Consent (Dunlap and Associates East, Inc.--See Appendix C).

- o Camp Atterbury Use Permit and Release from Liability Waver of Claims Against the U.S./State of Indiana (See Appendix D).

The Project Description and Statement of Informed Consent form outlined the general nature of the experiment and the activities to be performed by subjects and field experimenters. It also required that individuals execute the Camp Atterbury Use Permit and Release Form (Appendix D). The Camp Atterbury Use Permit and Release Form basically waived all claims, actions and demands against the U.S. Government and/or State of Indiana for the use of the facilities. Following execution of these forms, all students were given a dinner meal and beverage. Next all students were segregated as to whether they were subjects or field experimenters and asked to report to respective isolated briefing rooms. Here subjects and field experimenters ate their meals and simultaneously received their instructions for the upcoming experimental runs.

b. <u>Briefing of Subjects</u>

All subjects were given a copy of "Background and Instructions for Subjects" (see Appendix E), and the contents of this briefing package were carefully reviewed by a principal experimenter. The particularly important objectives of the briefing were to:

- o Establish a uniform set for responding to the treatments encountered on the course.
- o Thoroughly familiarize subjects with the intra-vehicle environment and required procedures for reporting "detections" and "recognitions."
- o Entreat subjects who have participated not to reveal descriptions of the treatments to subjects who have not yet participated.

What was called for from subjects was basically a stream of consciousness or narrative driving response set about what they saw at any given moment along the roadway as they drove the course. Rather than require subjects to identify every visible entity in the traffic environment, the following was stated and emphasized:

> "The roadside objects of interest are temporary or potentially/actually moving roadside objects such as bicyclists, pedestrians, parked or standing vehicles, hazard indicators, etc. which may require extra caution in approaching and passing them. We are not interested in routine traffic objects which are part of the normal fixed roadway setting, such as stop signs, speed limit signs, street lamps, etc..."

Whenever subjects detected an object of interest they were asked to say "yes" or whatever one word would quickly indicate a detection. Whenever a subject could identify the object again a succinct one word descriptor was requested like "Jogger" or "Bicyclist." "Reasonable" certainty of detection and recognition was stated as sufficient grounds for either rather than absolute certainty. In fact, the minimum criterion for accepting a subject's recognition of either a pedestrian or bicyclist was a declaration of seeing a "person" or "someone" up ahead. Thus, the precision of distinguishing between a pedestrian and a bicyclist was viewed as secondary to recognizing a "human being" as a roadside object. Finally, subjects were advised to keep their speed between 25 and 30 mph. They were also informed that no unusually hazardous situations were intentionally created on the course.

but that natural hazards (such as cattle and deer) might intervene. Subjects were aware that field experimenters were on the course but were unaware of their locations or the high visibility materials they would be wearing.

Following the briefing and ensuing questions, subjects were recruited in pairs for experimental runs. One experimental car would start on a three minute headway followed by the second experimental car to expedite the experimental process. A designated pair of subjects would report to the subject staging area for total dark adaptation approximately 20 minutes before commencing a run. Overhead lights in the general subject waiting area were kept at a fairly low level, but sufficient to support studying, card playing, etc.

c. Briefing of Field Experimenters

Eleven field experimenters each night were required to display the five experimental pedestrian, four experimental bicyclist and two fixed distractor pedestrian targets. All field experimenters were briefed on how each assigned treatment worked and how it was to be worn and/or used. All those displaying experimental pedestrian treatments P1-P5 were instructed on how to display a natural walking motion in place, without changing position on the roadway. They were advised to begin walking in place upon the approach of the experimental cars on the course and to continuing doing so until the second car had passed their position. Following this they were told to report the cars passing their position over the CB radio (to alert other field experimenters) using their alpha numeric designator (i.e., P1, P2, etc.). Once the cars had passed they were told they could relax and rest. Detailed instruction on the operation and desired use of the CB radios was provided as well as cautions against misuse. Pedestrian experimenters were instructed to remove or mask any shiny objects on their person and told how to stow the CB radio so the shiny antenna would not reflect light. Finally, P1-P5 were reminded to always face on-coming traffic at their designated locations on the driving course whenever experimental cars approached their position.

The same instructions applied to the fixed pedestrian distractor targets, except these individuals were told to simulate hitchhikers, i.e., standing (not walking in place), facing traffic, with the right arm and hand showing the familiar hitchhiker "thumbs-up" sign.

The bicycle field experimenters, B1-B4, received the same basic instructions. In addition, they were told to pedal the bicycle provided for them which was mounted on a bicycle stand on the side of the roadway pointed in the direction of flow for the adjacent traffic lane. The bicycle stand permitted the rear wheel to rotate freely when pedalled without the bicycle moving. A "natural" pedalling motion was requested prior to the approach of test vehicles, a motion that was neither too fast nor too slow--basically a sustainable cruising pedalling rate.

All field experimenters were cautioned to be sure the experimental treatments they were producing were properly displayed prior to being encountered by the experimental cars, and to inform the base station promptly of any difficulties experienced. Field experimenters were also informed that after the two experimental cars passed their position twice, that all field experimenters would be moved to new locations on the course prior to the next group of four subjects driving the course.

Finally, field experimenters were advised to be vigilant and exercise extreme caution at the approach of any vehicle. Specifically, they were told to be ready to bail out of their positions if they thought they were in any danger whatsoever. The safety and well being of all subjects and experimenters was a matter of intensive discussion and constant concern throughout the experiment.

d. Coordination of Target Presentations

As has been mentioned, to control for order and location effects, the experimental design (see Table 10) called for relocating pedestrian targets P1-P5 and bicyclist targets B1-B4 among the nine movable locations on the course (see Figure 1) after four subjects had traversed the course. This was done using a third principal experimenter driving a van truck. This individual had a complete set of nine Camp Atterbury course target set-up maps. Each map had clear indications of locations of all movable and fixed targets on the course for each of the nine set-ups. On each night of experimentation, immediately after field experimenters finished their dinner, donned their experimental treatments and were inspected for conformation to experimental requirements, they and their equipment were taken by the van and school bus to their designated locations on the course. After the first four subjects of the night had been run, all the field experimenters (and bicycles) were picked up by the van and relocated according to the next target location set up required by the experimental design. Subsequent to the next four subjects traveling the course, field experimenters were relocated for the final target set up of the night and the last four subjects of the evening were run.

e. Experimental Trials

The following steps and events constituted the basic sequence of study activities conducted on a nightly basis:

1) At about 4:00 p.m. the principal experimenters arrived at the Base Station and carried out experimental preparations which consisted mainly of the following:

- Refueling the experimental cars and van.
- Checking and cleaning the headlights and windshields of the experimental cars.
- Loading fresh audio tape and data recording sheets into the cars and verifying the presence of target set-up maps.
- Calibrating or verifying the of calibration the Nu-Metrics K-5000 units (See Appendix F for the complete list of Nu-Metrics procedures employed), and checking the P-5000 printers.

- Checking for the presence and integrity of all treatments to be used.
- Installing new batteries in all active treatments and the portable CB units.
- Implementing the Trial Start Checklist (See Appendix G) which was used for every experimental run.
- Positioning the inanimate distractor targets on the course (e.g., barricade light, cones, warning triangle).

2) At about 6:30 p.m., the subjects and field experimenters arrived at the Base Station and were given their meals and briefings.

3) After the field experimenters had been briefed and donned their treatments, all boarded the van or bus and were transported to their assigned locations for the first set up of the night.

4) The first two subjects of the night, having already been dark adapted, entered the two experimental cars along with the principal experimenters. The vehicles were started, and the headlights were turned on and verified as being on low beam. When the signal was received from the van driver that all targets were nearly in place on the course, the first experimental car proceeded to the start point.

5) After checking and zeroing the Nu-Metrics K-5000 unit and verifying that the audiotape recorder was on and running with a new tape, the principal experimenter gave the Subject Pre-Launch Briefing (shown in Appendix H) to the subject, reviewing the essential points of the experimental procedure. The first car now proceeded onto the course.

6) Approximately three minutes after the first car left, the second car moved out onto the course after completing the above preparations. The three minute headway was determined to be a desirable margin of separation to expedite the completion of trials without causing headlight glare interference for either car. The same order of vehicle type and associated principal experimenter was maintained throughout the experimental trials.

7) After the second experimental car returned to the base station, a Trial End Checklist (See Appendix I) was executed by each principal experimenter which resulted in a labeled printout of the distances stored in each Nu-Metrics K-5000 and a tape recording of the audio environment of each car during the trial run. Immediately after the first two subjects returned, two new dark adapted subjects entered the cars and the above sequence was repeated.

The first two subjects retired to a quiet room to complete the Conspicuity Experiment Subject Debriefing Form (see Appendix J). Completion of these forms, which requested reactions to the experimental procedure and targets seen, created a base of subjective data which was analyzed and is presented in Appendix J.

8) Shortly after the last two of a group of four subjects began their experimental runs, the van was dispatched to begin repositioning field experimenters according to the next required set up of target locations.

Thus, after every four subjects were run, a change of experimental target positions was made. This resulted in three different target arrays nightly, each being seen by four different subjects. All trials for a given night were completed by about 11:30 p.m.

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In the next major section the results of this study are presented.

IV. RESULTS

The preceding sections have detailed the rationale behind the selection of the treatments tested and the test methods employed. The experiment was designed as a full factorial of car (two experimental vehicles) by target (five "movable" pedestrian and four "movable" bicycle) by location (nine target locations with varying terrain, background and ambient light conditions). This permitted the use of full factorial analysis of variance (ANOVA) to isolate the role played by each of the factors (car, target and location) and their interactions.

The application of ANOVA techniques to the experimental data determined if each of the factors played a statistically significant part in the experiment. With respect to the target factor, however, this was not sufficient information. Given a significant main effect of target, it was also of interest to test statistically the differences between individual target presentations. This was accomplished using oneway analysis of variance ("oneway") with multiple range tests.

Before presenting the results of the ANOVA and oneway testing in this section, two additional analysis topics will be addressed. First, the dependent measures used in the various tests will be described together with the rationale for their inclusion in the study. Then, descriptive data for each of the measures will be presented. These data will provide the reader with an initial familiarity with the range of values taken on by each of the dependent measures as a function of major independent variables. They will also serve as a basis for examining the influence of those controlled variables, e.g., experimental session or night, which were not fully replicated across the design.

A. Measures

The basic data collected during the experiment, as discussed earlier, consisted of the elapsed distance (in feet) of the defined "detection" and "recognition" points and the location of each of the nine movable and nine fixed targets. Subtracting the distance at the points of detection and recognition from the target locations produced detection and recognition distance measures in feet. Each of these measures was examined and utilized in all analytical steps to provide a range of values which delimit the concept of conspicuity.

Many researchers have agreed that a target is not necessarily conspicuous at the point it is detected by an alerted observer. However, "detection" is often considered absolute threshold detection. In this experiment, the measured detection point was defined to be further along in the perception-decision process (closer to the target) than the detection threshold. In fact, the subjects had decided that the object they were viewing was a "target," i.e., not part of the natural, fixed environment at the test site, when the detection point was recorded.

Likewise, the measured point of recognition in this experiment was earlier in the perception-decision process than absolute recognition. The measurement of recognition distance was prompted by the subject's statement that the detected object was a person, typically identified as either a pedestrian <u>or</u>

a bicyclist. Measurement of absolute recognition would, in addition, have required the correct identification of the person's status as a pedestrian or bicyclist.

The choice of these two basic dependent measures appeared consistent with a reasonable operational view of the upper and lower limits of effective conspicuity on the highway. It can be argued that there is little possible safety benefit until the driver arrives at the conclusion that the object he or she has seen is not a part of the normal static traffic environment and therefore has the ability to cross the driver's path. This is the detection point measured in this study. On the other hand, once a driver has discerned that the detected object is a (potentially) mobile person (pedestrian or bicyclist), a compelling need to continue tracking the person has been established. Thus, virtually the entire safety potential of the target signal has been utilized by the time the driver closes to the recognition point as defined in this study. More detail on the target will be acquired, e.g., its direction of motion, as the driver draws closer. However, this additional information is used primarily to select an appropriate evasive action and not to determine that action is needed. The need to be alert and exercise avoidance is fully established at the defined recognition point.

Examination of the performance of each of the test targets with respect to the basic detection and recognition distance measures provided one basic means of comparison. Simply, the extent that the detection or recognition of an enhanced target exceeded that for the baseline pedestrian or bicyclist provided a direct measure of improved performance. However, it has been argued by researchers that detection and recognition are not equally important. Bloom (1976), for example, conjectured that greatly increased detection distances without a concomitant increase in recognition distance might be of little safety value and might even be a distraction. Once a driver detects a target, he or she has an expectation of resolving its identity in a reasonable time. If this is not the case, the driver may actually begin to ignore the target probably based on the conclusion that anything of such high brightness and low recognizability is likely inanimate or at least of little concern.

To provide a single measure of a target's conspicuity, Bloom (1976) defined a "Visibility Index" as the geometric mean of the measured detection and recognition distance, i.e., the square root of the product of detection and recognition. The Visibility Index (VI) is a compromise between detection and recognition which is weighted toward the smaller recognition distance by virtue of the defined mathematical relationship. Such a weighting is consistent with the notion that the recognition point has more influence than the detection point on a driver's perception-decision process for objects relatively far away (perhaps 1,500 feet or more) and particularly for objects in a complex visual field.

A problem with the Visibility Index is that it assigns no value to a target that was not recognized regardless of the magnitude of its detection distance. While an absence of recognition is not a desirable target property, it is not logical to assign no merit whatsoever to a target which had a measured detection distance but failed to be recognized. Therefore, a fourth measure was constructed as the straight arithmetic average of the detection and recognition distances ("D+R Average"). All four measures were utilized in each analytical step and are reported in the sections which follow.

B. Descriptive Data

The central study design was factorial in nature with nine "movable" targets (five pedestrian and four bicycle) presented to four subjects at each of nine movable locations. The total of 36 trials (nine target/location combinations x four subjects per combination) were evenly divided across three consecutive nights of data collection. Two different experimenters and instrumented cars were used, and each experimenter stayed in the same car throughout the experiment. Nine "fixed" targets were also placed on the course to serve as distracters and to provide some performance data on treatments which could not be accommodated in the factorial design. The next parts of this section will examine each of these factors in terms of the four measures enumerated above.

1. Movable Locations

The a priori rationale for rotating the nine movable targets through each presentation location was the apparent diversity of ambient illumination, background, terrain and available sight distance among the target locations on the course. It was therefore of interest to examine the average performance of the nine pedestrian and bicycle targets at each of the movable locations. Table 11 presents the mean and standard deviation of the 36 data points for each location on each of the four defined measures (detection distance, recognition distance, Visibility Index, and D+R Average).

Inspection of Table 11 shows a quite considerable range of mean detection distances. Locations 2 and 3 had an average detection of only about 600 feet, while locations 4 and 9 were over 1000 feet and locations 7 and 8 approached 1,000 feet. A comparison of the measured mean detection distances with the available sight distances to the target showed that the measured variation across locations is consistent with the differences in available sight distance. Thus, it appears as though detection distance was influenced by location and that the decision to rotate targets among locations was clearly warranted.

The mean recognition distance by location data in Table 11 show a far more stable pattern than the detection measures. The range from the lowest (271.75 feet at location 5) to the highest value (468.17 feet at location 7) is under 200 feet, with most values falling in a narrow range between 300 and 350 feet. There does not appear to be an obvious relationship between detection and recognition distance or between recognition distance and available sight distance or other site-descriptive parameters. In particular, the poor recognition performance at location 4, which had dark ambient lighting, a totally quiet background and a long available sight distance, is difficult to explain. Perhaps some degree of background illumination aids recognition of a target as human by causing a silhouette effect. It is also possible that recognition at location 4 suffered because the immediately preceding fixed location contained the bright, flashing belt beacon. A third potential explanation is that the darkness and relatively bumpy and narrow road leading to location 4 created a high driving taskload reduced the ability of the subjects to track the target continuously.

The Visibility Index and D+R Average by location behave as one would expect from their mathematical derivation. The range of Visibility Index values is relatively low because of the higher weighting of the more consistent

Table 11. Summary Data for "Movable" Locations (in feet)

Location Number	Detection Distance		Recognition Distance		Visibility Index		D+R Average	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	834.44	376.02	321.08	195.04	496.61	234.96	577.76	248.00
2	597.31	304.82	328.58	178.89	432.74	216.72	462.94	223.80
3	603.39	245.45	343.97	167.16	444.86	185.72	473.68	185.29
4	1045.50	675.57	271.75	173.90	502.33	270.78	658.63	376.79
5	769.75	468.41	302.39	179.99	447.81	221.98	536.07	266.48
6	711.78	317.19	393.81	221.34	513.62	225.14	552.79	232.94
7	989.39	424.59	468.17	254.52	663.61	298.90	728.78	306.92
8	940.08	391.03	321.03	209.87	528.99	270.26	630.56	272.88
9	1089.39	490.95	334.81	202.87	575.28	245.11	712.10	288.46
All movable locations	842.34	456.83	342.84	204.66	511.76	249.86	592.59	283.51

recognition distance measure. The D+R Average also shows more stability than the raw detection measure because of the inclusion with equal weighting of the more stable recognition distance measure.

A review of the results by location for all four measures should provide the reader with a good overall view of the way the composite measures (Visibility Index and D+R Average) behave as the basic detection and recognition measures vary.

2. Night

The study design involved data collection over three consecutive nights. While the major factors of target and location were not fully replicated on each night, it is still of interest to examine the results by night for at least two reasons. First, much of the data on the third night were collected in rain of varying intensity. Thus, it is possible that results on that night were atypical and might have to be weighted or at least viewed with caution. Second, there is always the possibility in experiments of this type that the experimenters, no matter how well trained, will change over time. Typical causes of change relevant to this experiment might have been fatigue, learning or an alteration, subtle or deliberate, in the way the criteria for recording detection and recognition distance were applied.

Table 12 presents the study data broken down by night. The first four lines in the table show the data for all targets, movable and fixed, by night and for all three nights combined. These data show some variation, with the second night yielding the highest values of both detection and recognition distance and the third night producing the lowest values. It was not, however, considered reasonable to test these values for statistical significance because of potential confounding due to variation in observed performance by location. Since only three targets were deployed at each movable location on a given night, observed differences might be a result of a location effect or a target by location interaction as well as a true difference by night.

In order to examine the effect of night in isolation, the data for only the nine fixed targets were examined. Since these targets did not move during the entire experiment, an examination of the effect of night on the measures collected on them would be relatively free from confounding influences. Oneway analyses of variance were conducted on the night-by-night data for all four measures. None of these analyses showed significant effects due to night which even approached the .05 level of significance. Therefore, it was concluded that there were no significant effects of night on the experimental findings.

3. Car

Two different car/experimenter combinations were utilized in the study. The data by car are shown in Table 13 for all targets, fixed and movable. As with the data for night discussed above, the data by car were tested for significant differences using oneway analysis of variance. The detection distance and Visibility Index measures were not statistically significant (.05 level). Recognition distance was, however, significant ($F = 8.807$ $p < .01$) as was the D+R Average ($F = 6.296$ $p < .05$). In all cases, higher values were associated with car number 1. The observed results may have been due to

Table 12. Summary Data by Night (in feet)

Night	Detection Distance		Recognition Distance		Visibility Index		D+R Average	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1 - (All targets)	779.04	500.83	285.71	237.82	417.16	297.51	532.38	310.98
2 - (All targets)	823.63	460.22	309.65	265.62	453.01	317.84	566.64	309.97
3 - (All targets)	728.71	459.47	275.31	241.59	395.19	286.32	502.01	293.31
All nights/all targets	777.13	474.76	290.23	248.68	421.79	301.32	533.68	305.53
1 - (Fixed only)	720.65	483.64	241.91	272.82	337.71	324.84	481.28	315.31
2 - (Fixed only)	756.23	502.76	262.02	292.80	363.40	335.34	509.13	327.87
3 - (Fixed only)	658.86	464.30	208.90	262.91	294.33	301.80	433.88	301.62
All nights/Fixed only	711.91	484.00	237.61	276.47	331.81	321.24	474.76	315.68

Table 13. Summary Data by Experimental Vehicle (in feet)

Vehicle	Detection Distance		Recognition Distance		Visibility Index		D+R Average	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Car 1 - (all targets)	808.29	474.49	319.04	248.68	441.14	319.96	563.67	304.81
Car 2 - (all targets)	745.96	473.70	261.41	262.09	402.43	280.60	503.68	303.77
Total - (all targets)	777.13	474.76	290.23	231.34	421.79	301.32	533.68	305.53

differences in the way in which the experimenters dealt with the concept of recognition, their reaction times (the measured average recognition distance difference is 57.63 feet or about 1.3 seconds at 30 miles per hour) or their weights. The experimenter in car number 2 was approximately 50 pounds heavier than his counterpart in car number 1. This additional weight might have lowered the headlight aim enough to account for the observed difference.

The presence of some significant differences between the experimental vehicles suggested the inclusion of car as a factor in the multi-way analyses of variance (ANOVAs) discussed below. Simply, since car was known to be a source of variation which was likely unrelated to target performance, the power of the ANOVAs with respect to target performance would be increased by accounting for this fully replicated factor.

4. Fixed Targets

Table 14 presents the performance of the nine fixed targets on the four study measures. Although the initial purpose of these targets was to serve as distracters, the results they produced provide some interesting findings concerning the conspicuity of items typically found on the highway. An examination of Table 14 leads to the following interesting observations:

- The "Dark Ped" target consisting of a person in blue jeans and a navy blue sweat shirt was practically invisible. Its average detection distance of 70.33 feet for alerted subjects at approximately 30 mph represents less than two seconds of preview time. At 55 mph, this represents less than one second from detection to target. The average recognition distance of 49.39 feet for this target is only slightly more than one second under the conditions of the experiment and would be only a little over one-half second at 55 mph.

- The performance of the "Hot Dots" target was still poor with average detection and recognition distances of only 155.36 feet and 70.97 feet, respectively. However, the "Hot Dots" target was identical to the "Dark Ped" target except for the addition of four closely spaced retroreflective dots, each approximately the size of a penny. This small amount of retroreflective material on a flexible subsurface which provided less than ideal performance characteristics still more than doubled detection distance and almost doubled recognition distance.

- The active light sources ("Strobe," "Barricade" and "Belt Beacon") yielded the best detection ranges (over 1,100 feet). The bicycle fitted with standard reflectors plus the retro-reflective "Arrow" was almost as good, with a detection range of over 1000 feet. However the "Arrow" and, particularly, the "Belt Beacon" were not readily recognized as indicated by mean recognition distances of 114.42 feet and 24.31 feet, respectively. Part of the poor recognition performance of these targets was likely due to the fact that they were set on riderless bicycles, a phenomenon not typically encountered by drivers. The addition of a rider and associated pedal reflector motion would likely have

Table 14. Summary Data for "Fixed" Targets (in feet)

Target	Detection Distance		Recognition Distance		Visibility Index		D+R Average	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
T1 - Strobe	1200.75	338.26	396.19	374.42	592.90	419.00	798.47	295.91
T2 - Barricade	1119.11	140.29	617.33	266.21	786.82	289.19	868.22	165.94
T3 - Hot Dots	155.36	75.00	70.97	24.31	98.91	52.70	113.17	50.64
T4 - Belt Beacon	1340.97	73.93	24.31	26.12	134.12	121.06	682.64	36.80
T5 - Triangle	336.17	25.66	202.06	75.01	251.65	69.74	269.11	40.50
T6 - Dark Ped	70.33	26.35	49.39	27.61	57.78	25.34	59.86	24.82
T7 - Arrow	1038.61	295.06	114.42	179.05	256.73	258.91	576.51	189.94
T8 - Cones	473.11	192.51	155.42	194.81	228.92	200.80	314.26	167.48
T9 - Triangle	672.81	103.04	508.39	174.25	578.48	143.87	590.60	129.55
All fixed targets	711.91	484.00	237.61	276.47	331.81	321.24	474.76	315.68

improved recognition. The barricade, on the other hand, did not suffer from poor recognition. Its combination of a flashing amber light and retroreflective diagonally-striped band are obviously quite familiar to drivers, thereby resulting in a mean recognition distance of over 600 feet, the best achieved by any target in the experiment.

o The dramatically different performance of the two warning triangles is attributed to their display locations. The triangles, themselves, were identical. However, the one at the first encountered location was set in a small hollow with limited available sight distance. It tended to be detected as soon as it was revealed by the roadway geometry. The second triangle was potentially visible at considerable distance although it was quite left of the headlight pattern when it was first observable. The measured detection and recognition distances for this triangle (672.81 feet and 508.39 feet) are considered more representative of the potential of this target in unobstructed viewings than are the values (336.17 feet detection and 202.06 feet recognition) for the first triangle. It is interesting to note that the distance from detection to recognition was consistent for both presentations (164.42 feet for the second triangle and 134.11 feet for the first), indicating that on average subjects took over three seconds (at 30 mph average speed) to recognize the triangle after it had been detected regardless of where the detection occurred. This is startling since the inverse square law indicates that the triangle at 336 feet should be four times brighter (assuming similar angular conditions) than the triangle at 672 feet.

5. Movable Targets

The nine movable targets (five pedestrian and four bicycle) were the central interest of the experiment. Summary data for these targets are shown in Table 15. It can be seen from these data that mean detection distance across all 36 trials (four trials at each of the nine movable locations) ranged from a low of 223.83 feet for the Base Ped (blue jeans and white shirt) to a high of 1379.22 feet for a pedestrian with a regular two-cell flashlight. Recognition distance showed a smaller range but still varied from a low mean of 104.81 feet for the Base Ped to a high of 481.42 feet for the bicyclist using a Leg Lamp.

The data for the movable targets were the subject of extensive analyses to determine the existence and extent of differences among targets: The results of these analyses are presented below.

C. Three-way Analyses of Variance

The first major analytic question considered concerned whether each type of movable target, pedestrian or bicycle was a significant factor in the experiment. Obviously, if the experimental variation produced by the five pedestrian or four bicycle targets was not significant, it would be impossible to conclude that any of the treatments tested was a potentially viable countermeasure, i.e., was significantly better than the untreated base condition. The chosen experimental design permitted the application of a

Table 15. Summary Data for "Movable" Targets (in feet)

Target	Detection Distance		Recognition Distance		Visibility Index		D+R Average	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
P1 - Base Ped	223.83	113.78	104.81	60.30	145.34	73.27	164.32	75.03
P2 - Dangle Tags	532.22	215.77	143.53	74.54	263.74	109.05	337.88	124.34
P3 - Flashlight	1379.22	492.91	316.19	237.23	602.75	234.63	847.71	254.75
P4 - Jogging Vest	744.19	305.30	321.92	178.30	469.32	188.84	533.06	197.87
P5 - Rings	759.56	300.40	436.39	148.64	566.66	181.37	597.97	198.00
B1 - Base Bike	844.06	273.71	439.44	171.48	593.26	184.57	641.75	182.66
B2 - Spokes & Crank	838.64	296.11	373.36	157.74	545.80	173.12	606.00	187.88
B3 - Leg Lamp	1302.69	356.59	481.42	202.40	761.12	184.35	892.06	185.53
B4 - Fanny Bumper	956.61	336.21	468.53	126.79	657.86	168.78	712.57	196.44
All Movable Targets	842.34	456.83	342.84	204.66	511.76	249.86	592.59	283.51

multi-dimensional analysis of variance (ANOVA) as a means of testing the effect of target variation. For reasons discussed above, a three-way design was chosen in which the factors (main effects) examined were location (the nine movable locations), target (the five pedestrian or four bicycle movable targets) and car (the two experimental vehicles).

1. Pedestrian Targets

a. Detection Distance

Table 16 presents the ANOVA results for the detection distance measure on pedestrian targets. The main effects of location and target are significant, with target accounting for approximately ten times the amount of variation explained by location. The main effect of car was not significant. Thus, based on the main effect of pedestrian target, it could be concluded that the differing target configurations yielded different detection distances.

All three of the two-way interactions for detection distance shown in Table 16 were significant. The location by car interaction was examined and showed no clear pattern. The target by car interaction showed a quite regular pattern. The two cars showed equal performance for the Base Ped (222.89 feet for car number 1 and 224.78 feet for car number 2). Car number 2, however, showed a larger mean detection distance for the Flashlight target than did car number 1 (1435.11 feet versus 1323.33 feet). For all three other pedestrian targets, car number 1 showed greater mean detection distances (587.61 feet versus 476.83 feet for Dangle Tags; 802.00 feet versus 686.39 feet for Jogging Vest; and 802.50 feet versus 716.61 feet for Rings). Each of these three targets uses a retroreflective treatment which would be expected to suffer in performance if the headlights were aimed more downward as was suggested by the additional weight of the experimenter in car number 2. The effect of this weight difference is further suggested by the particularly large difference for the Jogging Vest which only had retroreflective treatment at chest level and the Dangle Tags, which were displayed at knee level on the body. The Rings treatment included leg bands and showed a less pronounced difference between cars as would be anticipated from the inclusion of retroreflective material closer to the ground. The Flashlight would not, of course, be expected to show this effect because it is an active light source. In fact, a slight nose-down attitude of an experimental vehicle might be expected to reveal the Flashlight somewhat earlier or produce less headlight scatter to interfere with the Flashlight signal, as was observed with these data.

The location by target interaction was examined and generally followed no overall pattern. The three-way interaction of Location by Target by Car was not significant for detection distance.

b. Recognition Distance

The analysis of variance on Recognition Distance is shown in Table 17. All three main effects are significant, but none of the interactions reached significance when tested at the .05 level. The main effect of target accounts for the majority of the variation in the main effects. Table 17 leads to the straightforward conclusion that the targets performed differently when compared on the basis of recognition distance in the context of the entire experiment.

Table 16. Analysis of Variance for Detection Distance (Feet) for "Movable" Pedestrian Targets

Source	Degrees of Freedom	Mean Square	F	Significance of F
Main Effects				
Location	8	675768.231	23.828	.001
Target	4	6460750.556	227.807	.001
Car	1	71003.472	2.504	---
2-Way Interactions				
Location x Target	32	231213.840	8.153	.001
Location x Car	8	66550.497	2.347	.05
Target x Car	4	84652.000	2.985	.05
3-Way Interactions				
Location x Target x Car	32	22112.166	0.780	---
Residual	90	28360.694		

Table 17. Analysis of Variance for Recognition Distance (Feet) for "Movable" Pedestrian Targets

Source	Degrees of Freedom	Mean Square	F	Significance of F
Main Effects				
Location	8	91859.237	4.730	.001
Target	4	680862.161	35.060	.001
Car	1	328875.756	16.935	.001
2-Way Interactions				
Location x Target	32	30468.317	1.569	---
Location x Car	8	13363.218	0.688	---
Target x Car	4	8502.700	0.438	---
3-Way Interactions				
Location x Target x Car	32	7811.412	0.402	---
Residual	90	19420.089		

c. Visibility Index/D+R Average

The ANOVAs on Visibility Index and D+R Average are presented in Tables 18 and 19. All three main effects for both measures are significant as are the location by target interactions for each measure. An examination of the location by target data showed many of the same interactions discussed above with respect to detection distance. However, the Visibility Index and D+R Average have scaled the results into values which are intermediate between a liberal view of sufficient conspicuity represented by detection distance and the conservative view represented by recognition distance. Both composite measures also smooth the data somewhat.

2. Bicycle Targets

The same basic three-way ANOVA design (target by car by location) was used to analyze the data for the four movable bicycle targets. The results by measure are presented below.

a. Detection Distance

The ANOVA results on detection distance (Table 20) show significant main effects of location, target and car and a significant location by target interaction. As with the pedestrian measures, the target main effect accounted for the majority of the variation leading to the conclusion that the four targets performed differently with respect to detection distance.

An examination of the location by target data showed several cell means which clearly contributed to the significant interaction. However, no explanation was apparent to account for the observed data. For example, location 4 was associated with generally higher than average detection distances (1213.44 feet versus 985.50 feet for all locations). This appears consistent with the fact that location 4 had the longest available sight distance and was in a dark area of the course. However, only the Leg Lamp and Fanny Bumper showed performance better than their average (1890.75 feet versus 1302.69 feet for the Leg Lamp and 1508.25 feet versus 956.61 feet for the Fanny Bumper). The Spokes and Crank treatment yielded approximately average performance (821.00 feet at location 4 versus 838.64 feet overall), but the Base Bike was fully 210.31 feet below its average detection distance of 844.06 feet when presented at location 8. Results such as these might have been the result of incorrect alignment of the Base Bike when it was set at location 4. Although this was not noticed by either of the experimenters or the researcher who set the course, it cannot be totally discounted. In particular, the Base Bike appeared at location 4 for the last four trials of the entire experiment, and these were conducted on the rainy test evening.

Another unexplained location by target interaction involved the Spokes and Crank at location 6. This treatment performed 199.36 feet better than its overall average of 838.64 feet at this location while all three other targets yielded below-average detection ranges.

The Leg Lamp showed below-average performance of 1253.25 feet at location 8 as compared with its grand mean of 1302.69 feet. All three other

Table 18. Analysis of Variance for Visibility Index (Feet) for "Movable" Pedestrian Targets

Source	Degrees of Freedom	Mean Square	F	Significance of F
Main Effects				
Location	8	123714.497	5.663	.001
Target	4	1409850.691	64.536	.001
Car	1	319983.493	14.647	.001
2-Way Interactions				
Location x Target	32	38003.478	1.740	.05
Location x Car	8	13779.753	0.631	---
Target x Car	4	13628.126	0.624	---
3-Way Interactions				
Location x Target x Car	32	8553.552	0.392	---
Residual	90	21845.822		

Table 19. Analysis of Variance for D + R Average (Feet) for "Movable" Pedestrian Targets

Source	Degrees of Freedom	Mean Square	F	Significance of F
Main Effects				
Location	8	192210.060	12.649	.001
Target	4	2434369.801	160.204	.001
Car	1	176375.501	11.607	.001
2-Way Interactions				
Location x Target	32	65317.895	4.299	.001
Location x Car	8	22402.501	1.474	---
Target x Car	4	31094.269	2.046	---
3-Way Interactions				
Location x Target x Car	32	8645.984	0.569	---
Residual	90	15195.451		

Table 20. Analysis of Variance for Detection Distance (Feet) for "Movable" Bicycle Targets

Source	Degrees of Freedom	Mean Square	F	Significance of F
Main Effects				
Location	8	600660.453	15.671	.001
Target	3	1716259.204	44.777	.001
Car	1	315282.250	8.226	.01
2-Way Interactions				
Location x Target	24	175676.532	4.583	.001
Location x Car	8	54842.953	1.431	---
Target x Car	3	36832.602	0.961	---
3-Way Interactions				
Location x Target x Car	24	60507.055	1.579	---
Residual	72	38329.292		

targets performed well above their overall averages when at this location (1,169.50 feet versus 844.06 feet for the Base Bike; 1,031.25 feet versus 838.64 feet for the Spokes and Crank; and 1,173.25 feet versus 956.61 feet for the Fanny Bumper). This reduced performance of the Leg Lamp at location 8 may be the result of the lower available sight distance to the target at this location which could have simply truncated the detection distance measure for the bright Leg Lamp but not for less powerful targets.

b. Recognition Distance

The ANOVA on recognition distance for the movable bicycle targets showed that the main effects for target and car were the only statistically significant effects. This is shown in Table 21. It is interesting, but not surprising in light of the apparently uniform recognition performance of the four bicycle targets as shown above in the summary data table, that the car effect accounted for almost as much of the observed variation as did the target factor. It is also of interest that the ANOVA on recognition distance of the bicycle targets was the only ANOVA for which the main effect of location and all location interactions were not significant. That is, the recognition of these targets as bicycles was not significantly influenced by the large variation in characteristics across the nine movable locations.

c. Visibility Index and D+R Average

The composite measures are of particular interest for the four movable bicycle targets because of the relatively smaller (compared to the pedestrian targets) detection and recognition variations across targets. Table 22 shows the ANOVA results for the Visibility Index measure. All three main effects were significant with the target factor accounting for only slightly more of the observed variation than the location factor.

The location by target interaction was significant and showed a pattern similar to the findings for the detection measure described above. Examination of the data revealed that most of the observed interaction effect came from highly variable performance of the Base Bike and Spokes and Crank targets across locations. For example, location 6 showed generally lower than average Visibility Index performance except for the Base Bike target which yielded an index which was 20.48 feet above its average. Location 4 showed better than average performance for the Leg Lamp and Fanny Bumper but worse than average Visibility Indexes for the Base Bike and Spokes and Crank. There was no readily apparent explanation for these observed variations.

The target by car interaction for the Visibility Index was also significant. As shown earlier, car number 1 produced a higher Visibility Index over all fixed and movable targets (441.14 feet versus 402.43 feet) than did car number 2. This difference was even greater for just the nine movable targets (553.25 feet versus 470.27 feet). All of the movable bicycle targets yielded a higher Visibility Index from car number 1 <u>except</u> for the Leg Lamp which was slightly superior when viewed from car number 2 (763.32 feet versus 758.92 feet). It is once again interesting to note that the Leg Lamp is an active light source which should not be negatively influenced by a slight nose-down attitude which the additional weight of the experimenter in car number 2 may have caused. All three other targets depend on retroreflective

Table 21. Analysis of Variance for Recognition Distance (Feet) for "Movable" Bicycle Targets

Source	Degrees of Freedom	Mean Square	F	Significance of F
Main Effects				
Location	8	48257.734	1.976	---
Target	3	83620.007	3.425	.05
Car	1	152165.007	6.232	.05
2-Way Interactions				
Location x Target	24	34492.512	1.413	---
Location x Car	8	8242.366	0.338	---
Target x Car	3	45435.729	1.861	---
3-Way Interactions				
Location x Target x Car	24	23750.589	0.973	---
Residual	72	24417.993		

Table 22. Analysis of Variance for Visibility (Feet) for "Movable" Bicycle Targets

Source	Degrees of Freedom	Mean Square	F	Significance of F
Main Effects				
Location	8	98304.102	5.257	.001
Target	3	312546.851	16.713	.001
Car	1	237996.157	12.726	.001
2-Way Interactions				
Location x Target	24	52315.706	2.797	.001
Location x Car	8	12740.652	0.681	---
Target x Car	3	58588.610	3.133	.05
3-Way Interactions				
Location x Target x Car	24	21819.906	1.167	---
Residual	72	18700.953		

materials whose performance would be degraded by a downward shift of the headlight beam axis.

Table 23 shows the D+R Average ANOVA. All three main effects and the location by target interaction were significant. The obvious sources of the interaction effect were essentially the same as for the other measures and, as before, an examination of the data did not lead to a plausible explanation for the observed phenomena.

3. Target Comparisons

The ANOVAs presented above show that the target factor was significant for pedestrian and bicycle movable targets on each of the four measures. The existence of a significant target main effect does not necessarily mean that the performance of any one specific target was significantly better or worse than the performance of any other specific target or targets. To determine differences between target pairs of interest, oneway analysis of variance procedures were used ("oneway"). These analyses examined the target groups of interest, e.g., movable bicycle targets, on each of the four measures to determine if the variation among targets was statistically significant. The Duncan Multiple Range test was then applied, using the .05 level of significance to determine if specific targets could be considered to have performed differently on the various measures as compared with the remaining targets. Comparisons were run for each possible pedestrian and bicyclist target pair.

a. Movable Pedestrian Targets

The first set of oneway comparisons involved the movable pedestrian targets. The results of the paired target comparisons are shown in Table 24. The oneway analysis of variance across the five targets was statistically significant for all four measures ($F = 66.48$ $p < .001$ for detection; $F = 28.52$ $p < .001$ for recognition; $F = 50.04$ $p < .001$ for Visibility Index; and $F = 74.06$ $p < .001$ for D+R Average).

Inspection of Table 24 shows that all of the enhanced targets performed significantly better than the Base Ped on all measures with one exception. Recognition of the Dangle Tags was not significantly larger than the recognition distance for the Base Ped. The Flashlight showed superior detection and D+R Average performance to all other targets and was better on Visibility Index than everything but the Rings. The retroreflective Rings target was the best recognition target and scored higher on this measure than any of the other pedestrian targets. This superior recognition performance together with a detection range which was significantly higher than the Base Ped or Dangle Tags resulted in excellent Visibility Index results with Rings scoring higher than the Base Ped, Dangle Tags and Jogging Vest but not the Flashlight.

It is notable that even the simple enhancement provided by the Dangle Tags was capable of more than doubling average detection distance. It is also of interest that none of the retroreflective targets could even approach the detection performance of a common two-cell flashlight. Moreover, the Flashlight treatment also more than tripled recognition distance when compared to the Base Ped even though the target was deployed so that the flashlight

Table 23. Analysis of Variance for D + R Average (Feet) for "Movable" Bicycle Targets

Source	Degrees of Freedom	Mean Square	F	Significance of F
Main Effects				
Location	8	165471.680	10.252	.001
Target	3	583039.256	36.123	.001
Car	1	226377.710	14.026	.001
2-Way Interactions				
Location x Target	24	62855.384	3.894	.001
Location x Car	8	17453.546	1.081	---
Target x Car	3	37190.451	2.304	---
3-Way Interactions				
Location x Target x Car	24	20276.938	1.256	---
Residual	72	16140.245		

Table 24. Oneway Comparisons of "Movable" Pedestrian Targets

Target & Measure	Mean (Feet)	P1 Base Ped	P2 Dangle Tags	P3 Flash-light	P4 Jogging Vest	P5 Rings
P1 - Base Ped						
Detection	223.83					
Recognition	104.81					
Visibility Index	145.34					
D+R Average	164.32					
P2 - Dangle Tags						
Detection	532.22	+				
Recognition	143.53					
Visibility Index	263.74	+				
D+R Average	337.88	+				
P3 - Flashlight						
Detection	1379.22	+	+		+	+
Recognition	316.19	+	+			
Visibility Index	602.75	+	+		+	
D+R Average	847.71	+	+		+	+
P4 - Jogging Vest						
Detection	744.19	+	+			
Recognition	321.92	+	+			
Visibility Index	469.32	+	+			
D+R Average	533.06	+	+			
P5 - Rings						
Detection	759.56	+	+			
Recognition	436.39	+	+	+	+	
Visibility Index	566.66	+	+		+	
D+R Average	597.97	+	+			

+ = target listed in the row has significantly larger value than target listed in the column at the .05 level.

beam would be in front of the pedestrian and not shine directly in the driver's eyes. Obviously, the normal walking arm motion imparted to the Flashlight provided a readily recognizable cue to the subjects.

The Flashlight was an active treatment which yielded clearly superior results on most measures. However, active treatments have limited service lives without a replenishment of their energy sources. It was therefore of interest to examine just the passive pedestrian treatments in isolation. Since all of the targets had performed significantly better than the Base Ped, only the three retroreflective treatments (Dangle Tags, Jogging Vest and Rings) were included in this analysis. The results are shown in Table 25.

The oneway for these three targets was significant for all four measures ($p < .001$). The calculated F ratios were 7.58, 39.58, 32.11 and 21.10 for detection, recognition, Visibility Index and D+R Average, respectively. The paired comparisons in Table 25 show that the Jogging Vest and Rings were superior to the Dangle Tags on every measure. Rings was a better recognition target than the Jogging Vest and scored significantly higher on the Visibility Index which emphasizes recognition.

b. Movable Bicycle Targets

The movable bicycle targets were subjected to the same types of analyses. The oneway analyses of variance were significant for each measure ($F = 17.04$ $p < .001$ for detection; $F = 3.01$ $p < .05$ for recognition; $F = 9.88$ $p < .001$ for Visibility Index; and $F = 16.46$ $p < .001$ for D+R Average). Table 26 shows the individual target comparisons. The vastly superior detection performance of the Leg Lamp is obvious from this Table. Its average detection range was far superior to any of the other three targets. This improved detection was sufficient to yield significantly superior performance on both the Visibility Index and D+R Average measures.

The relatively poor recognition performance of the Spokes and Crank treatment cannot be explained. There certainly is no apparent reason why the addition of retroreflective material to the rear spokes and cranksets of a bicycle equipped identically to the Base Bike should have interfered with recognition.

It is also noteworthy that the Base Bike, unlike its pedestrian counterpart, performed relatively well. It took the addition of an active light source (Leg Lamp) to significantly improve performance above that achieved by the Base Bike equipped to CPSC standards.

c. Other Comparisons

Two other comparisons between targets were of interest either because they shed insight on the merits of certain enhancements or because they examined popularly held beliefs. The first of these is shown in Table 27 and compares the three "low intensity" pedestrian targets, i.e., the Dark Ped (fixed target), Hot Dots (fixed target) and Base Ped (movable target). While these three targets were not all viewed under the same experimental conditions because the fixed targets were only measured at a single location, their comparison is interesting for at least two reasons. First, the Dark Ped and Hot Dots targets were basically identical except for the inclusion of the four

Table 25. Oneway Comparisons of Retroreflective Pedestrian Targets

Target & Measure	Mean (Feet)	P2 Dangle Tags	P4 Jogging Vest	P5 Rings
P2 - Dangle Tags				
Detection	532.22			
Recognition	143.53			
Visibility Index	263.74			
D+R Average	337.88			
P4 - Jogging Vest				
Detection	744.19	+		
Recognition	321.92	+		
Visibility Index	469.32	+		
D+R Average	533.06	+		
P5 - Rings				
Detection	759.56	+		
Recognition	436.39	+	+	
Visibility Index	566.66	+	+	
D+R Average	597.97	+		

+ = target listed in the row has significantly larger value than target listed in the column at the .05 level.

Table 26. Oneway Comparisons of "Movable" Bicycle Targets

Target & Mean		B1	B2	B3	B4
Target & Measure	Mean (Feet)	Base Ped	Spokes & Crank	Leg Lamp	Fanny Bumper
B1 - Base Bike					
Detection	844.06				
Recognition	439.44				
Visibility Index	593.26				
D+R Average	641.75				
B2 - Spokes & Crank					
Detection	838.64				
Recognition	373.36				
Visibility Index	545.80				
D+R Average	606.00				
B3 - Leg Lamp					
Detection	1302.69	+	+		+
Recognition	481.42		+		
Visibility Index	761.12	+	+		+
D+R Average	892.06	+	+		+
B4 - Fanny Bumper					
Detection	956.61				
Recognition	468.53		+		
Visibility Index	657.86		+		
D+R Average	712.57		+		

+ = target listed in the row has significantly larger value than target listed in the column at the .05 level.

Table 27. Oneway Comparisons of Dark Pedestrian, Hot Dots and Base Pedestrian

Target & Mean		T6	T3	P1
Target & Measure	Mean (Feet)	Dark Ped	Hot Dots	Base Ped
T6 - Dark Ped				
Detection	70.33			
Recognition	49.39			
Visibility Index	57.78			
D+R Average	59.86			
T3 - Hot Dots				
Detection	155.36	+		
Recognition	70.97	+		
Visibility Index	98.91	+		
D+R Average	113.17	+		
P1 - Base Ped				
Detection	223.83	+	+	
Recognition	104.81	+	+	
Visibility Index	145.34	+	+	
D+R Average	164.32	+	+	

+ = target listed in the row has significantly larger value than target listed in the column at the .05 level.

retroreflective dots on the latter targets. These targets were included to be a worst-case presentation and to examine the benefits of a very minimal retroreflective treatment. Since both the Dark Ped and Hot Dots yielded very low detection and recognition distances and both were displayed at totally dark locations, any location effects on their data are considered minimal.

The second reason for comparing the three targets shown in Table 27 is that much conventional safety wisdom has advocated "wear white at night." The Base Ped may be thought of as the Dark Ped with the addition of a new, clean, white shirt in place of the dark sweat shirt. Data previously presented showed that any of the retroreflective enhancements used on the movable pedestrian targets resulted in significantly improved performance over the Base Ped. Therefore, the only possible benefit of wearing white would be when compared to wearing dark colors.

Oneway analyses of variance for the Dark Ped, Hot Dots and Base Ped targets yielded statistically significant F values ($p < .001$) of 33.15, 13.97, 23.58 and 33.45 for detection, recognition, Visibility Index and D+R Average, respectively. Table 27 shows that the Hot Dots were superior to the Dark Ped on all measures, but the Base Ped was significantly better than either the Hot Dots or Dark Ped on all measures. It is of considerable interest that the addition of only a minimal amount of retroreflective material on a dark target can more than double detection distance and almost double recognition distance while covering the entire upper torso with white fabric produces only about a 50 percent gain over the Hot Dots. It is also noteworthy, as discussed in the next chapter of this report, that none of these three targets could be considered "safe" by any reasonable definition of conspicuity.

The second additional comparison was of the two active, movable targets, the Leg Lamp (bicycle) and Flashlight (pedestrian). The results of oneway comparisons of the four measures for these two targets are shown in Table 28. Since only two targets were included in this comparison, the significance of the calculated F ratio identifies directly the existence of a difference between the targets.

The two noteworthy findings in Table 28 relate to the detection and recognition measures. Even though the Leg Lamp bicycle target included powerful retroreflectors in addition to the active lamp, there was no significant difference between its detection range and that of the Flashlight. The Leg Lamp was, however, recognized significantly further out. The difference in mean recognition distances of over 165 feet is more than a 50 percent increase for the Leg Lamp over the Flashlight. From these findings it is reasonable to conclude that the bicycle/Leg Lamp combination presented a more familiar cue or "target signature" to the subjects than did the Flashlight. This is likely due to the up and down motion of both the Leg Lamp and the pedal reflectors. Anecdotal reports of the subjects suggested that the moving pedal reflectors were likely the most important factor in establishing this signature.

Table 28. Oneway Comparison of Flashlight and Leg Lamp

Condition	P3 Flash-light Mean	B3 Leg Lamp Mean	F	Significance
Detection	1379.22	1302.69	0.57	N.S.
Recognition	316.19	481.42	10.11	.01
Visibility Index	602.75	761.12	10.14	.01
D+R Average	847.71	892.06	0.71	N.S.

V. DISCUSSION

The results of this experiment lead to several conclusions and observations concerning the nighttime conspicuity enhancement of pedestrians and bicyclists. By inference, the findings of this study can be extended to estimate the relative safety benefits of the tested treatments. However, before addressing the target data, it is of interest to discuss the experiment itself to establish a context in which to view the study conclusions.

The maximum utility of the experimental results of this study rests in their ability to transfer to the day-to-day highway environment. While the absolute safety benefit of any of the tested treatments cannot be accurately assessed with the available data, the estimate of the relative merit of the tested targets appears to be valid and reliable. The test environment at Camp Atterbury did not differ markedly from that which a driver would encounter in a small, U.S. town. The range of ambient and background lighting conditions was broad and likely covered most typically encountered roadway situations. Overall, the physical environment was conducive to generalizing the results beyond the bounds of the experiment and, in particular, matched the target accident types very well.

The driving situation faced by the experimental subjects was also sufficiently realistic to permit generalizing the study findings. To be sure, the subjects were motivated and alerted, sober, screened to rule out vision pathology, encountered no oncoming headlight glare and were aware that there was no competing vehicular traffic. These factors would tend to improve their performance and make the targets seem more conspicuous. On the other hand, the subjects were told to maintain a speed which made the driving task over totally unfamiliar roads reasonably difficult. Potholes and other surface irregularities were encountered and certainly served to distract the subjects from looking for pedestrians or bicyclists. The random and unpredictable appearance of cattle and other animals required the constant alertness of the drivers to avoid collisions. The headlights used were of the conventional, sealed-beam design which does not have the brightness of the new halogen lamps. Thus, experimental subjects had many tasks to perform in addition to searching for targets, and this task loading would be expected to limit target performance.

There is no sure way to determine if the observed results over or under state performance if the various targets had been viewed by the same subjects in free-flowing traffic with opposing and following vehicle headlights. It is the belief of the authors that there likely was a slight target performance enhancement in the experiment due primarily to the absence of other vehicle headlight glare and the lower attentional demands of driving in the known absence of other vehicular traffic. This enhancement is considered to have been applicable to all experimental targets.

The results of this experiment clearly highlight the merits of active conspicuity treatments. The Flashlight was detected over 600 feet farther away than the next best pedestrian target (Rings). This difference represents over an 80 percent increase in detection distance. Moreover, even though the Rings were recognized farther away on average (436.39 feet versus 316.19 feet), both composite measures showed the Flashlight to be superior. It is also noteworthy that the initial cost of the Flashlight of between $1.00 and $3.00 is only a fraction of the $18.00 current estimated cost for a Rings treatment. Thus, even accounting for replacement batteries, the life-cycle cost-effectiveness of the Flashlight is likely far above any of the other tested pedestrian treatments. It should also be remembered that a flashlight has numerous other uses in addition to enhancing a pedestrian's conspicuity while the tested passive treatments are essentially single purpose. However, it must be emphasized that the performance of the Flashlight target was probably enhanced by the experimental deployment. The pedestrian holding the Flashlight was facing traffic and walking in place. The Flashlight, held in the pedestrian's right hand, had a translucent red hood, and was moving and produced a blinking signal. Fresh batteries were used each evening and the Flashlight was off between trials. In particular, it is likely that the performance of the Flashlight would have been reduced if the pedestrian holding it were not in motion or not facing traffic or if an opaque hood model was employed.

The same findings held for the bicycle targets. The Leg Lamp yielded the best performance on all measures while its marginal cost (about $6 above the CPSC mandated reflectors on the Base Bike) was about the same as the Spokes and Crank and somewhat less than the Fanny Bumper treatment (which included leg bands).

The comparison of the Flashlight and Leg Lamp treatment (including CPSC reflectors) is also of interest because it highlights the importance of a target signature. Both targets were detected at approximately the same distance, but the Leg Lamp was recognized at significantly greater range. It must be assumed that the cyclic up-and-down motion of the pedal reflectors used with the Leg Lamp were the main source of this additional recognition distance, since the Leg Lamp did not perform significantly better on recognition than the Base Bike. Motorists are obviously becoming familiar with this signature, and this familiarity was displayed by the experimental subjects. The high recognizability of the fixed barricade target also supports the notion that a target signature can be established and, when learned by motorists, will improve recognition.

The Jogging Vest and Rings pedestrian targets also support the importance of an anthropomorphic shape in establishing a target signature. The benefit of conspicuity enhancers which conveyed the human form was suggested by Bloom (1976) and further supported by Blomberg, Leaf and Jacobs (1980). The Rings treatment which outlined the human shape was recognized on average over 114 feet farther away than the Jogging Vest even though there was no significant difference in their mean detection distances. The significantly improved recognition performance of the Rings target is attributed to the greater anthropomorphism inherent in its design.

When viewing the results of this study, it is important to remember that all targets were viewed from only a single aspect with the motorist closing directly on the target. All pedestrians were by the right side of the road facing traffic. All bicycles were just off the right edge of the road and parallel with it. While overtaking accidents are the most frequent and serious nighttime situation, particularly for bicyclists, the conspicuity of the targets in other viewing directions should not be forgotten.

The various bicycle targets would likely have performed quite differently if approached from a different aspect. As viewed in this study, the front white reflector and side spoke reflectors were not factors. The pedal and rear-red reflectors were the primary signal source for the Base Bike. All of the enhancements were deployed primarily to increase conspicuity in the overtaking situation. However, two of these bicycle additions, the Leg Lamp and the leg bands used with the Fanny Bumper target, were designed to improve conspicuity in other directions as well. The Glo-Wheel spoke reflectors used in the Spokes and Crank treatment were designed primarily for side conspicuity improvement but were tested in this study for rearward enhancement. The various treatments have performance properties in directions other than to the rear, which were not measured as part of this study. Therefore, it is not possible to conclude that a treatment such as the Spokes and Crank is not worthy of consideration as a countermeasure simply because it did not show an improvement to the rear compared with the Base Bike. Its signal potential to the side would have to be assessed to reach a final determination with respect to its countermeasure potential.

To this point in this report, all results have been expressed and discussed in terms of actual measured distances. Targets have been compared to each other and to their respective base conditions, and it has been concluded that active light sources outperform passive treatments under the conditions of this study. The concepts of safety or sufficient conspicuity have yet to be addressed. While it is impossible to determine or even estimate potential safety benefits in terms of accident reduction based on this study, it is reasonable to examine a level of acceptable or sufficient conspicuity to see which targets meet or exceed this level.

Any definition of minimally sufficient or minimum acceptable conspicuity must consider:

- Prevailing ambient road conditions (light, background, surface, curvature, etc.).
- Presence or absence of glare.
- Vehicle speed.
- Driver human factors, such as fatigue or alcohol.
- Selected driver response modality, e.g., stop or swerve.
- Vehicle response characteristics.
- Vehicle type or configuration insofar as it determines the observation or divergence angle the driver's eyes will make with the headlight beam.
- Test conditions under which data will be gathered.
- Extent of immediacy acceptable in the decision-making process, i.e., the amount of time available for reaching a decision.
- Target response, i.e., will safety depend totally on the driver's actions or will the pedestrian or bicyclist take positive steps to avoid a crash?

- Driver learning or set with respect to target signatures.

Unfortunately, there is no universally accepted set of standards with respect to these factors and, hence, there is no current operative definition of sufficient conspicuity. The notion of a threshold or minimum level of conspicuity can, however, be addressed.

In the context of this study, it is believed that any level of minimum acceptability adopted should be fairly stringent because the test conditions, as discussed above, tended to overstate slightly the performance of the targets. To compensate for the somewhat liberal view of target effectiveness provided by these data, it is therefore suggested that the developed safety criteria include a requirement for motorists to stop before reaching the target. The requirement to stop also simplifies the derivation of a quantitative criterion because it permits the use of the numerous traffic engineering and law enforcement guides which specify nominal stopping distances for passenger cars. Stopping is rarely the chosen evasive action of drivers except in situations when the hazard is clearly blocking the roadway. However, the preview time needed to permit a stop should be sufficient for any other reasonable evasive maneuver, e.g., slowing and moving left away from the hazard.

Given a hypothetical requirement to stop, it is necessary to specify a speed of travel in order to derive a stopping distance. While the national speed limit is 55 mph, prevailing open road speeds are typically higher. However, 55 mph is a reasonable minimum criterion level if the generally defined Stopping Sight Distance (SSD) is used because SSD already assumes a 2.5 second perception-reaction time. Standard SSD tables (ITE, 1976) show an SSD of 550 feet for 55 mph, and this seems to be a reasonable threshold level for an initial consideration of "acceptable" conspicuity based on the results of this experiment.

The remaining question is which measure to apply to the 550-foot threshold criterion. Detection distance is likely overly liberal because the driver at the point of detection probably does not have enough information to reach a reliable decision on the proper evasive action. Recognition distance, on the other hand, is too conservative because most drivers in the majority of roadway situations will have made a proper decision before reaching the recognition point. The composite measures, Visibility Index and D+R Average, would therefore appear to be the best choices. Both fall between detection and recognition with the D+R Average giving equal weight to detection and recognition performance and the Visibility Index emphasizing recognition.

In light of the foregoing, it appears reasonable to consider a minimum threshold of conspicuity for this experiment (or for any data collected in a similar manner) as a Visibility Index or a D+R Average of 550 feet or more. Hence, a target with "good" combined detection and recognition distance would be considered minimally acceptable. Using this criterion, the following movable treatments were above the threshold on both measures:

- Flashlight
- Rings
- Base Bike
- Leg Lamp
- Fanny Bumper

In addition, the Spokes and Crank was above the criterion for D+R Average (606.00 feet) and just below for Visibility Index (545.80 feet), and the Jogging Vest almost reached criterion on the D+R Average (533.06 feet). Each of the five treatments which met criterion on both measures may be considered sufficiently conspicuous to improve (but certainly not insure) safety. The Spokes and Crank and Jogging Vest would also likely result in some significant safety improvement.

Care must be exercised in applying any minimal threshold criterion for optical materials for at least two reasons. First, retroreflectors and active light sources degrade with use due to dirt, abrasion and lowered power levels. Second, any threshold level is, by definition, minimally "acceptable" and subject to being rendered unacceptable by conditions beyond the control of the user, e.g., driver intoxication, inclement weather. In essence, a threshold level should be used to exclude obviously unacceptable conspicuity treatments. Approaches which surpass the threshold by significant amounts are to be sought with the ultimate goal of increasing safety. However, it must be emphasized that the threshold itself is a measure of optical qualities and the subjective response to them and not a direct measure of safety.

Finally, certain comments are essential on the operational use of these targets and the notion of a safe level of conspicuity. First, even though all of the bicycle treatments, including the Base Bike, performed at or above the hypothetical criterion discussed above, significant doubt must still exist concerning the efficacy of the basic reflectors as required by CPSC and used on all bicycles in this study. The most complete accident investigation of bicycle/motor-vehicle accidents in the literature (Cross and Fisher, 1977) indicates that most bicycles struck at night had their required rear reflectors in place. Hence, something in the driver/bicyclist system is likely negating the inherent conspicuity of these reflectors as measured in this experiment. Driver intoxication, particularly at night, is certainly a major factor in nullifying the standard reflectors but other influences, such as the possible confusing meaning of the single, bright, red rear reflector, must also be considered. Overall, it is the consensus of bicycle safety experts that bicycles do not belong on the roadway at night. However, if they must venture onto darkened highways, it is essential that they be equipped with a well designed lighting system in addition to the prescribed reflectors.

Likewise, it would clearly be best if pedestrians avoided unnecessary trips during darkness. However, the need for mobility, particularly among teenagers who are too young to hold a drivers license, often prompts nighttime travel as a pedestrian or bicyclist. In addition, motorists often become pedestrians in relatively dangerous highway situations when their vehicles break down or an accident occurs. Therefore, it is important to interpret the findings of this study to provide operational guidelines for those cases in which a person <u>must</u> be exposed at night as a pedestrian or bicyclist.

It must also be noted that active sources, in spite of their measured superiority, are not free of operational problems. Their power sources are relatively short-lived and can add extra weight to a pedestrian or bicyclist. Therefore, in designing a conspicuity-enhancing countermeasure employing active sources, consideration must be given to the target value of the design without power or under low battery conditions. Hence, for example, the Leg Lamp treatment is overall considered better than the Flashlight because it reverts to an "acceptable" Base Bike when the batteries fail while a Base Ped with a dead flashlight is well below the defined level of acceptable conspicuity. In general, it is strongly recommended that the design of any active conspicuity-enhancement also include a retroreflective "standby" treatment to take over if the power source gives out. Automobile tail lamp assemblies employ this principle as do the required rear bicycle lamps in Switzerland. Similarly, by including fluorescent pigments with retroreflective treatments, daytime conspicuity, which was not specifically tested in this study, may be simultaneously enhanced.

It is also important to remember that active sources contain an inherent status signal which passive treatments do not. When batteries run low or cease to operate, the pedestrian or bicyclist gets an immediate indication that the system is not functioning normally. When passive materials degrade through factors such as wear or the accumulation of dirt, the user has no ready indication that protection has diminished or ceased. In fact, an otherwise perfect retroreflective treatment can be effectively degraded through headlight misalignment or failures, dirt on the windshield or other problems at the light source.

The Dangle Tags and Jogging Vest showed some promise with the latter approaching criterion performance. In fact, it is probable that the addition of retroreflectors to the jogger's shoes would improve the Jogging Vest treatment to above the acceptable level. Placement of the additional retroreflectors low on the body might improve detection distance and almost certainly would enhance recognition. The use of a universal jogger symbol on the vest might also aid recognition if coupled with sufficient education or experience to insure that drivers knew its meaning. The two parallel retroreflective horizontal stripes used in this study may be approaching the level of a signature for joggers as they are widely used on commercially available vests for runners.

The Dangle Tags did not yield acceptable performance largely because they did not promote recognition. While they more than doubled detection distance over the Base Ped (532.22 feet versus 223.83 feet), they did not significantly increase recognition. This is not surprising since their observed white twinkling signal did not immediately suggest the presence of a human and often appeared like the background illumination. More research would be needed to ascertain whether the target signature of the Dangle Tags would be readily learned (as it may have been in Scandinavia) or if the treatment itself could be redesigned to improve recognition. However, the extension of detection range to well over 500 feet cannot be ignored, particularly since two pendant reflectors of the type used for the Dangle Tags treatment can be purchased for two dollars or less. It certainly seems reasonable to use pendant reflectors routinely as zipper pulls on jackets and to encourage manufacturers to incorporate them in the design of outer garments. They would also likely be a reasonable, low-cost backup to an active treatment such as the Flashlight.

In summation, all of the movable pedestrian treatments improved performance over the Base Ped, and each should provide some additional conspicuity. All were clearly better than a white shirt. However, only the Rings and Flashlight treatments improved conspicuity enough to exceed the defined criterion of acceptability. It would seem wise for any pedestrian needing to walk on the roadway at night to combine a flashlight and an anthropomorphic-shaped set of retroreflective materials, such as the Rings treatment, in order to achieve a reasonable degree of safety.

There was little difference among the bicycle targets with the exception of the Leg Lamp which was clearly superior. The combination of an active light source such as the Leg Lamp and the CPSC-mandated reflectors would appear to be a minimum requirement for rearward conspicuity in night bicycle riding. However, the dynamics of a bicyclist sharing a nighttime road with motor vehicles and the need to provide 360 degree illumination still suggest that night bicycling should be avoided if at all possible.

The study results and foregoing considerations lead to the derivation of several recommendations for specific, frequently encountered use situations. It should be noted that none of these recommendations cover pedestrians walking with traffic, which is almost always illegal in all states, or bicyclists riding facing traffic, which also is universally prohibited. Even though these situations are frequently associated with accidents, there is no justification for tacitly condoning them by suggesting conspicuity-enhancing countermeasures for use while walking with traffic or bicycling against it.

Specific recommendations for use are:

- White clothing should not be used as a conspicuity enhancer. If a pedestrian or bicyclist is unexpectedly caught on the roadway during darkness, deploying white, e.g., by removing a dark jacket to reveal a white shirt, would likely be beneficial. However, the preponderance of evidence suggests that white alone is not sufficient to promote an acceptable level of safety. Safety campaigns should certainly <u>not</u> promote the use of white clothing as a countermeasure but, rather, should concentrate on retroreflective and active treatments for nighttime use and fluorescent materials for daytime applications.

- Motorists should carry a flashlight or other active light source in their vehicles in case of a breakdown or accident. The flashlight would also be helpful in performing repairs at night. In addition, some retroreflective treatment should also be carried. Based on the findings of Ulmer, Leaf and Blomberg (1982), care should be exercised to insure that this treatment returns a strong signal from the side of a kneeling or standing pedestrian, an aspect often presented by a motorist changing a tire.

- Pedestrians who must undertake a purposeful nighttime trip should carry a flashlight or other light source and wear anthropometric shaped retroreflective materials like the Rings treatment.

- If someone must bicycle at night, an active source, such as the Leg Lamp, supplemented by at least the standard CPSC reflectors should be used. In addition, consideration should be given by those who ride regularly at night such as bicycle commuters to purchasing one of the available high intensity bicycle lighting systems. The belt beacon type of flashing light, tested herein as a fixed target, would also appear to be a reasonable choice for both pedestrians and bicyclists.

- Joggers who are willing to risk running at night should wear a vest with two horizontal stripes of bright, retroreflective material in addition to carrying a flashlight or other active light source. This configuration of a vest, as tested in this study, seems to be sufficiently common to have created a target signature as indicated by post-trial subject debriefings. Adding retroreflective trim visible to the front of running shoes or, in fact, any footwear, although not tested in this study, also seems advisable. It places the material low to the ground where headlights can easily strike it and should achieve additional attention-getting value from the normal foot motion.

To the extent that retroreflective materials are used, countermeasures from the point of view of the motorist should be considered. The basic physics of the performance of retroreflectors, together with the range of measured values suggest that the widespread use of halogen or other high-intensity headlamp systems would be desirable. In addition to providing better illumination on targets without enhancement, they should also improve the performance of treatments such as those tested in this study. Likewise, any efforts to get motorists to keep their windshields and headlights clean would also have obvious advantages if the widespread use of retroreflective material is achieved. The increased use of high beams should also be examined to determine if its safety benefits outweigh the possible additional glare to oncoming motorists.

There likely is no absolute countermeasure for nighttime crashes. The intoxicated driver or one who falls asleep at the wheel or is totally distracted from a visual search of the roadway will be difficult to combat through the types of approaches examined in this study. Nevertheless, if people must venture out in darkness, the use of conspicuity-enhancing materials in accordance with the principles enumerated herein will almost certainly have a safety benefit and represents a reasonable approach both for individuals to employ and for governmental agencies to promote.

Additional research is suggested both by the results of this study and because interesting issues arose which could not be covered with the resources available for the present effort. Specific recommendations include:

- An examination of daytime conspicuity enhancement, particularly for bicyclists, utilizing a paradigm similar to the one used in the present study.

- Research on ways to improve the conspicuity of obstructed objects through the use of enhancements such as bicycle flags.

- A thorough examination of the concept of a target signature for pedestrians and bicyclists. This work should include consideration of training the motoring public to understand a signature versus creating a unique and inherently recognizable target.

- Research on the performance degradation or enhancement of targets such as those used in this experiment under varying conditions of driver fatigue, alcohol intoxication and age and windshield defects (dirt, scratches, etc.) and headlamp illumination (high versus low beams, halogens versus conventional headlamps).

- Public acceptability of conspicuity countermeasures and the best educational approach to promote their use.

- A field study of the safety benefits of conspicuity enhancement. This would involve the longitudinal tracking of accidents in a defined population, e.g., city or county, large company, and the mandatory use of a conspicuity countermeasure.

Any of these or similar research ideas should be able to build upon the results of the present study to improve knowledge of the ways in which the conspicuity of pedestrians and bicyclists can be altered to reduce accidents.

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APPENDIX A.

Acquisition of Photometric Data

ACQUISITION OF PHOTOMETRIC DATA

Measurement of target luminance and background illumination conditions was deemed desirable due to the variety of treatments employed (e.g., active and passive materials) and apparent range of background illumination at target locations (i.e., virtually dark to varying degrees of illumination provided by buildings and street lights). All measurements were taken on a Pritchard Spectra Photometer by Dr. Merrill J. Allen, Professor, Indiana University School of Optometry.

1. Measurement of Ambient Illumination at Target Locations

Measurements of ambient illumination at each target location were made using a tripod with the sensor set at the hypothetical driver eye height of 44 inches. A standard target consisting of a person wearing a new, white tee shirt was placed at each target location. The Pritchard sensor was set back 16 paces or 48 feet away from each target location oriented in the direction of travel to be followed by subjects navigating the driving course. The acceptance angle configured for the Pritchard was one degree corresponding to a field of view which was less than the width of the tee shirt on the pedestrian model at 48 feet. The Pritchard and automobile power supply (headlights extinguished during measurements) did not significantly affect the ambient illumination falling on the tee shirt which in fact integrated the light from all sources falling on the front of the pedestrian model. There was virtually no illumination from the moonless sky and stars. The higher levels of illumination recorded were thus from building illumination, street and yard lighting. All measurements were taken after all apparent light had faded from the sunset (approximately 1 hour after sunset). The results of these target background illumination measurements are presented in Table A-1. Also presented are verbal descriptions of the background lighting conditions as noted by the authors, as well as a description of the roadway. The roadway was judged to have an effect on experimental results due to color contrast with the target, relative degree of improvement as it affects the driving (tracking task) and condition of the surface. Surface condition, smooth or rough with bumps or potholes, presents the possibility of premature revelation of retroreflective targets due to momentary displacement of the headlight beam pattern. In all cases, the approaches to the movable target locations did not have any appreciable rises or depressions that would have significantly altered the orientation of the projected headlight beam axis.

2. Measurement of Target Luminance

Target luminance was measured in foot-candles returned to the Pritchard. As the Pritchard is not a foot-candle meter as normally used, measurements were taken of all light being returned through a 2° aperture with the Pritchard located at 60 paces or 180 feet. A 2° aperture covered approximately a 6.28-foot diameter circle at 180 feet. The Pritchard was located at the driver eye height of 44 inches and midway between the headlights of one of the experimental vehicles. The headlights were new, sealed beams recently aligned, and the engine was left running at idle. Each target was displayed in front of a black corduroy curtain eight feet wide by ten feet tall which did not

Table A-1. Target Location Background Illumination Measurements and Descriptions

Target Location*	Pritchard Reading in Foot-candles	Lighting Description	Approaching Roadway Surface
Fixed Strobe	0.0234	Diffuse light, low level, open, no point sources	Smooth blacktop
Movable #1	0.003262	Basically dark, buildings on right side, open on left	Textured, patched blacktop
Fixed Barricade Light	0.02676	Dark with parked trailer and red reflectors to left	Partial blacktop and unpaved with ruts and craters
Movable #2	0.002007	Numerous, distant bright point sources of light, open	Unpaved, rough with potholes
Movable #3	0.002090	Open, yard lights and motor pool to left, no point sources in background	Blacktop with patches and irregularities
Fixed Ped with Hot Dots	0.005016	Basically dark, rural, no buildings or point sources of light	Basically smooth blacktop
Fixed Bike with Belt Beacon	0.007026	"	"
Movable #4	0.0006021	"	Blacktop with slight washboard effect
Fixed Warning Triangle	0.0003513	"	"
Fixed Dark Ped	0.0003262	"	Basically smooth blacktop
Fixed Bike with Arrow	0.0002677	"	Basically smooth blacktop with large bump about 600' from target
Movable #5	0.0004266	Reflectorized stop sign and background of distant streetlights and lighted buildings	Basically smooth blacktop
Fixed Cones	0.01472	Buildings with lights and periodic high overhead street lights	"
Fixed Warning Triangle	0.2509	Same as above with parked pick-up truck and reflectors	"
Movable #6	0.03680	Backdrop of buildings with strong window lights	"
Movable #7	0.004600	Dark background with reflectorized stop sign, yard lights to left of target	"
Movable #8	0.001422	Basically dark, rural quality	"
Movable #9	0.03178	Dark background with bright yard lights to left casting bright band of light on road about 300' from target	Basically smooth blacktop with large bump about 1000' from target

Note: Measurements were taken at approximately 48 feet, with a 1^{o} aperture. A calibration of x 0.0102 = Foot Lamberts and a tee shirt R = 0.61 were used.

*See Figure 1.

measurably contribute to the meter reading. A small amount of pavement (less than one percent of field) was sampled by the Pritchard. Hence, for some low-output retroreflective treatments some stray light may have been measured.

All experimental treatments were measured with the pedestrians in motion, walking in place, and a bicyclist atop each bicycle on the support stand pedaling at a normal rate. P3-Flashlight was measured with the flashlight held stationary in the forwardmost position of the arm swing arc.

The results of target luminance measurement are shown in Table A-2.

Table A-2. Target Luminance Measurements

Target	Luminance in Foot Candles
P1 - Baseline Pedestrian	1.32
P2 - Dangle Tags*	1.25
P3 - Flashlight	32.0
P4 - Jogger's Vest	3.8
P5 - Rings	5.4
B1 - Baseline Bicyclist	1.9
B2 - Crank and Spokes*	2.2
B3 - Leg Lamp	3.7
B4 - Fannybumper and Anklebands	6.3
F1 - Strobe*	(unmeasurable)
F2 - Barricade Light*	(unmeasurable)
F3 - Ped with Hot Dots	1.2
F4 - Bike with Belt Beacon*	50.0 (estimated)
F5 - Warning Triangle	5.0
F6 - Dark Ped	1.0
F7 - Bike with Arrow	4.4
F8 - Cones	10.0

*These were targets of fluctuating intensity, making accurate measurements difficult.

APPENDIX B.

Nu-Metrics Procedures

NU-METRICS PROCEDURES

Calibration

Frequency: At start of experiment and check each night.

Steps:

- o Make sure "7 Feet" light is on. If not, press MODE and number 2 then, MODE and number 7
- o Line up on start mark
- o Press MODE and 1
- o Press DIST RESET
- o Enter 1000 (unless already displayed)
- o Drive to end mark DO NOT OVERSHOOT
- o Press MODE and 1 to display calibration number. Write number on unit
- o Press MODE 2 <u>before</u> <u>moving</u> to store calibration

Data Recording (MODE 3)

<u>Normal Targets</u> (11, 22, 33)

- o Enter 11 as quickly as possible when subject says he sees something (detection)
- o Enter 22 as quickly as possible when subject correctly recognizes target
- o Enter 33 at target
- o Call out occurrence number shown in display (e.g., "6")

<u>Coincident Recognition and Detection</u> (22, 11, 33)

- o Enter 22
- o Enter 11 as soon after 22 as possible
- o Enter 33 at target
- o Call out occurrence number in display

No Recognition (11, 33, 22)

- Enter 11 at detection
- Enter 33 at target
- Enter 22 as soon as possible

Missed Target (33, 11, 22)

- Enter 33 at target
- As quickly as possible after target enter 11, 22
- Call out occurrence number in display

Incorrect or Multiple Recognitions

- Enter 22 at first recognition. If correction is made, enter 88 for each correction
- Note occurrence number of target (not 88 entry) and mark on tape at dump
- Call out "(occurrence #) change in ID"

Phantom Target

- Record as normal target
- Note occurrence number preceded by word "number"(e.g.,"number 6")

End of Run/Dump

- Press MODE 4
- Attach printer (POWER OFF)
- Hold down PAPER ADVANCE button and press POWER ON. Unit will print test
- Release PAPER ADVANCE and press again to advance paper. Release button
- Press 00 on K-5000 -- data will dump
- When finished, disconnect printer, CHECK DUMP, repeat if necessary

Clearing

- Press MODE 3
- Hold LAST EVENT CLEAR until steady beep is heard

APPENDIX C.

Project Description and Statement of Informed Consent

DUNLAP AND ASSOCIATES EAST, INC.

17 WASHINGTON STREET, NORWALK, CONNECTICUT 06854 (203) 866-8464

CONSPICUITY RESEARCH

Project Description and Statement of Informed Consent

The nature of this project and any possible hazards have been described to me, as summarized herein. I understand this project to consist of an experiment in automobile driving and visual perception. I will either be required to drive a specially instrumented, conventional-type of automobile at night using low-beam headlights or during the day as a "subject" and/or to walk in place or pedal a bicycle on a stand by the side of the road as an "experimenter." The driving will take place at Atterbury Research Forces Training Area, Edinburgh, Indiana, with limited other vehicular traffic. As a "subject" I will be reporting on objects seen during the course of travel. As an "experimenter" I will actually serve as one of those objects. The driving trials will be carried out during sessions of several hours, with my participation being required for one trial as a driver and/or several trials walking in place or pedaling a bicycle at the roadside. The extent of my participation has been made clear to me.

I will be paid $50.00 for each session completed. My selection as a paid participant will be contingent upon tests of my vision made with standard and safe measuring procedures and equipment and upon my pledge that I have not ingested alcohol or other impairing substances prior to the session.

Barring unforeseen circumstances, I will be present during the scheduled session times and will participate according to the pre-arranged timetable involving me and other participating paid volunteers. I understand that all participant must be present in order to conduct each experimental session. If any participants fails to appear, the session will probably be cancelled without payment, and a new date will be set for the paid session. I will provide as much advance notice as possible if I expect to be unable to attend a scheduled session, so that all others involved can be notified or a replacement found.

I have a currently valid vehicle operator's license from the state of

______________________________.

I have volunteered for this project of my own free will, aware of any hazards, rewards and recognition involved. I understand that I am free to terminate my participation at any time and for any reason by providing fair notice to Mr. Richard D. Blomberg or Mr. Allen Hale of Dunlap and Associates East, Inc.

I understand that this experiment is not associated with Indiana University and that I am acting as an independent contractor with respect to taxes and insurance. I also agree to sign a "Use Permit and Release from Liability/Waiver of Claims Against the United States/State of Indiana" which is required by the Atterbury Reserve Forces Training Area and will be presented to me by Dunlap and Associates East, Inc.

In consideration of the foregoing, I hereby waive any and all claims, actions, or demands that may arise in favor of myself, or my heirs, successors, executors, administrators, or assigns, against Dunlap and Associates East, Inc., or any officer, director, agent or employee thereof, out of damage to persons or property, or the death of any person in any manner caused or contributed to by me while participating in the Conspicuity Research Project described above.

This release shall be binding upon my heirs, executors, administrators, or assigns.

Signature: ______________________ Date: ____________

Witness: ______________________

(Please Print)

My Name: ______________________ Date of Birth: ________

Address: ______________________

____

Telephone No: ______________________

Person to be Notified in Emergency: ______________________

Address: ______________________

____

Telephone No.: ______________________

APPENDIX D.

Camp Atterbury Use Permit and Release Form

ATTERBURY RESERVE FORCES TRAINING AREA
EDINBURG, INDIANA

DATE ______________

USE PERMIT AND RELEASE FROM LIABILITY/WAIVER OF
CLAIMS AGAINST THE UNITED STATES, STATE OF INDIANA

NAME ______________________ ______________________ AGE ______

STREET ____ RFD ______

CITY ____ Tel No ______

*I, being a United States citizen, request permission to use the facilities at ARFTA, Edinburg, Indiana, during the following period:____________________. I AGREE TO OBEY all post regulations, special hunting rules, instructions and notices.

IN CONSIDERATION OF BEING GRANTED PERMISSION TO use the facilities on military property, I HEREBY WAIVE any and all claims, actions, or demands, that may arise in favor of myself, or my heirs, successors, executors, administrators, or assigns, against the United States Government and/or the State of Indiana or any department or agency thereof, or any agent or by any one or more of such employees; I FURTHER AGREE TO INDEMNIFY AND DEFEND THE UNITED STATES GOVERNMENT and/or the State of Indiana and its agents from any and all claims arising out of damage to persons or property, or the death of any person in any manner caused or contributed to be me while in or about the military reservation.

This release shall be binding upon the heirs, executors, administrators or assigns of applicant.

______________________ ______________________
WITNESS Signature of Applicant

____
(Parent or Guardian - Minors)

*Cross out that portion which does not apply. Responsible parent or guardian must countersign release for persons not of age, in the presence of the official issuing this permit. Children who have not attained their sixteenth birthday must be accompaned at all times by a properly licensed and qualified adult.

APPENDIX E.

Background and Instructions for Subjects

BACKGROUND AND INSTRUCTIONS FOR SUBJECTS

BACKGROUND

You will be a subject in a field experiment to determine the visibility of various objects on the highway at night. The research is being sponsored by the U.S. Department of Transportation. In particular, you will be asked to drive an automobile around a predetermined course on the roadways of Cam Atterbury. These are two-lane, two way blacktop roads with the usual traffic control devices (i.e., stop signs, speed limit signs). The course is between eight and nine miles in length and takes approximately one-half hour to drive at a speed of 25-30 mph. You will be driving the course with a passenger in the front seat who will be the Experimenter (E). E will be in charge of each trip around the course. E will perform the following activities:

- Provide directions on how to steer around the course.
- Operate various distance measurement and audio recording equipment.
- Operate a CB unit from time to time.
- Exercise supervisory control of the vehicle while it is on the experimental course to include issuing instructions for maneuvering the vehicle and stopping and starting the vehicle at any time on the course.

While waiting for your turn to drive the course we ask that you treat the government facilities provided for your comfort with respect. Please be as neat as possible. While waiting to be a subject you are free to study, play cards, converse, etc. Please refrain from noisy or boisterous activities. Also, please don't adjust the lights beyond the settings intended to facilitz the dark adaptation of your eyes later. Of great importance to our study that you not reveal any aspects of what you see or do during your experimental run to anyone who is yet to serve as a subject. It is very important that subjects not be informed on specific experimental conditions before encountering them.

When the time comes, two of you at a time will go to the start point of the course--a short distance down the road to the left. At the start point you will report in to the parked school bus wherein you will have approximately 20 minutes to adapt to the ambient lighting conditions.

Prior to your starting your experimental run your car will have its windshield and headlamps cleaned. We also ask that any subjects wearing spectacles be sure to clean them before driving the course. When indicated by E, you will take the driver's seat in the assigned vehicle, fasten your seat belt and await final instructions and the start signal.

SPECIFIC INSTRUCTIONS

Your overall task while driving the course will be that of a "narrative driver." On a continuous basis we want you to loudly and clearly verbalize your thoughts about what you're seeing when you're seeing it. E will have a tape recorder running to record your narrative comments and occasional comments of his own. In addition E will be operating distance measuring equipment in response to your narrative comments.

Basically we want you to tell us as soon as you first see and recognize certain roadside traffic objects of interest to this study. The roadside objects of interest are temporary or potentially/actually moving roadside objects such as bicyclists, pedestrians, parked or standing vehicles, hazard indicators, etc. which may require extra caution in approaching and passing them. We are not interested in routine traffic objects which are part of the normal fixed roadway setting such as stop signs, speed limit signs, street lamps, etc, although we want you to mention them when you see them. Whenever and as soon as you think you have detected an object of interest to this study we want you to clearly say "YES" to minimize communication time. When you recognize/identify what you see, say the word or phrase for whatever it is you see, i.e., "FLARE," BICYCLIST," "PEDESTRIAN" and "JOGGER." Use whatever word or words best describe what you're looking at as soon as you think you know. Please continue to do so until you're absolutely certain what the object is. Should you detect and immediately recognize something you need only announce the object name. You also can change you mind on an initial detection or recognition. We only ask that you let us know as soon as you may have changed your mind.

In making your detections and recognitions we don't want you to wait until you're absolutely sure you see or recognize something before you make an announcement. Instead we want you to be <u>reasonably sure</u> of your detections and recognitions as you would be on the open road to continue paying attention to what you see in order to assure a safe passing of the object. In any event, keep talking to tell us your thought processes.

In summary, whenever you detect a roadside object of possible interest and don't know what it is say "YES" loudly and clearly. Whenever you think you know what you're looking at (even if you're not absolutely sure), announce the name of the object loudly and clearly. You may change any initial detections and recognitions whenever you wish until you're absolutely sure of what you're looking at. Please talk about any aspect of any object that you're seeing at any time. Your perception of various aspects of the roadside objects are important to our study of highway visibility. Such estimates by you of whether objects appear to be fixed or moving, coming toward you or going away, close to you or far away, in or near your pathway are of interest to us as well as whatever else you may think interesting in your narrative.

While there will be virtually no outside traffic on the course during experimental runs, all due normal caution is required to drive the course safely. Rest assured that no unusually hazardous traffic situation has been intentionally created by the conditions created for this experiment on the driving course. However, in the more remote and dark areas of the course, deer and cattle have been known to cross or loiter in the roadway at night.

Thank you!

APPENDIX F.

Nu-Metrics Procedures

NU-METRICS PROCEDURES

Calibration

Frequency: At start of experiment and check each night.

Steps:

- Make sure "7 Feet" light is on. If not, press MODE and number 2 then,
  MODE and number 7
- Line up on start mark
- Press MODE and 1
- Press DIST RESET
- Enter 1000 (unless already displayed)
- Drive to end mark DO NOT OVERSHOOT
- Press MODE and 1 to display calibration number. Write number on unit
- Press MODE 2 <u>before</u> <u>moving</u> to store calibration

Data Recording (MODE 3)

<u>Normal Targets</u> (11, 22, 33)

- Enter 11 as quickly as possible when subject says he sees something (detection)
- Enter 22 as quickly as possible when subject correctly recognizes target
- Enter 33 at target
- Call out occurrence number shown in display (e.g., "6")

<u>Coincident Recognition and Detection</u> (22, 11, 33)

- Enter 22
- Enter 11 as soon after 22 as possible
- Enter 33 at target
- Call out occurrence number in display

No Recognition (11, 33, 22)

- Enter 11 at detection
- Enter 33 at target
- Enter 22 as soon as possible

Missed Target (33, 11, 22)

- Enter 33 at target
- As quickly as possible after target enter 11, 22
- Call out occurrence number in display

Incorrect or Multiple Recognitions

- Enter 22 at first recognition. If correction is made, enter 88 for each correction
- Note occurrence number of target (not 88 entry) and mark on tape at dump
- Call out "(occurrence #) change in ID"

Phantom Target

- Record as normal target
- Note occurrence number preceded by word "number"(e.g.,"number 6")

End of Run/Dump

- Press MODE 4
- Attach printer (POWER OFF)
- Hold down PAPER ADVANCE button and press POWER ON. Unit will print test
- Release PAPER ADVANCE and press again to advance paper. Release button
- Press 00 on K-5000 -- data will dump
- When finished, disconnect printer, CHECK DUMP, repeat if necessary

Clearing

- Press MODE 3
- Hold LAST EVENT CLEAR until steady beep is heard

APPENDIX G.

Trial Start Checklist

TRIAL START CHECKLIST

Trial # ________ Subject Name ________________________

Experimenter ________________ Subject Sex ________________________

Subject Weight ________________________

Car # ________________________

Windshield Clean _____

Headlights Clean ______

Clear DMD ______

Push DIST RESET ______

Verify 0 Reading ______

Verify Calibration # ______

Select MODE 3 ______

Seat Belts on ______

CB radio check with bus or truck ______

New cassette in, label, start, slate ______

Slate START TIME __________________

APPENDIX H.

Subject Pre-Launch Briefing

SUBJECT PRE-LAUNCH BRIEFING

- I will tell you when and where to turn throughout the course. I will give you advance notice and landmarks where possible.
- If I say STOP and pull over at any time, please do so as quickly as possible.
- Please observe all traffic control devices and maintain your speed between 25 and 30 mph where appropriate unless you feel unsafe at that speed.
- Please watch for cows and other animals which are hard to see and do what is necessary to avoid them.
- Keep telling me what you are seeing, i.e., "white light."
- Whenever you think you see a roadside object of interest as described in the briefing, say "YES" loudly and clearly.
- Whenever you think you can identify what you're looking at, say the name of the object loudly and clearly.
- Continue to verbalize your thoughts about any object of interest as we approach it until it is totally visible.
- Please do not respond to anything said over the CB, my notes verbalized to the tape recorder or any sounds made by the instrumentation, which will "beep" from time to time.

APPENDIX I.

Trial End Checklist

TRIAL END CHECKLIST

Slate END TIME ____________

Stop cassette ________

Select MODE 4 ________

Plug in printer ________

Dump data ________

Label and check dump ________

File data ________

Clean windshield ________

Clean headlights ________

Dismiss subject ________

Need to screen tape ________

APPENDIX J.

Conspicuity Experiment Subject Debriefing Form

and Analysis of Subject Responses

CONSPICUITY EXPERIMENT SUBJECT DEBRIEFING FORM AND ANALYSIS OF SUBJECT RESPONSES

Figure J-1 shows the Subject Debriefing Form which was completed by every subject immediately after having driven the experimental course. The results of all 36 respondents are presented and analyzed below for each question.

1. Was there anything about the way the experiment was organized or conducted that may have made your responses better or worse than you would have given in a regular driving situation?

   No_____ Yes_____(Explain, please.)

   29 (81%) indicated "Yes"
   7 (18%) indicated "No"

   The "Yes" responses were further analyzed to reveal the ways in which subjects thought test performance differed from actual on-the-road performance. The amplified response categories were as follows:

   o 18 (62%) indicated that they were more actively looking for roadside objects than they would have been normally.

   o 6 (21%) said they would have used high beams if they had not been required to use low beams.

   o 5 (17%) offered a variety of contributions to other than a normal driving situation, such as the lack of opposing traffic and the requirement for a running commentary.

2. Please list the visual characteristics that helped you to recognize objects as pedestrians. Then place a number next to each item to rank order its importance (i.e., 1, 2, 3, etc.).

   All responses, irrespective of rank order, were analyzed and categorized in the following manner:

   o 43 (40%) mentioned highlighting or capitalizing on natural object motion.

   o 18 (17%) indicated highlighting object shape as important.

   o 15 (14%) mentioned flashing or bright lights as important.

   o 15 (14%) indicated bright reflectors as a determining feature.

   o 17 (15%) grouped into a miscellaneous category.

   For those responses associated with "No. 1" ranking, 16 (39%) mentioned "natural object motion," 9 (21%) "object shape," 8 (20%) "bright reflectors," 4 (10%) "flashing or bright lights," and 4 (10%) miscellaneous.

Figure J-1. Subject Debriefing Form

CONSPICUITY EXPERIMENT SUBJECT DEBRIEFING FORM

NAME________________________________ DATE__________________ TIME___________

1. Was there anything about the way the experiment was organized or conducted that may have made your responses better or worse than you would have given in a regular driving situation?

   No____ Yes____ (Explain, please)

2. Please list the visual characteristics that helped you to recognize objects as pedestrians. Then place a number next to each item to <u>rank order</u> its importance (i.e., 1,2,3, etc.).

   ____

   ____

   ____

   ____

   ____

3. Please list the visual characteristics that helped you to see and recognize objects as bicyclists. Then place a number next to each item to <u>rank order</u> its importance (i.e., 1,2,3, etc.).

   ____

   ____

   ____

   ____

   ____

Figure J-1. Subject Debriefing Form (continued)

4. Please list the 5 most conspicuous objects, not just pedestrians or bicyclists, you saw on the course tonight in <u>descending rank order</u> (i.e., 1 is the most conspicuous and 5 is the least).

1.____________________ 2.____________________

3.____________________ 4.____________________

5.____________________

5. In driving toward and safely passing such temporary roadside objects as pedestrians and bicyclists, please indicate the value of seeing the following light signal features as soon as possible (please check one column for each item).

	NO VALUE	2	3	4	GREAT VALUE
Bright and steady					
linking or flickering					
One that reveals natural object motion					
One that reveals the shape of the object					
One which creates a unique symbol for the object					
One which reveals how far away the object is					
One which reveals the direction of object orientation or movement					
One of a unique color					

6. Please indicate any other comments you might have on anything about the exoeriment or the targets. THANK YOU!

3. Please list the visual characteristics that helped you to see and recognize objects as bicyclists. Then place a number next to each item to rank order its importance (i.e., 1, 2, 3, etc.).

All responses, irrespective of rank order, were analyzed and categorized in the following manner:

- 37 (39%) indicated that pedal reflectors (a motion component) were important.
- 18 (19%) indicated that the red rear reflector was important.
- 17 (18%) indicated miscellaneous items (e.g., white clothing, unique arrangement of reflectors) as important.
- 8 (8%) indicated that reflectors-no further specification were important.
- 5 (5%) indicated that motion-no further specification was important.
- 5 (5%) indicated that the shape of the person/bicycle was important.
- 4 (4%) indicated that the light (leg lamp) was important.
- 3 (3%) indicated that the fanny bumper was important.

For those responses associated with "No. 1" rankings, 28 (78%) mentioned "pedal reflectors," 3 (8%) "red rear reflector," 3 (8%) "reflectors-n.f.s.," and 2 (6%) "the light (leg lamp)."

4. Please list the 5 most conspicuous objects, not just pedestrians or bicyclists, you saw on the course tonight in descending rank order (i.e., 1 is the most conspicuous and 5 is the least).

All responses, irrespective of ranking, were distributed in the following manner:

	n	%
Warning Triangle	30	17
Miscellaneous	14	8
Rings	12	7
Flashing Lights	12	7
Pedal Reflectors	11	7
Bicyclist/Bicycle	11	7
Barricade Light	11	7
Cones	10	6
Jogger's Vest	10	6
Strobe	6	4
White Shirt	6	4
Flashlight	5	3
Stop Sign	5	3
Street Lights	4	2
Reflectors-n.f.s.	4	2

	n	%
Fanny Bumper	3	2
Moving Reflectors	3	2
AAA Arrow	3	2
Red Rear Bicycle Reflector	2	1
Dangle Tags	2	1
Lighted Buildings	2	1
	n = 166	100%

For those responses associated with the "No. 1" rankings, 11 (31%) mentioned the "warning triangle," 5 (14%) "barricade light," 5 (14%) "flashing lights," 4 (11%) "rings," 2 (6%) "bicyclist/bicycle," 2 (6%) "street lights," 2 (6%) "stop sign," 1 (3%) "pedal reflectors," 1 (3%) "jogger's vest," 1 (3%) "strobe,", and 1 (3%) "lighted buildings."

From all responses which could be categorized as "passive" or "active" treatments, 111 (73%) responses were passive treatments and 42 (27%) were active treatments.

5. In driving toward and safely passing such temporary roadside objects as pedestrians and bicyclists, please indicate the value of seeing the following light signal features as soon as possible (please check one column for each item). The mean values assigned to these categories using the scale shown were:

(Assigned #1)				(Assigned #5)
NO VALUE	2	3	4	GREAT VALUE

	Mean Ranking	(Rank Order)
One that reveals natural object motion	4.57	(2)
One that reveals the shape of the object	3.80	(4)
One which creates a unique symbol for the object	4.09	(3)
Blinking or flickering	3.60	(1)
One which reveals how far away the object is	3.59	(5)
One which reveals the direction of object orientation or movement	3.57	(6)
Bright and steady	3.31	(7)
One of a unique color	2.97	(8)

6. Please indicate any other comments you might have on anything about the experiment or the targets. THANK YOU!

Close paraphrasings and quotations of all comments offered for this item appear below:

- Realistic presentation of targets.
- "Experiment smoothly run."
- "Items should be bright, moving, flickering."
- Bicyclists should have had side to side movement.
- "Fun!"
- Pedal reflectors were very noticeable, so were the rings.
- Rings treatment "... got my attention as to something there; it wasn't until a couple of seconds later that I figured out what it was."
- Triangle and barricade light were easiest to see. "The jogger was visible fairly far away but not recognizable as such until we got pretty close."
- "A target having just a single reflector as compared to no reflectors was <u>much</u> easier to see."
- "Reflectors make all the difference in the world."
- "That pedestrian with dark clothes and no reflectors was very hard to see and hazardous! Riding country roads with dimmed lights was also difficult."
- "Seemed to be too many bicycles." "In general the experiment was enjoyable."
- "A universal target reflector <u>color</u> would be good once it caught on. In this study, though, I felt that knowing <u>exactly what</u> the object was was not as important as early detection of that object."
- "It appears that the flashing light was the most visual object on the course."
- "Flashing lights or moving reflective lights caught my attention the quickest. Motion and blinking caught my attention."

APPENDIX K.

Enacted Pedestrian Conspicuity Ordinances

- o Ottawa Hills OH (April 1981)
- o Montclair NJ (May 1981)
- o Charlotte NC (June 1983)

VILLAGE OF OTTAWA HILLS, OHIO

ORDINANCE No.

CONSENTING TO AND APPROVING AMENDMENTS TO CHAPTER 10 OF THE OTTAWA HILLS TRAFFIC CODE, VILLAGE OF OTTAWA HILLS, OHIO, REPEALING CERTAIN SECTION AND DECLARING AN EMERGENCY.

BE IT ORDAINED BY THE COUNCIL OF THE VILLAGE OF OTTAWA HILLS, OHIO, THAT:

SECTION 1. Section 10.02 of Chapter 10 of the Ottawa Hills Traffic Code be, and the same hereby is, amended, so that as so amended the same shall read as follows:

"10.02 PEDESTRIANS ALONG ROADWAY

(a) Any pedestrian walking, running or jogging along and upon a roadway shall walk, run or jog as near as practicable to an outside edge of the roadway, and if on a two-way roadway, shall walk, run or jog only on the left side.

(b) In the case of two or more pedestrians walking, jogging or running along and upon a roadway, the provisions of paragraph (a) above shall apply and each pedestrian shall proceed in single file when vehicular traffic approaches from the opposite direction.

(c) During the time from one-half hour before sunset to one-half hour after sunrise, and at any other times when there are unfavorable atmospheric conditions (including insufficient natural light) which prevent persons from being clearly discernible at a distance of 300 feet; every pedestrian shall either:

1) Wear between neck and waist, material such as a vest, sash band or tape which is reflectorized so as to be clearly discernible at night at a distance of 300 feet, or

2) Vacate the non-crosswalk roadway immediately upon the approach of a vehicle from the front of the pedestrian, and also vacate such roadway at any intersection or driveway where a vehicle is approaching the roadway, in each instance remaining off such roadway until the vehicle has passed the pedestrian."

and the same are consented to and approved.

SECTION 2. Section 10.02 of Chapter 10 of the Ottawa Hills Traffic Code as presently written be, and the same hereby is, repealed and the same is consented to and approved.

SECTION 3. It is hereby found and determined that all formal actions of this Council concerning and relating to the passage of this Ordinance were adopted in an open meeting of this Council, and that all deliberations of this Council and any of its committees that resulted in such formal actions, were in meetings open to the public, in compliance with all legal requirements, including Section 121.22 of the Revised Code of Ohio.

VILLAGE OF OTTAWA HILLS, OHIO

ORDINANCE No. 81-19

-2-

SECTION 4. This Ordinance is hereby declared to be an emergency measure and shall take effect and be in force immediately from and after its passage. The reason for the emergency lies in the fact that this Ordinance is necessary for the immediate preservation of the public peace, health and safety in that said emergency designation is urgently needed for the safety of pedestrians within the Village of Ottawa Hills.

Vote on emergency clause: Yeas 6 Nays 0

Passed as an emergency measure: April 13th, 1981.

President of Council

ATTEST:

Clerk

DENNIS ISABELL [illegible]
County, Ohio, do hereby certify [illegible]
that publication of the foregoing [illegible] 81-19
copies thereof at five of the most [illegible]
as follows: BULLETIN [illegible]
SECOR ROAD [illegible]
SECOR ROAD [illegible]
INDIAN ROAD [illegible]
BANCROFT [illegible]
for a period of fifteen days commencing [illegible] 81

Clerk [illegible]
Village of Ottawa Hills [illegible]

81-25

81-25
PENDING ORDINANCE
AN ORDINANCE REGULATING JOGGING IN THE TOWNSHIP OF MONTCLAIR

The Council of the Township of Montclair in the County of Essex, does ordain the following

Section 1. As used in this Article, the following terms shall have the meanings indicted

Jog or Jogging – The recreational activity of running at any pace for physical exercise or personal enjoyment

Hours of darkness shall mean any time from a half-hour after sunset to a half-hour before sunrise and at any other time when there is not sufficient light to render clearly discernible persons and vehicles on the highway at a distance of five hundred feet ahead.

Section 2. This ordinance shall not be construed to permit jogging where prohibited by any Law of the State of New Jersey

Section 3. It shall be unlawful to jog on any public thoroughfare, road or way which is used by motor vehicles, during the hours of darkness without wearing reflective material. Such material shall be worn between the waist and shoulders on the front and back of the person jogging and shall give an indication of the jogger's presence through reflected light from the headlamp beams of motor vehicles at a distance of at least 500 feet.

Section 4. It shall be unlawful for any 2 or more persons to jog side by side, or abreast of each other, and not in single file, on any public thoroughfare, road or way which is used by motor vehicles.

Section 5. Any person who shall violate any provison of this Article shall, upon the first conviction thereof be punished by a fine not exceeding twenty-five dollars ($25.00) and upon any subsequent conviction by a fine not exceeding two hundred dollars ($200.00).

Section 6. This ordinance shall take effect immediately upon final passage and publication as required by law.

NOTICE

The foregoing ordinance passed first reading April 28, 1981 and was ordered to a second reading to take place May 12, 1981 on which latter date the Township Council will meet in the 2nd floor Conference Room in the Municipal Building, 205 Claremont Avenue, Montclair, New Jersey, at 8:00 P.M. to consider final action thereon. At the time and place so stated all persons interested will be given an opportunity to be heard concerning such ordinance.

CONSTANCE B. ARNOTT
TOWNSHIP CLERK

April 30, 1981 $18.85

ADOPTED MAY 12 1981

ORDINANCE NO. 1365 AMENDING CHAPTER 20

AN ORDINANCE AMENDING CHAPTER 20 OF THE CITY CODE RELATIVE TO RUNNING AND JOGGING ON PUBLIC STREETS OR HIGHWAYS.

BE IT ORDAINED by the City Council of the City of Charlotte that:

Section 1. Chapter 20, Article III, of the City Code is hereby amended by the addition of a new sub-section 20-53 to read as follows:

"Sec. 20-53(a) No person shall run or jog in any public street or highway open to motor vehicle traffic other than in a safety zone, during the time from one-half hour after sunset to one-half hour before sunrise, or at any other time when there is not sufficient natural light to render discernible persons, vehicles, and substantial objects on the street or highway at a distance of five hundred (500) feet ahead, unless such person is wearing reflective clothing or a reflective device. The reflective clothing or reflective device shall be worn on the person and be of sufficient size and reflective capacity to be seen at a distance of not less than five hundred (500) feet to the person's front and rear, when illuminated by two standard automobile headlights operating at the lawful lower beam setting.

"(b) For the purposes of this section, the public street or highway shall not include the sidewalk or a crosswalk.

"(c) A violation of this section shall constitute a misdemeanor punishable by a fine not to exceed $50."

Section 2. This ordinance shall become effective August 1, 1983.

Approved as to form:

Henry W. Underhill Jr.
City Attorney

Read, approved and adopted by the City Council of the City of Charlotte, North Carolina, in regular session convened on the 13th day of June, 1983, the reference having been made in Minute Book 80, and recorded in full in Ordinance Book 32, at Page 71.

Pat Sharkey, City Clerk