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# Traffic Operations Control for Older Drivers

Research and Development
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## FOREWORD

This report will be of interest to traffic engineers and administrators responsible for traffic controls at intersections. There has been some concern that older drivers and pedestrians have a disproportionate number of accidents at intersections. This research was to define the safety problems of older drivers and to recommend solutions for these problems.

The researchers reviewed the literature, analyzed accident data bases to determine the statistics on older driver and pedestrian accidents, held focus groups with older persons to get their views on intersection traffic problems, and developed an extensive table of problem causes and countermeasure treatments for the problems. Three major field studies were conducted to address:

- The comprehension of left-turn signal displays.
- The comprehension of pedestrian signals and the development and testing of an educational plaque.
- The measurement of driver response and stopping behavior related to the yellow traffic signal change interval.

Two copies of this report are being sent to each Region, and six copies are being sent to each Division office. At least four of the copies sent to the Division should be sent to the State highway agency by the Division office.

Lyle Saxton, Director
Office of Safety and Traffic Operations
Research and Development

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16. Abstract

The objectives of this project were to define the problems older drivers and pedestrians have at intersections, and make recommendations for changes. A literature review, a detailed accident analysis, and eight focus groups were conducted to identify the specific kinds of traffic-control-related problems experienced by older drivers and pedestrians at intersections. Three problem areas were targeted.

The Left-Turn Signal Comprehension Study examined the lack of understanding associated with a variety of protected and permitted left-turn signal displays. It was found that many drivers, young and old alike, do not understand the protected/permitted signal phasing. Efforts to improve motorist comprehension of left-turn signal phasing should be targeted at the entire driving population.

Older pedestrians frequently indicated that they don't have enough time to cross the street. This complaint is exaggerated by the lack of understanding of the clearance—Flashing DON'T WALK—phase. The Pedestrian Signal Comprehension Study involved the development and evaluation of a pedestrian signal explanation placard. The wording of the placard was empirically developed. Fieldtesting failed to demonstrate a change in pedestrian comprehension or compliance. However, the placard did produce a small, but significant, increase in pedestrian comprehension level. Recommendations for the wording of the pedestrian signal education placard are made.

The Driver Signal Response and Stopping Behavior Study compared the responses of older and younger drivers to amber onset and the braking ability of older and younger drivers. Testing was done in a controlled fieldtest facility with the subjects driving their own cars. No important differences between older and younger drivers were found. Current standards for amber signal duration and red signal onset do not need to be modified.

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# SI* (MODERN METRIC) CONVERSION FACTORS

## APPROXIMATE CONVERSIONS TO SI UNITS

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | 25.4 | millimeters | mm |
| ft | feet | 0.305 | meters | m |
| yd | yards | 0.914 | meters | m |
| mi | miles | 1.61 | kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 645.2 | square millimeters | $mm^2$ |
| $ft^2$ | square feet | 0.093 | square meters | $m^2$ |
| $yd^2$ | square yards | 0.836 | square meters | $m^2$ |
| ac | acres | 0.405 | hectares | ha |
| $mi^2$ | square miles | 2.59 | square kilometers | $km^2$ |
| | | **VOLUME** | | |
| fl oz | fluid ounces | 29.57 | milliliters | mL |
| gal | gallons | 3.785 | liters | L |
| $ft^3$ | cubic feet | 0.028 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.765 | cubic meters | $m^3$ |
| NOTE: Volumes greater than 1000 l shall be shown in $m^3$. | | | | |
| | | **MASS** | | |
| oz | ounces | 28.35 | grams | g |
| lb | pounds | 0.454 | kilograms | kg |
| T | short tons (2000 lb) | 0.907 | megagrams (or "metric ton") | Mg (or "t") |
| | | **TEMPERATURE (exact)** | | |
| °F | Fahrenheit temperature | 5(F-32)/9 or (F-32)/1.8 | Celcius temperature | °C |
| | | **ILLUMINATION** | | |
| fc | foot-candles | 10.76 | lux | lx |
| fl | foot-Lamberts | 3.426 | candela/$m^2$ | cd/$m^2$ |
| | | **FORCE and PRESSURE or STRESS** | | |
| lbf | poundforce | 4.45 | newtons | N |
| lbf/$in^2$ | poundforce per square inch | 6.89 | kilopascals | kPa |

## APPROXIMATE CONVERSIONS FROM SI UNITS

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| mm | millimeters | 0.039 | inches | in |
| m | meters | 3.28 | feet | ft |
| m | meters | 1.09 | yards | yd |
| km | kilometers | 0.621 | miles | mi |
| | | **AREA** | | |
| $mm^2$ | square millimeters | 0.0016 | square inches | $in^2$ |
| $m^2$ | square meters | 10.764 | square feet | $ft^2$ |
| $m^2$ | square meters | 1.195 | square yards | $yd^2$ |
| ha | hectares | 2.47 | acres | ac |
| $km^2$ | square kilometers | 0.386 | square miles | $mi^2$ |
| | | **VOLUME** | | |
| mL | milliliters | 0.034 | fluid ounces | fl oz |
| L | liters | 0.264 | gallons | gal |
| $m^3$ | cubic meters | 35.71 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.307 | cubic yards | $yd^3$ |
| | | **MASS** | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.202 | pounds | lb |
| Mg (or "t") | megagrams (or "metric ton") | 1.103 | short tons (2000 lb) | T |
| | | **TEMPERATURE (exact)** | | |
| °C | Celcius temperature | 1.8C + 32 | Fahrenheit temperature | °F |
| | | **ILLUMINATION** | | |
| lx | lux | 0.0929 | foot-candles | fc |
| cd/$m^2$ | candela/$m^2$ | 0.2919 | foot-Lamberts | fl |
| | | **FORCE and PRESSURE or STRESS** | | |
| N | newtons | 0.225 | poundforce | lbf |
| kPa | kilopascals | 0.145 | poundforce per square inch | lbf/$in^2$ |

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

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# INTRODUCTION

This report describes the work performed under the contract, Traffic Operations Control for Older Drivers. The objectives and scope of the contract were as follows:

## CONTRACT OBJECTIVES

The objectives of this contract are:

- To define the safety problems of older drivers and pedestrians at intersections.
- To evaluate alternate designs that will accommodate the perceptual, cognitive, and psychomotor capabilities of older drivers and pedestrians.
- To make recommendations regarding changes to current standards.

## SCOPE OF WORK

This research is limited to traffic and pedestrian operations at intersections and includes: a literature search; accident analyses; focus group meetings; and laboratory and controlled field experiments. Urban, suburban, and rural intersections shall be considered. Older drivers and pedestrians are people who are age 65 and older. A group of young to middle-aged drivers shall be included in the empirical research.

Intersection features to be studied include: traffic signal display type; signal placement; supplemental signing; signal phasing; novel displays (e.g., Michigan and Washington permitted left-turn displays); flashing displays; off-peak and on-peak operations; day and night operations; left-turn arrows; intersection geometry (e.g., divided highways, turning lanes, etc.); traffic volumes; and environmental visual complexity. Stop- and yield-controlled intersections are also to be studied. Both driver and pedestrian behavior shall be studied relative to intersection features with the purpose of improving the safety and mobility of older users at intersections without imposing significant traffic delays.

The first project activity was a critical review of a selected number of relevant references to document specific age-related decrements in functioning that may affect the ability of older drivers and pedestrians to function safely at intersections. Others have conducted comprehensive reviews of age-related diminished capabilities, notably Staplin et al., and no attempt was made to replicate their effort.

The second project activity involved conducting a detailed accident analysis to identify any differences in the accident patterns experienced by older and younger drivers and pedestrians.

The third project activity involved conducting a series of focus group sessions with older drivers and pedestrians. The purpose of these sessions was to identify the kinds of traffic-control-related problems experienced by older drivers and pedestrians at intersections.

The first three project activities were conducted to identify specific problem areas that older drivers and pedestrians experience in negotiating intersections. Of the various problem areas identified, three were selected as most relevant to the contract objectives. First, it was obvious that older drivers have difficulty at signalized intersections, especially with left-turn maneuvers. Second, it was apparent that older pedestrians have problems crossing at signalized intersections and that they do not understand the meaning of the pedestrian WALK/DON'T WALK signals. Third, there is some evidence that older drivers have difficulty responding to traffic signals and stopping appropriately. These three specific problem areas led to the development of three laboratory/field study procedures to further investigate the nature and extent of these problems and to identify possible solutions.

The three procedures addressed:

- Left-turn signalization comprehension.
- Pedestrian signal comprehension.
- Driver signal response and stopping behavior.

The Left-Turn Signal Comprehension Study investigated the level of understanding associated with various protected and permitted left-turn signal displays.

The Pedestrian Signal Comprehension Study involved the development and evaluation of a pedestrian signal explanation placard. This placard, intended to be installed at intersections with pedestrian signals, was designed to improve pedestrian understanding of the signal phasing.

The Driver Signal Response and Stopping Behavior Study was designed to measure the responses of drivers to the onset of the amber signal and to quantify the stopping behavior of both older and younger drivers.

The remainder of this report describes each of these project activities. Since this is a project final report, it is, of necessity, limited in length. Additional detail on the activities conducted is available in the various project task working papers.

# 1. LITERATURE REVIEW

## INTRODUCTION

Older persons as drivers or pedestrians appear to have a disproportionate number of crashes at intersections and to be overly involved in certain types of crashes (e.g., rear-end, turning, right-angle). The purpose of this literature review was to identify information that might document age-related decrements in functioning that might affect driver/pedestrian performance at intersections. A comprehensive search was made of journals and reports in appropriate subject areas, and a listing was made of articles with potential relevance to this project. These articles were prioritized and 23 were selected for review. This synopsis highlights several of the most relevant.

Many studies have focused on very specific decrements as they affect older people, such as hand grip strength. As such, they are too specific to provide insight into the functioning of older people as drivers or pedestrians. Moreover, very little research in the area of aging and performance has been directly linked to driving performance. Many research studies suffer from methodological inadequacies, including poor experimental design and sampling biases. Many fail to consider, or were not able to consider, potential cohort effects, including the difficulties encountered by many older persons in testing situations. Perhaps as a consequence of these limitations, many of the conclusions are fragmented and, in some cases, contradictory.

A review of the literature by Staplin et al. described research findings relevant to this study. Our literature review builds on that work. It is noted that many findings pertinent to the driving task also suggest or indicate older pedestrian intersection problems.

### Useful Field of Vision and Cognition

There is a strong interaction between the visual factors and the cognitive performance of older drivers and pedestrians. Owsley et al. described driving-related outcome measures. The importance of the interaction of both visual ability and cognitive functioning is reflected in useful field of vision (UFOV), which is dependent not only on the ability to see, but also on visual information processing—the ability to ignore distractors, and the ability to prioritize divided attention tasks both efficiently and effectively. They found that individuals who failed the UFOV test experienced 4.2 times more crashes than those who passed. The UFOV and Mattis Organic Mental Status Syndrome Examination (MOMSSE) were better predictors of intersection accidents than of overall crashes. Jointly, these two variables predicted 29 percent of the variance in intersection crashes. Those individuals with higher MOMSSE scores had 6.3 times more intersection crashes. Individuals who failed the UFOV had 15.6 times more intersection crashes. This suggests that UFOV and mental status tests evaluate crucial aspects of visual cognitive information processing necessary for handling the complexity of the driving task—particularly those aspects involved in performance on psychomotor tests and reported driving problems.

Apparently, many reported age-related decrements in cognitive performance are associated with deterioration in the frontal lobes of the brain. The frontal lobes affect arousal and attention, visiospatial skills, visual search behavior, memory functions, and complex problem solving. These decrements may be exacerbated by the use of medications. Laux et al. reported that older subjects failed to see another car or failed to see a stop sign or stop light. Staplin et al. identified several illnesses and attendant medications that have the potential to affect functions crucial to the driving task. Specific conditions noted were cardiovascular disease, cerebrovascular disease, diabetes mellitus, senile dementia of the Alzheimer's type, and depression.

### Attention-Related Deficits

Owsley et al. also discussed the quality of processed visual information and emphasized the importance of visual attention, since this early stage of attention is used to "quickly capture and direct one's attention to highly salient events." Attention-related deficits affect scanning and other maneuvers that require rapid reorientation of attention. Decrements in this area may affect the crash involvement of both older pedestrians and older drivers at intersections, since so much of the driving/walking task involves scanning and other maneuvers requiring rapid reorientation of one's attention. Older adults appear to have difficulty refocusing their attention to respond to changing stimuli.

Hancock et al. examined gap acceptance and factors influencing the turn decisions of older drivers. They found that there was a tendency to accept a particular gap size as the oncoming vehicle velocity increased. Collision frequency patterns indicated a greater number of collisions at highest velocities and lowest gaps.

Stamatiadis et al. found that increases in rural intersection crashes accompanied increases in age and attributed this to the likelihood of higher speeds and fewer signalized controls at rural intersections. The results suggest that older people may not be able to adjust their scanning and orientation under high-speed conditions.

### Visual Search

Another important cognitive function involves visual search. Decrements in this ability may result in longer response times for older drivers because it takes more time for them to identify relevant stimuli, which may slow decision-making ability. There is a lack of data on visual clutter and its relation specifically to intersection crashes; although, clearly, visual clutter contributes to visual search and latency in general decision making.

### Divided Attention

Related to visual search is the ability to handle divided attention tasks. The driving and/or walking task requires rapid processing of information, including prioritizing of important information and the elimination of extraneous information. As Staplin notes, "For multitask performance, the most important issue may be the ability to consistently maximize performance on a high priority task regardless of any change in the nature or the difficulty of the overall situation." Decrements in this capacity among older people may lead to their taking more time to make decisions and/or it may also mean that they are overloaded by the information they receive at intersections, particularly those with excessive visual clutter. Thus, higher speeds or short protective phases at turn lanes may overtax the decision-making ability of older people at such intersections.

### Gender-Related Factors

Garber et al. reported that the frequency of left-turn accidents involving the elderly increased over the age of 62, but females had a higher risk of intersection crash involvement at age 50 and above. Grubb used a simulator to study how older people process and react to information at intersections. He found that older subjects experienced an increase in heart rate when there was an increase in visual complexity of the intersection scene. The increased heart rate was an indication of a higher workload and increased decision latency could result. Older women experienced greater increases in heart rate. In addition, he found that women, starting in their forties, made more pedal errors.

Scialfa et al. examined age-related differences in judgment of vehicle velocity and distance. He found that older women tended to overestimate vehicle velocity more than men or younger women; and older men judged stationary vehicles to be further away than younger men or adult women. This tendency may lead men to attempt mergings and road crossings when approaching automobiles are too close.

Grubb also reported that men do not experience increases in heart rates as high as those of women. This should mean that they do not experience the same degree of decision latency as women. Unfortunately, this benefit is seemingly eroded by their diminished ability to judge distances. The authors believed that the males, who were more accustomed to driving and making decisions based on larger vehicles, consequently judged smaller cars to be more distant than they, in fact, were.

### Summary

It is apparent that there are wide variations in the driving and/or walking performance among the older population. Also, many of the visual and/or cognitive functions important to drivers and pedestrians decline as a result of the aging process. It is not surprising that older people are more often involved in crashes at intersections.

What is not readily apparent is which specific intersection characteristics could be changed to benefit the older driver and pedestrian. Sound traffic engineering practices, such as reducing visual clutter and increasing signal conspicuity, should especially benefit older pedestrians and drivers.

# 2. ACCIDENT ANALYSES

## OLDER DRIVERS

### Methodology

The Minnesota State accident files for the years 1985 through 1987 were examined to identify the characteristics of older driver intersection accidents. The findings were verified by examining Illinois State accident files for the same period. For analysis purposes, the accident involvement of three age groups were compared, namely, the "old elderly" group (75 years and older), the "young elderly" group (65 to 74 years), and a middle-aged comparison group (30 to 50 years old).

The accident type and vehicle maneuver prior to crash was examined for urban and rural signalized and stop-controlled intersections. The data showed that the young elderly and, to a greater extent, the old elderly are overrepresented in turning and angle accidents at both signalized and stop-controlled intersections. Further analysis was done on those specific crash types to see if the accidents were a result of the driver's disregard for a traffic signal, lack of attention, failure to stop, failure to yield, or some other factor.

By linking the crashes with the Minnesota Intersection file, it was possible to develop linear regression models for predicting elderly driver accidents as a function of the number of entering vehicles and other intersection characteristics. The models developed were neither very good predictors of total elderly accidents nor good indicators of the proportion of elderly accidents at the intersection. However, they did indicate that the number of entering vehicles is a significant, although weak, predictor of elderly intersection accidents.

### Results

An initial examination of the Minnesota and Illinois data showed that at rural and urban signalized and stop-controlled intersections, elderly drivers were much less likely than their middle-aged counterparts to be involved in rear-end collisions. However, elderly drivers appear to be more involved in left-turn and angle collisions at both urban and rural locations, with right-angle collisions presenting a particular threat to elderly drivers at stop-controlled intersections.

Turning appears to present a problem for older groups, especially at signalized intersections. There is little difference between the three age groups' involvement in "turning" crashes at stop-controlled intersections. The two older groups were more likely to be involved in left-turn crashes at signalized intersections in rural areas, and the old elderly, in particular, were more likely to be involved in left-turn crashes at signalized intersections in urban areas.

## Analysis of Pre-Accident Maneuvers - Minnesota Data

The type of maneuver that both the elderly and middle-aged drivers were performing prior to their crashes was examined. In both left-turn, right-turn, and right-angle collisions at urban and rural signalized intersections, middle-aged drivers were more likely to have been going straight, while the older driver groups were more likely to have been involved in some type of turning maneuver, regardless of the accident type involved.

In the few cases where turning presented a problem at urban and rural stop-controlled locations, the old elderly drivers were still more likely to have been involved in the turning maneuvers, while the young elderly and middle-aged drivers were more likely to have been traveling straight, slowing, or stopping.

Right-angle collisions, previously found to pose risk to elderly drivers at stop-controlled intersections, were further analyzed for both urban and rural locations. The pattern of accidents in rural areas was similar to that in urban areas. A higher proportion of the middle-aged drivers were either going straight, slowing, or stopping, while a higher proportion of the two older age groups were more likely to have been starting from a stop (9.1 percent, 17.6 percent, 19.2 percent, respectively) and/or making a left turn across traffic (10.8 percent, 11.1 percent, 15.8 percent, respectively). Given the nature of vehicle movements at a stop-controlled intersection, it would appear that elderly drivers were more likely to be starting from the stop-controlled leg and pulling out in front of an oncoming vehicle.

In rear-end collisions at urban locations, middle-aged drivers were more likely to have been slowing or stopping prior to the crash (57.3 percent, 53.1 percent, 37.4 percent, respectively), while the old elderly drivers were more likely to have been noted as going straight (30.6 percent, 37.4 percent, 52.2 percent, respectively) or changing lanes (1.1 percent, 1.9 percent, 2.5 percent, respectively).

Rear-end accidents in the rural stop sign locations had a somewhat different pattern. While middle-aged drivers again were more likely to have been slowing or stopped (36.3 percent, 29.3 percent, 27.0 percent, respectively), they also were found to have been making a left turn (15.0 percent, 12.1 percent, 10.8 percent, respectively). The young and old elderly groups were more likely to have been going straight (30.6 percent, 48.3 percent, 37.8 percent, respectively), and the old elderly were more likely to have been starting from a stopped position (5.8 percent, 3.5 percent, and 8.1 percent, respectively).

## Pre-Accident Maneuvers in "Matched" Crashes - Illinois Data

To verify the Minnesota patterns, Illinois data for only those accidents involving ***both*** an elderly driver and a middle-aged driver were selected. This reduces potential biases resulting from differential exposure (i.e., more elderly drivers at certain types of intersections). The analyses were done with matched pairs and, with one exception, seemed to support all of the findings of the Minnesota data analysis. In the Illinois matched pairs angle collision data there are no differences between the distribution of maneuvers by age groups. All three age groups were more likely to have been going straight.

The analysis of angle and turning collisions verifies the Minnesota findings. At both signalized and stop-controlled intersections, middle-aged drivers were much more likely to have been going straight, while elderly drivers, particularly the old elderly drivers, were more likely to have been turning left. Both elderly groups were more likely to have been turning right. In angle collisions at both urban and rural stop-controlled locations, the elderly driver appeared to be much more likely to have been starting in traffic. This suggests that the elderly driver is more likely to be the driver starting from the stop-controlled leg and pulling out in front of an oncoming vehicle.

With rear-end collisions at urban stop-controlled intersections, the findings of the Minnesota data were also supported. The old elderly drivers were much more likely to have been going straight or backing, while the younger two groups were more likely to have been slowing or stopping in traffic.

## Contributing Factors in Angle and Turning Collisions – Minnesota Data

A restricted sample of Minnesota matched cases of middle-aged and elderly drivers (similar to the Illinois sample previously discussed) was drawn to examine the factors cited as the primary "cause" of the accident. Because of the limited availability of information on the other types of crashes, the sample was further restricted to only those crashes involving right-angle and turning collisions.

For both urban and rural signalized and stop-controlled locations, the middle-aged comparison group driver was much more likely to have been indicated by the officer as having exhibited no improper driving, while the two elderly groups were much more likely to have been cited for failure to yield. Failure to yield in a stop-controlled situation could mean pulling out in front of a crossing vehicle that has the right-of-way and/or failure to yield to an oncoming vehicle when making a left turn. In signalized locations, disregard for traffic signals and making improper turns also were contributing factors for older drivers. At urban signalized locations in particular, the elderly were seen as exhibiting a higher proportion of "driver inattention."

The contributing factors were then examined for each pre-accident maneuver type. For situations where a driver was turning left, the middle-aged driver was more likely to have been cited as having no improper driving behavior, while elderly drivers were more likely to have been shown to fail to yield. This was true at all types of locations. Middle-aged drivers going straight prior to a crash at a stop-controlled intersection exhibited no improper driving twice as often as the young elderly, and almost three times as often as the old elderly drivers who were going straight. The two elderly groups again were much more likely to have been cited for inattention, failure to yield, or disregarding the stop sign. Finally, in the rural cases in which a driver was "starting from a stop," the old elderly drivers had a much lower probability of having no improper driving indicated than the middle-aged drivers. Both elderly groups exhibited higher proportions of failure to yield, and the old elderly exhibited a higher proportion of disregarding the stop sign.

## Modeling of Minnesota Intersection Data

The Minnesota Intersection file contains information on approximately 6,200 intersections of U.S./U.S. and U.S./State numbered routes across Minnesota. A sample of 600 signalized intersections were linked to the intersection accident locations. Records containing specific intersection characteristics and accident counts for the middle-aged comparison group and the elderly group were built.

The linear regression models developed were neither very good predictors of total elderly accidents nor of the proportion of elderly accidents at the intersection. Only two of the variables, entering vehicle volume and maximum speed limit, explained any of the variance between the two groups. The degree of variance explained was only 20 percent. Further modeling was done with a full file. As before, the number of entering vehicles and the maximum speed were significant predictors, but the degree of variance explained by this model—less than 1 percent—was much lower. None of the other variables examined—type of intersection, whether the signal phase was fixed or variable, or the general and specific environmental character of the surrounding area—were found to be significant predictors.

It is interesting to note that while the number of elderly driver accidents increases with entering vehicles, it does not increase as rapidly as do the number of accidents involving middle-aged drivers. This relationship could simply reflect the fact that elderly drivers may avoid high-volume locations more often than middle-aged drivers. The modeling of the location-based data did not lead to any additional information on intersection characteristics that might cause elderly driver problems. It is not known if this is due to a lack of risk or a lack of exposure of the older driver at these locations.

## Summary

The accident analyses indicate that both the young elderly and old elderly do appear to have problems at intersections. These problems often involve left-turn maneuvers (at signalized intersections) and turning or entering maneuvers at stop-controlled intersections. It appears that elderly drivers have difficulties in distinguishing target vehicles from surrounding clutter, judging velocity of target vehicles, judging closing speed of target vehicles, and/or an inability to use the acceleration capabilities of the cars they are driving in order to use what would be safe gaps for younger drivers.

## OLDER PEDESTRIANS

## Methodology

A limited new analysis of elderly pedestrian accidents was combined with past analyses of elderly pedestrians conducted by the Highway Safety Research Center

(HSRC) for the Centers for Disease Control. Previous analyses examined police-reported motor vehicle crashes in North Carolina from 1980 through 1990 and looked at all fatal police-reported motor vehicle crashes occurring nationwide from 1980 through 1989 in order to isolate factors surrounding accidents involving elderly pedestrians.

For the study, specific crash factors associated with older pedestrian accidents were compared to those associated with younger age groups to identify abnormally high trends among those 65 years and older. The factors of most interest were those related to time, light condition, type of location (i.e., intersection-related), and crash type.

**Results**

Of the total North Carolina pedestrian-motor vehicle crashes from 1980 through 1990, 1,758 (6.7 percent) involved pedestrians age 65 and older. Nationwide, 16,568 (21 percent) of pedestrian fatalities from 1980 through 1990 involved persons age 65 and older. Although older persons are less likely than younger persons to be struck by motor vehicles, they are much more likely to be killed if struck. For age groups under 44 years old, 11 percent of crashes result in death, as compared to 18.6 percent of crashes to pedestrians ages 65 to 74 and 25.1 percent of crashes to those age 75 and older.

Examination of both the North Carolina and the national data showed that deaths to individuals age 65 and older are most likely to occur during the winter months, and that next to young children, older adults have the highest percentage of crashes occurring during daylight hours.

Compared to younger pedestrians, older adults are overinvolved in crashes while crossing streets at intersections. This is probably a reflection of the greater likelihood of older pedestrians crossing at intersections. North Carolina data indicate that pedestrians age 65 and older and those ages 45 to 64 both had high percentages of accidents on roadways with four or more lanes (37 percent for each). This compares to 23.7 percent for pedestrians 10 to 44 years old and 13.6 percent for those 9 years of age or younger. This supports the widely accepted assumption that older pedestrians have difficulty crossing wide streets.

Concerning crash types, analyses of national data reveal that 84.0 percent of all pedestrian fatalities, including both intersection and non-intersection crashes, involved a vehicle traveling straight ahead. Older pedestrians, however, are overrepresented in fatal crashes involving turning vehicles. Right-turning motorists pose a threat to the young elderly, while left-turning motorists are a danger for the old elderly. In North Carolina, right-turn crashes, including right-turn-on-red, accounted for 18.9 percent of intersection crashes to pedestrians 65 to 74 years old, compared to 14.2 percent for pedestrians age 75 and older and 11.9 percent for pedestrians ages 30 to 50. Accidents involving left-turning vehicles accounted for 23.9 percent of the crashes to the oldest pedestrians, 18.1 percent of crashes to pedestrians ages 65 to 74, and 15.8 percent of crashes to pedestrians ages 30 to 50.

Evidence also suggests that older pedestrians are struck more often by backing vehicles than are younger pedestrians. A surprisingly high 9.5 percent of North Carolina's older pedestrian crash victims were struck by a backing vehicle, compared to only 3.9 percent for younger age groups.

### Summary

The most persistent trend appears to be that older drivers and older pedestrians are overrepresented in left-turn accidents at signalized intersections.

# 3. FOCUS GROUP SESSIONS

## INTRODUCTION

Eight focus group sessions were held to attempt to identify the problems that older drivers and pedestrians have at intersections. Two 2-h sessions were held in each of the following locations: Chevy Chase, MD; Chapel Hill, NC; Tampa, FL; and Phoenix, AZ. A moderator's guide was developed and used to guide the discussion in each of the sessions. In addition, a brief questionnaire was administered to the participants as they arrived for the sessions. Each of the sessions was audiotaped and participants' comments were extracted from the tapes as well as from notes taken from the actual sessions. Abstracts of the session discussions and tabulations of the questionnaire data were described in the task working paper. The final recommendations follow.

## RECOMMENDATIONS

During the course of the eight focus group sessions, a variety of suggestions and recommendations were offered by the participants to enhance their safety at intersections. Most of these pertained to traffic controls, while others were more general observations. Some have been tried, but should be reexamined; others are new. They are listed under the following three categories: driver, pedestrian, and general. Within each are the various subcategories or subject areas covered in the preceding text.

### Areas Pertaining to the Driver

#### Traffic Signals

- Make signals more uniform across the United States, including the warning (or amber) phase.
- Standardize position, size of signals.
- Provide traffic lights overhead and to the side at major intersections.
- Provide a warning to the driver when light is about to turn amber, such as a pulsing green phase of 1 to 2 s.
- Paint a yellow line in the pavement upstream of the signal such that if the driver has not reached the line before the light has turned amber, he or she cannot make it through before the light turns red.
- Provide borders around lights to minimize glare from the sun.

- Restrict holiday decorations, which are often red and green like the traffic signals.

**<u>Signs/Pavement Markings</u>**

- Reexamine both the size of the signs and the size of the letters (with the limitations of the elderly in mind) and upgrade accordingly.

- Implement large overhead cross-street signs along with upstream signs at major intersections.

- Provide reflectorized messages on non-reflectorized backgrounds; install more raised pavement markers.

- Provide pavement markings and signs upstream for TURN ONLY lanes.

- Place route signs further upstream as well as just after the intersection when a turn is required.

- Repaint lane lines, edge lines, and pavement markings more frequently.

- Provide better highway maintenance so that foliage does not obscure signs.

- Eliminate four-way stop at intersections.

**<u>Left Turns</u>**

- Provide as many protected left-turn opportunities as possible.

- When possible, standardize sequence for left-turn green arrow—<u>precede</u> either solid green (which then permits a left turn after yielding) or red (which prohibits a left turn).

- Lengthen the protected left-turn signal.

- Lengthen the left-turn lanes so that turning traffic does not block thru traffic.

- For dual left turns, lengthen the distance after the turn before a merge is required. Also, provide better lane markings and signs for these situations.

**Areas Pertaining to Pedestrians**

**<u>Pedestrian Signals</u>**

- Reevaluate length of pedestrian walk signals due to increasingly wider highways.

- Implement more Barnes Dance signals at major intersections.

## Refuge Islands

- Provide more pedestrian refuge islands on wide streets.
- Construct barriers around the islands to physically separate pedestrians from traffic as well as to ensure island visibility.

## Geometrics Improvements; Signs

- Round off the corners of blocks to allow more visibility of and by the pedestrian.
- Provide more YIELD TO PEDESTRIAN signs in the vicinity of heavy pedestrian traffic.

## General Areas

- Increase media coverage of traffic problems/construction at major intersections.
- Employ stricter enforcement policies for running red lights; failure to yield to pedestrians as with right-turn-on-red movements; and speeding.
- Eliminate darkly tinted windows.

# 4. COUNTERMEASURE IDENTIFICATION

In this section, many potential countermeasures (CM's) addressing the problems of older drivers and pedestrians at intersections are presented. For the most part, they are derived from the accident analysis and/or the focus group discussions. The physiological cause and/or psychomotor basis or bases of the problems are derived from the literature.

A summary of the CM's, along with problems, possible causes, and CM type (i.e., recommended practice, previously tested, and/or testing needed) are presented for drivers (table 1) and pedestrians (table 2) along with the relevant intersection type (signalized vs. unsignalized). The first column (Problem/Source) describes the nature of the problems confronting older drivers and/or pedestrians. The problem is indicated as an accident type and can be a safety-related issue, an issue perceived as safety related, or anything that affects the comfort and/or convenience of older drivers or pedestrians at intersections.

The second column (Possible Causes) shows the age-related performance decrement that possibly causes older drivers or pedestrians to experience the problem indicated. This may include any of the perceptual, cognitive, or motor performance-related factors addressed in the literature review or any other factors (see footnote 1 for table 1) that may be relevant.

The third column (Countermeasure Treatment) indicates the specific countermeasures or treatments that may help to ameliorate each specific cause identified for each problem. Thus, for example, problems with left-turn conflicts caused by an inability to determine acceptable gaps in traffic could be treated by providing a protected left-turn phase. Problems with left-turn conflicts caused by an inability to see oncoming traffic could be treated by reducing visual clutter or trimming vegetation to improve sight distance.

The next two columns (Intersection Type) simply indicate whether the problem, cause, and CM relate to signalized and/or unsignalized intersections. The final three columns (CM Type) suggest whether testing appears to be warranted. Some of the countermeasures consist of following standard or recommended practice. This category includes providing standard traffic control devices and maintaining them properly. Other countermeasures involve novel or experimental procedures that have been tested in previous research projects.

It should be noted that during the development of the countermeasures/treatments for pedestrians, one basic source of information was a chapter titled, "Engineering Countermeasures for Accidents Involving Older Pedestrians," written by HSRC under subcontract with Dunlap and Associates for the National Highway Traffic Safety Administration (NHTSA) project, Development, Implementation, and Evaluation of a Pedestrian Safety Zone for Elderly Pedestrians.

## Summary

Tables 1 and 2 summarize a wide variety of countermeasures and/or treatments that are intended to increase the safety and convenience of older drivers and pedestrians, respectively, at intersections. Many of these suggestions involve following recommended engineering practices and many others have been tested in previous research efforts. After reviewing the suggested countermeasures, it was decided that the following three general areas should be addressed in the current project:

- Left-turn signalization comprehension.
- Pedestrian signal explanation placard.
- Driver signal responses and stopping behavior.

The three research efforts undertaken to address each of these topics are described in the final three chapters of this report.

Table 1. Elderly drivers at intersections: countermeasure identification protocol.

| Problem/Source | Possible Causes[1] | Countermeasure Treatment | Intersection Type: Signal | Intersection Type: Unsig. | CM Type: Recomm. Practice | CM Type: Prev. Tested | CM Type: Testing Needed[2] |
|---|---|---|---|---|---|---|---|
| 1. ANGLE—START FROM STOP (i.e., driver starts from stop and attempts to cross thru street or turn left in front of cross-street traffic)<br><br>SOURCE: Accident analysis, focus groups | a. Driver fails to<br>- perceive oncoming vehicle<br>- judge speed/gap of oncoming vehicle<br>- control turning speed<br>- understand signal phasing (e.g., proceeds through on left-turn phase) | 1. Clear sight triangle | | ✓ | | | N |
| | | 2. Correct grade-related sight distance restrictions | | ✓ | | | N |
| | | 3. Gap judgment testing/training | ✓ | ✓ | | | M |
| | | 4. Test physical control capabilities | ✓ | ✓ | | | N |
| | | 5. Education concerning problems | ✓ | ✓ | | | L |
| | | 6. Consistency in signal indications for protected/ unprotected phasing | ✓ | | ✓ | | M |
| | | 7. Modify signal phase indicators for better understanding | ✓ | | | | H |
| | | 8. Place "warning bar" on thru approach lanes to designate "danger zone"— based on expected thru-vehicle speeds | ✓ | ✓ | | | M |
| | | 9. Vehicle modification-Radar warning of approaching vehicle | ✓ | ✓ | | | H |

1 See addendum at end of table

2 N = No further testing needed; L = Low priority for testing; M = Medium priority for testing; H = High priority for testing

Table 1. Elderly drivers at intersections: countermeasure identification protocol (continued).

| Problem/Source | Possible Causes | Countermeasure Treatment | Intersection Type: Signal | Intersection Type: Unsig. | CM Type: Recomm. Practice | CM Type: Prev. Tested | CM Type: Testing Needed |
|---|---|---|---|---|---|---|---|
| 2. ANGLE TURNING—FAILURE TO STOP (i.e., driver fails to stop for stop sign or signal)<br><br>SOURCE: Accident analysis, focus groups | a. Failure to see sign or signal due to clutter or visual problems<br><br>b. Failure to perceive oncoming traffic<br><br>(See footnote 1a, 1b,1c, 1d, 1e, 1f, 1g) | 1. Clear sight triangle | ✓ | ✓ | ✓ | | N |
| | | 2. Oversized stop sign | | ✓ | ✓ | | N |
| | | 3. Overhead signs | | ✓ | | ✓ | L |
| | | 4. Overhead flashing lights | | ✓ | | ✓ | L |
| | | 5. Improved advanced signing (including warning lights) | ✓ | ✓ | | | M |
| | | 6. Oversized lenses | ✓ | | | ✓ | N |
| | | 7. Back plates | ✓ | | | ✓ | N |
| | | 8. Double signal heads | ✓ | | | ✓ | N |
| | | 9. STROBE signals | ✓ | | | ✓ | N |
| | | 10. Appropriate and consistent amber phases | ✓ | | ✓ | | N |
| | | 11. Advanced warning for ISOLATED signalized location on main line | ✓ | | | ✓ | L |
| | | 12. Vehicle modification—Radar warning of approaching vehicles | ✓ | ✓ | | | H |

Table 1. Elderly drivers at intersections: countermeasure identification protocol (continued).

| Problem/Source | Possible Causes | Countermeasure Treatment | Intersection Type | | CM Type | | |
|---|---|---|---|---|---|---|---|
| | | | Signal | Unsig. | Recomm. Practice | Prev. Tested | Testing Needed |
| | | 13. Standardize position and phasing of traffic signal | ✓ | | | | L |
| | | 14. Reflectorized signs | ✓ | ✓ | | ✓ | N |
| | | 15. Pavement markings farther upstream | ✓ | ✓ | | | N |
| | | 16. Route signs farther upstream as well as just after inter-section where turn is required | ✓ | ✓ | | | N |
| | | 17. Overhead signs in large letters for major intersecting street(s) | ✓ | ✓ | | | N |
| | | 18. Pavement markings/signs farther upstream for TURN ONLY lanes | ✓ | ✓ | | | N |

Table 1. Elderly drivers at intersections: countermeasure identification protocol (continued).

| Problem/Source | Possible Causes | Countermeasure Treatment | Intersection Type | | CM Type | | |
|---|---|---|---|---|---|---|---|
| | | | Signal | Unsig. | Recomm. Practice | Prev. Tested | Testing Needed |
| 3. LEFT-TURN ACROSS TRAFFIC (i.e., elderly driver turns in front of opposing oncoming vehicle)<br><br>SOURCE: Accident analysis, focus groups | a. Driver fails to<br>- perceive oncoming vehicle<br>- judge speed and gap of oncoming vehicle<br>- control turning speed of own vehicle<br>- is confused by signal-phasing (protected turn or not?)<br><br>(See footnote 1a, 1b, 1d, 1e, 1f, 1g) | 1. Protected signal phase | ✓ | | ✓ | | L |
| | | 2. Consistency in signal indication and sequence for protected/unprotected phases | ✓ | | | ✓ | M |
| | | 3. Modify signal phase indicators for better understanding | ✓ | | | | M |
| | | 4. Gap judgment testing/training | ✓ | ✓ | | | M |
| | | 5. Test physical control capabilities | ✓ | ✓ | | | L |
| | | 6. Vehicle modifications—<br>Radar braking<br>Radar warning | <br>✓<br>✓ | <br>✓<br>✓ | | | <br>H<br>H |
| | | 7. Lengthen protected left-turn phase | ✓ | | | | N |
| | | 8. Lengthen left-turn lane (so that turning traffic does not block traffic) | ✓ | | | | N |
| | | 9. For dual left-turn lanes, lengthen distance after turn before merge | ✓ | | | | N |

Table 1. Elderly drivers at intersections: countermeasure identification protocol (continued).

| Problem/Source | Possible Causes | Countermeasure Treatment | Intersection Type | | CM Type | | |
|---|---|---|---|---|---|---|---|
| | | | Signal | Unsig. | Recomm. Practice | Prev. Tested | Testing Needed |
| 4. REAR-END (i.e., elderly driver strikes leading vehicle in rear)<br>SOURCE: Accident analysis | a. Failure to perceive and stop (e.g., due to confusion from distractions) | 1. Eliminate stopping sight distance restrictions | ✓ | ✓ | ✓ | | N |
| | | 2. Oversized stop signs | | ✓ | ✓ | | N |
| | b. Inability to judge closing speeds/gap | 3. Improve advanced warning signs | ✓ | ✓ | | ✓ | N |
| | c. Poor manual control of brake pedal pressure | 4. Gap judgment testing/training | ✓ | ✓ | | | L |
| | | 5. Testing of physical control capabilities | ✓ | ✓ | | | L |
| | (See footnote 1a, 1b, 1c, 1d, 1e, 1f, 1g) | 6. Education concerning problems | ✓ | ✓ | | | L |
| | | 7. Vehicle modifications— | | | | | |
| | | Radar braking | ✓ | ✓ | | | H |
| | | Radar warning | ✓ | ✓ | | | H |
| | | 8. Provide pulsating green when light is about to turn amber | ✓ | | | | N |
| | | 9. Green Extension System (GES) that extends the green interval for high-speed approaches at isolated signalized intersections | ✓ | | ✓ | ✓ | M |
| | | 10. Provide borders around lights to minimize glare | ✓ | | | | N |
| | | 11. Restrict holiday (red and green) decorations and neon lights near traffic lights | ✓ | | ✓ | | N |

Table 1. Elderly drivers at intersections: countermeasure identification protocol (continued).

| Problem/Source | Possible Causes | Countermeasure Treatment | Intersection Type | | CM Type | | |
|---|---|---|---|---|---|---|---|
| | | | Signal | Unsig. | Recomm. Practice | Prev. Tested | Testing Needed |
| 5. RIGHT TURN FROM STOP (i.e., driver starts from stop and turns right)<br><br>SOURCE: Accident analysis | a. Driver fails to<br>- see/perceive oncoming vehicle<br>- judge speed and gap of oncoming vehicle<br>- control turning speed of own vehicle | 1. Eliminate sight distance restrictions | ✓ | ✓ | ✓ | | N |
| | | 2. Staggered stop bars | ✓ | ✓ | | ✓ | M |
| | | 3. Prohibit right-turn-on-red (RTOR) at selected intersections | ✓ | | | | L |
| | b. Visual obstruction due to vehicle in adjacent left lane | 4. Gap judgment testing/training | ✓ | ✓ | | | L |
| | (See footnote 1a, 1b, 1e, 1f) | 5. Test physical control capabilities | ✓ | ✓ | | | L |
| | | 6. Education concerning problems | ✓ | ✓ | | | L |
| | | 7. Vehicle modifications-Radar warning | ✓ | ✓ | | | M |
| | | 8. Place "warning bar" on thru approach lanes to designate "danger zone"—based on expected thru-vehicle speeds | | ✓ | | | L |

[1] **Age-Related Decrements**

a. **Useful field of vision**. This is dependent on both the ability to see as well as on visual information processing, including the ability to ignore distractors and to prioritize divided attention tasks.

b. **Visual search**. A cognitive function that involves the ability to identify incoming stimuli. Decrements in this ability may result in longer response times. May be exacerbated by visual clutter.

c. **Visual spatial skills**. Deficits may affect interpretation and response to roadway milieu.

d. **Memory decrements**. Slower time in retrieving information from primary memory may place the older person at risk in situations requiring rapid manipulation of information. Short-term memory loss may affect appropriate responses.

e. **Attention-related deficits or decrements**. Deficits in these areas affect visual scanning and other maneuvers that require rapid reorientation of attention. May include distractability and difficulties in refocusing attention quickly enough to respond to changing stimuli. May result in problems in maintaining a cognitive "preparatory set."

f. **Divided attention deficits**. Deficits in this ability may affect the speed with which information is processed because it may affect prioritization of incoming information, including disregard for irrelevant distractions. May result in people requiring more time to make decisions. May be affected by visual clutter.

g. **Decrements in psychomotor skills**. Decrements in these skills may result in slower reaction time.

Table 2. Elderly pedestrians at intersections: countermeasure identification protocol.

| Problem/Source | Possible Causes[1] | Countermeasure Treatment | Intersection Type | | CM Type | | |
|---|---|---|---|---|---|---|---|
| | | | Signal | Unsig. | Recomm. Practice | Prev. Tested | Testing Needed |
| 1. VEHICLE TURN/ MERGE (i.e., vehicle turns left or right and strikes pedestrian)<br><br>SOURCE: Accident analysis, literature, focus groups | a. Right-Turn-on-Red (RTOR) Driver is looking for traffic from left, doesn't see pedestrian<br><br>(See footnote 1a, 1b, 1c, 1e, 1f) | 1. Prohibit/restrict RTOR | ✓ | | ✓ | ✓ | N[2] |
| | | 2. Offset stop bars | ✓ | ✓ | | ✓ | H |
| | | 3. Pedestrian/motorist warning signs related to turning vehicles (e.g., WATCH FOR TURNING VEHICLES warning sign or YIELD TO PEDESTRIANS WHEN TURNING regulatory signs) | ✓ | ✓ | | ✓ | M |
| | | 4. Exclusive pedestrian signal phasing | ✓ | | | | L |
| | | 5. Install NO TURN ON RED WHEN PEDESTRIANS ARE PRESENT sign | ✓ | | | ✓ | L |
| | | 6. Install larger NO TURN ON RED (NTOR) signs, variable message NTOR sign, or relocate NTOR sign next to signal | ✓ | | | ✓ | L |
| | | 7. Round off corners of blocks for visibility | ✓ | ✓ | ✓ | | N |

[1] See addendum at end of table.
[2] N = No further testing needed
L = Low priority for testing
M = Medium priority for testing
H = High priority for testing

Table 2. Elderly pedestrians at intersections: countermeasure identification protocol (continued).

| Problem/Source | Possible Causes | Countermeasure Treatment | Intersection Type | | CM Type | | |
|---|---|---|---|---|---|---|---|
| | | | Signal | Unsig. | Recomm. Practice | Prev. Tested | Testing Needed |
| 1. VEHICLE TURN/ MERGE (cont.) | b. Right Turn<br>Driver turns right on green light or stop sign, strikes pedestrian<br><br>(See footnote 1a, 1b, 1c, 1e, 1f, 1g) | 1. Pedestrian/motorist warning signs related to turning vehicles | ✓ | ✓ | | ✓ | M |
| | | 2. Exclusive ped phasing | ✓ | | | ✓ | L |
| | | 3. Restrict on-street parking | ✓ | ✓ | ✓ | | L |
| | | 4. Install curb extensions (neckdowns) | ✓ | ✓ | | | H |
| | | 5. Construct sharper turning radii | ✓ | ✓ | | | L |
| | c. Left Turn<br>Driver is watching for gaps in oncoming traffic, doesn't see pedestrians<br><br>(See footnote 1a, 1b, 1c, 1d, 1e, 1f, 1g) | 1. Prohibit left turns | ✓ | | ✓ | | M |
| | | 2. Ped/motorist signs related to turning vehicles | ✓ | | | ✓ | M |
| | | 3. Exclusive pedestrian phasing | ✓ | | ✓ | ✓ | L |
| | | 4. Coordinate left-turn phasing with pedestrian signals; provide protected movement | ✓ | | ✓ | | M |
| | | 5. Improve intersection lighting | ✓ | ✓ | ✓ | ✓ | N |
| | | 6. Pedestrians wear retro-reflective clothing | ✓ | ✓ | | ✓ | N |
| | | 7. Raise crosswalk above pavement and pave conspicuously (in brick, flagstone, or retroreflective white paint) | ✓ | ✓ | | | H |

Table 2. Elderly pedestrians at intersections: countermeasure identification protocol (continued).

| Problem/Source | Possible Causes | Countermeasure Treatment | Intersection Type | | CM Type | | |
|---|---|---|---|---|---|---|---|
| | | | Signal | Unsig. | Recomm. Practice | Prev. Tested | Testing Needed |
| 1. VEHICLE TURN/ MERGE (cont.) | d. Older pedestrian doesn't see turning vehicle approaching<br><br>(See footnote 1a, 1b, 1c, 1d, 1e, 1f, 1g) | 1. Prohibit/restrict RTOR | ✓ | | | | N |
| | | 2. Prohibit left turns | ✓ | ✓ | ✓ | | M |
| | | 3. Exclusive pedestrian phasing | ✓ | | | ✓ | L |
| | | 4. Pedestrian/motorist signs related to motor vehicles | ✓ | ✓ | | ✓ | M |
| | | 5. Reduce visual clutter around intersections | ✓ | ✓ | ✓ | | L |
| | | 6. Daytime running lights on vehicles | ✓ | ✓ | | | L |
| 2. INTERSECTION DASH (i.e., pedestrian appears suddenly in the street in front of oncoming vehicle at an intersection)<br><br>SOURCE: Accident analysis, literature, focus groups | a. Older pedestrians may not know when it's their turn to cross<br><br>(See footnote 1d, 1e, 1f, 1g) | 1. Install WALK/DON'T WALK signals | ✓ | | ✓ | ✓ | L |
| | | 2. Signal explanation signs | ✓ | | | ✓ | M |
| | | 3. DON'T START ped signal | ✓ | | | ✓ | M |
| | | 4. Install audible message with pedestrian signals | ✓ | | | ✓ | L |
| | | 5. Push-button signals | ✓ | | | ✓ | L |
| | | 6. Consider Barnes Dance installation | ✓ | | ✓ | | L |

Table 2. Elderly pedestrians at intersections: countermeasure identification protocol (continued).

| Problem/Source | Possible Causes | Countermeasure Treatment | Intersection Type | | CM Type | | |
|---|---|---|---|---|---|---|---|
| | | | Signal | Unsig. | Recomm. Practice | Prev. Tested | Testing Needed |
| 2. INTERSECTION DASH (cont.) | b. Older peds may not know where they should cross | 1. Marked crosswalks | ✓ | ✓ | ✓ | ✓ | N |
| | (See footnote 1b, 1f, 1g) | 2. Install WALK/DON'T WALK signals | ✓ | | ✓ | ✓ | N |
| | | 3. Sidewalk barriers | ✓ | ✓ | | | M |
| | | 4. Consider Barnes Dance installation | ✓ | | | ✓ | L |
| | c. There isn't an adequate gap in traffic | 1. Install traffic and pedestrian signals | | ✓ | ✓ | ✓ | N |
| | (See footnote 1g) | 2. Push-button pedestrian signals | ✓ | | ✓ | | L |
| | | 3. Increase WALK interval | ✓ | | ✓ | ✓ | H |
| | | 4. Install pedestrian refuge islands with pedestrian signals | ✓ | | | | M |
| | | 5. Consider Barnes Dance installation | ✓ | | | ✓ | L |
| | | 6. More and better protected refuge islands | ✓ | | | | M |

Table 2. Elderly pedestrians at intersections: countermeasure identification protocol (continued).

| Problem/Source | Possible Causes | Countermeasure Treatment | Intersection Type | | CM Type | | |
|---|---|---|---|---|---|---|---|
| | | | Signal | Unsig. | Recomm. Practice | Prev. Tested | Testing Needed |
| 2. INTERSECTION DASH (cont.) | d. Pedestrian can't see traffic coming from the left because view is blocked by parked cars (See footnote 1a, 1b, 1c, 1e, 1g) | 1. Restrict/remove curb parking | ✓ | ✓ | ✓ | | L |
| | | 2. Install curb extensions | ✓ | ✓ | | | H |
| | e. Older pedestrians may become confused looking in several directions and not perceive oncoming vehicles (See footnote 1b, 1c, 1d, 1g) | 1. One-way streets | ✓ | ✓ | | ✓ | L |
| | | 2. Reduce visual clutter around intersections | ✓ | ✓ | ✓ | | L |
| | | 3. Pedestrian/motorist warning signs about turning vehicles | ✓ | ✓ | | ✓ | M |
| | | 4. Install traffic and/or pedestrian signals | ✓ | ✓ | ✓ | | N |
| | | 5. Install curb extensions | ✓ | ✓ | | | H |

Table 2. Elderly pedestrians at intersections: countermeasure identification protocol (continued).

| Problem/Source | Possible Causes | Countermeasure Treatment | Intersection Type | | CM Type | | |
|---|---|---|---|---|---|---|---|
| | | | Signal | Unsig. | Recomm. Practice | Prev. Tested | Testing Needed |
| 3. MULTIPLE THREAT (i.e., one or more vehicles stop in thru lane, usually at a crosswalk at an unsignalized inter-section; pedestrian steps in front of stopped vehicle(s) and into path of thru vehicle in adjacent lane)<br><br>Source: Literature | a. Vehicle in curb lane has stopped to allow pedestrian to cross but drivers in other lanes and peds don't see each other<br><br>(See footnote 1a, 1b, 1c, 1e, 1f) | 1. Install traffic signals | ✓ | | ✓ | | N |
| | | 2. Install WALK/DON'T WALK signals | ✓ | | ✓ | | N |
| | | 3. Marked crosswalks | ✓ | ✓ | | ✓ | N |
| | | 4. Push-button signals | ✓ | | ✓ | ✓ | L |
| | | 5. Offset stop bars behind crosswalk | ✓ | ✓ | | ✓ | H |
| | | 6. Channel pedestrian from unsignalized to signalized intersection | | ✓ | ✓ | | L |
| 4. BUS STOP-RELATED (i.e., pedestrian steps out from in front of a stopped bus and is struck by a vehicle moving in the same direction as the bus)<br><br>Source: Literature | a. Pedestrian can't see traffic coming from the left because view is blocked by bus<br><br>(See footnote 1b, 1c, 1f, 1g) | 1. Use far-side bus stops | ✓ | ✓ | ✓ | | M |
| | | 2. Construct bus pull-off areas | ✓ | ✓ | ✓ | | L |

Table 2. Elderly pedestrians at intersections: countermeasure identification protocol (continued).

| Problem/Source | Possible Causes | Countermeasure Treatment | Intersection Type | | CM Type | | |
|---|---|---|---|---|---|---|---|
| | | | Signal | Unsig. | Recomm. Practice | Prev. Tested | Testing Needed |
| 5. PEDESTRIAN TRAPPED (i.e., at a signalized intersection, a pedestrian is hit when traffic signal turns red (for pedestrian) and cross-traffic vehicles start moving) | a. Older peds walk more slowly and may not finish crossing before light turns green for traffic | 1. Increase pedestrian walk interval | ✓ | | ✓ | ✓ | H |
| | | 2. Push-button signals | ✓ | | ✓ | ✓ | L |
| | (See footnote 1g) | 3. DON'T START ped signal | ✓ | | | ✓ | M |
| | | 4. Ped refuge islands | ✓ | ✓ | | | M |
| | | 5. Signal explanation signs | ✓ | | | ✓ | M |
| SOURCE: Accident analysis, literature, focus groups | | 6. Install curb extensions | ✓ | ✓ | | | H |
| | | 7. Uniform traffic-signal phasing | ✓ | | | | L |
| | | 8. Lengthen pedestrian walk signal interval for wide streets | ✓ | | | | H |
| | b. Older pedestrians may not know when light has turned green for traffic | 1. Install WALK/DON'T WALK signals | ✓ | | ✓ | ✓ | N |
| | | 2. DON'T START ped signal | ✓ | | ✓ | ✓ | M |
| | (See footnote 1a, 1b, 1c, 1e, 1f, 1g) | 3. Install larger traffic signals and/or pedestrian signals | ✓ | | | ✓ | L |
| | | 4. Install audible message with pedestrian signals | ✓ | | ✓ | ✓ | L |

Table 2. Elderly pedestrians at intersections: countermeasure identification protocol (continued).

| Problem/Source | Possible Causes | Countermeasure Treatment | Intersection Type | | CM Type | | |
|---|---|---|---|---|---|---|---|
| | | | Signal | Unsig. | Recomm. Practice | Prev. Tested | Testing Needed |
| 6. NIGHTTIME (i.e., pedestrian is struck at night when crossing at an intersection)<br><br>SOURCE: Accident analysis and literature | a. Older pedestrians may need more light to see<br><br>(See footnote 1a, 1e, 1g) | 1. Adequate overhead lighting | ✓ | ✓ | ✓ | ✓ | N |
| | | 2. Use larger traffic signals and/or pedestrian signals | ✓ | | ✓ | | L |
| | | 3. Restrict/remove curb parking | ✓ | ✓ | ✓ | | L |
| | b. Drivers can't see pedestrians<br><br>(See footnote 1a, 1e, 1g) | 1. Adequate overhead lighting | ✓ | ✓ | ✓ | | N |
| | | 2. Pedestrians wear retroreflective clothing | ✓ | ✓ | ✓ | ✓ | N |
| | | 3. Exclusive pedestrian phasing | ✓ | | | ✓ | L |
| | | 4. Restrict/remove curb parking | ✓ | ✓ | | | L |
| | | 5. Raise crosswalk above pavement and pave conspicuously (in brick, flagstone, or retroreflective white paint) | ✓ | ✓ | ✓ | ✓ | H |

[1] **Age-Related Decrements**

a. **Useful field of vision**. This is dependent on both the ability to see as well as on visual information processing, including the ability to ignore distractors and to prioritize divided attention tasks.

b. **Visual search**. A cognitive function that involves the ability to identify incoming stimuli. Decrements in this ability may result in longer response times. May be exacerbated by visual clutter.

c. **Visual spatial skills**. Deficits may affect interpretation and response to roadway milieu.

d. **Memory decrements**. Slower time in retrieving information from primary memory may place the older person at risk in situations requiring rapid manipulation of information. Short-term memory loss may affect appropriate responses.

e. **Attention-related deficits or decrements**. Deficits in these areas affect visual scanning and other maneuvers that require rapid reorientation of attention. May include distractability and difficulties in refocusing attention quickly enough to respond to changing stimuli. May result in problems in maintaining a cognitive "preparatory set."

f. **Divided attention deficits**. Deficits in this ability may affect the speed with which information is processed because it may affect prioritization of incoming information, including disregard for irrelevant distractions. May result in people requiring more time to make decisions. May be affected by visual clutter.

g. **Decrements in psychomotor skills**. Decrements in these skills may result in slower reaction time.

# 5. LEFT-TURN SIGNALIZATION COMPREHENSION

## RESEARCH PROCEDURE

The purpose of the Left-Turn Signalization Comprehension Study was to determine how well older drivers understand the various configurations of protected and permitted left-turn signals currently in use. To properly measure a driver's understanding of a specific signal configuration, the testing scenario should provide the proper context. Drivers do not react to the various parts of the signal cycle in isolation. They see one cycle change to another and react based on the relationship between the signals. Simply showing a driver a particular display without providing some indication of what preceded it is not realistic and may lack some of the contextual cues that drivers use to determine appropriate responses.

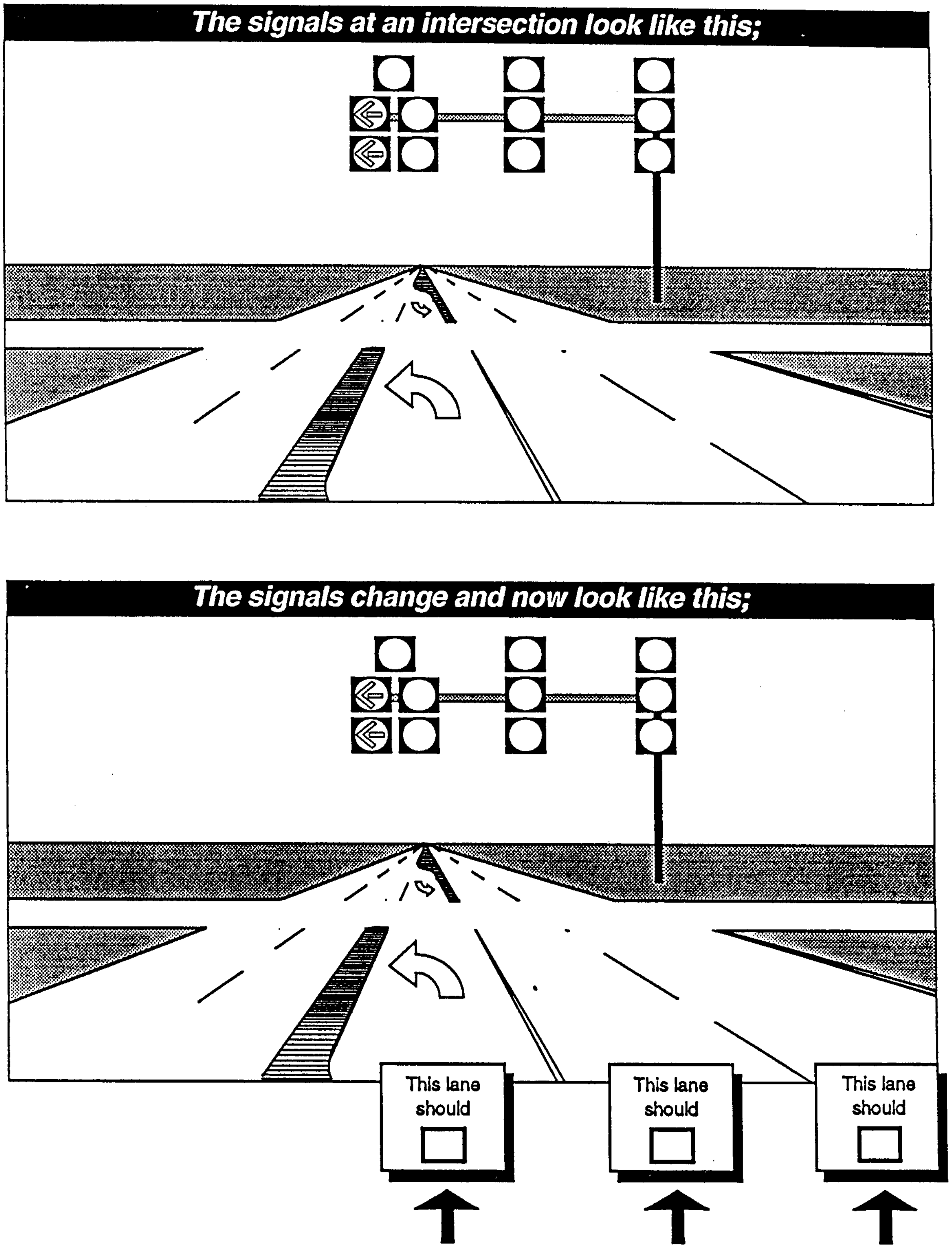
To provide a sequential signal configuration, a two-section paper-and-pencil questionnaire was developed. Each page of the questionnaire had two nearly identical illustrations of an intersection. The top section depicted the signal configuration before the signal changed to the configuration shown in the lower section. The subjects were asked to indicate an appropriate response as if they were driving in the left-most lane, the center lane, and the right-most lane. The traffic signal faces were colored red, green, or amber, depending on the test scenario. A sample page from the questionnaire is included as figure 1. No signal color is shown on this sample page.

The signal configurations that were tested included a variety of lens arrangements and signal faces. These included the *Manual on Uniform Traffic Control Devices* (MUTCD) standard protected and permitted left-turn arrangement with a 4-lens vertically stacked, a 5-lens vertically stacked, and a 5-lens doghouse arrangement. The permitted configurations used in Delaware, Michigan, and Washington State, and a standard 3-lens signal were also tested.

A pilot test was conducted at the Division of Motor Vehicles (DMV) office in Fairfax, VA. Subjects were asked to complete the questionnaire. Most of the participants were thoroughly debriefed to determine the strengths and weaknesses of the questionnaire and answer sheet. The questionnaire was also sent to the Federal Highway Adminstration (FHWA) for review and comment. The results of these activities led to the development of the final questionnaire.

Two versions of the questionnaire—one in a randomly selected presentation order and the other in the reverse order—were prepared. Each signal was manually colored with high-intensity red, green, or amber marking pens as appropriate for the test scene.

A total of 247 questionnaires were administered during June and July 1993 at DMV's, senior centers, churches, and private homes. Subjects were tested in Bel Air, MD, Buffalo, NY, Hamburg, NY, and Fairfax, VA. Approximately one-fourth of the sample was from each geographic area. The subjects were approximately evenly divided




**What should the drivers in each lane do ?**

**Choose the best answer for each blank from the blue answer sheet.**

Figure 1. Sample page from questionnaire.

between those younger than 65 years of age (n=121) and those age 65 and older(n=126). Only licensed drivers who drove at least once a week were used. Subjects were given a $5 incentive fee for their participation.

Approximately half (n=128) of the subjects received one version of the questionnaire, while the other half (n=119) received the other version. ANOVA (analysis of variance) techniques were used to test for any differences between the two versions and for any interactions between subject age and test version. None was found. The remainder of the data analysis used the combined results of all 247 subjects tested.

Some of the scenes had separate left-turn signals, while others had shared signals. A sign with the legend LEFT TURN MUST YIELD ON GREEN (ball) (MUTCD Regulatory Sign R10-12) was added to the scene depicting several of the permitted left-turn signal configurations. Several "practice" scenes and scenes not involving left-turn maneuvers were also prepared. Table 3 presents a complete description of the 16 test scenarios. The subjects were provided with a separate blue answer sheet from which they selected the most appropriate response. The seven response choices included:

1. Stop or remain stopped.
2. Proceed straight.
3. Proceed straight or turn **right**.
4. Turn **left** when there is a large enough gap in oncoming traffic.
5. Turn left without stopping because you have the right-of-way.
6. Stop, but can turn **left** when there is a large enough gap in oncoming traffic.
7. Stop, but can turn **right** when there is a large enough gap in oncoming traffic.

Table 3. Stimulus configurations—protected and permitted turning movements.

| Stimulus No. | Condition | Lane/Signal Configuration | Pre-Test Stimulus | Test Stimulus |
|---|---|---|---|---|
| 1 | Distractor | Left - stacked 5 lens<br>Center - 3 lens<br>Right - 3 lens | Red Ball<br>Amber Ball<br>Amber Ball | Red Ball<br>Red Ball<br>Red Ball |
| 2 | Protected Left-Turn Movement | Left, Center } doghouse 5 lens<br>Right - 3 lens | Red Ball<br>Red Ball<br>Red Ball | Green Arrow<br>Red Ball<br>Red Ball |
| 3 | Standard Signal | Left, Center } 3 lens<br>Right - 3 lens | Red Ball<br>Red Ball | } Green Ball<br>Green Ball |
| 4 | Delaware Permitted Left Turn | Left - stacked 5 lens<br>Center - 3 lens<br>Right - 3 lens | Amber Arrow<br>Red Ball<br>Red Ball | Red Arrow (flashing)<br>Green Ball<br>Green Ball |
| 5 | Protected Left-Turn Movement | Left, Center } doghouse 5 lens<br>Right - 3 lens | Green Arrow<br>Red Ball<br>Red Ball | Green Arrow<br>Green Ball<br>Green Ball |
| 6 | Permitted Left-Turn Movement with Advisory Sign | Left, Center } doghouse<br>Right - 3 lens | Amber Arrow<br>Green Ball<br>Green Ball | } Green Ball<br>Green Ball |
| 7 | Washington State Permitted Left Turn | Left - stacked 5 lens<br>Center - 3 lens<br>Right - 3 lens | Amber Arrow<br>Red Ball<br>Red Ball | Amber Ball (flashing)<br>Green Ball<br>Green Ball |
| 8 | Protected Left Turn with Advisory Sign | Left, Center } doghouse 5 lens<br>Right - 3 lens | } Red Ball<br>Red Ball | Green Arrow<br>Red Ball<br>Red Ball |

Table 3. Stimulus configurations—protected and permitted turning movements (continued).

| Stimulus No. | Condition | Lane/Signal Configuration | Pre-Test Stimulus | Test Stimulus |
|---|---|---|---|---|
| 9 | Permitted Left Turn | Left, Center - doghouse 5 lens<br>Right - 3 lens | Amber Arrow<br>Green Ball<br>Green Ball | Green Ball (Left, Center)<br>Green Ball |
| 10 | Permitted Left Turn | Left, Center - doghouse 5 lens<br>Right - 3 lens | Amber Arrow<br>Red Ball<br>Red Ball | Green Ball (Left, Center)<br>Green Ball |
| 11 | Michigan Permitted Left Turn | Left - stacked 5 lens<br>Center - 3 lens<br>Right - 3 lens | Amber Arrow<br>Red Ball<br>Red Ball | Red Ball (flashing)<br>Green Ball<br>Green Ball |
| 12 | Permitted Left Turn | Left - stacked 4 lens<br>Center - 3 lens<br>Right - 3 lens | Red Ball<br>Red Ball<br>Red Ball | Green Ball<br>Green Ball<br>Green Ball |
| 13 | Distractor | Left, Center - 3 lens<br>Right - 3 lens | Amber Ball (Left, Center)<br>Amber Ball | Red Ball (Left, Center)<br>Red Ball |
| 14 | Permitted Left-Turn with Advisory Sign | Left, Center - doghouse 5 lens<br>Right - 3 lens | Amber Arrow<br>Red Ball<br>Red Ball | Green Ball (Left, Center)<br>Green Ball |
| 15 | Protected Left Turn | Left - stacked 4 lens<br>Center - 3 lens<br>Right - 3 lens | Red Ball<br>Red Ball<br>Red Ball | Green Arrow<br>Red Ball<br>Red Ball |
| 16 | Permitted Left Turn | Left, Center - doghouse<br>Right - 3 lens | Red Ball (Left, Center)<br>Red Ball | Green Ball (Left, Center)<br>Green Arrow |

## RESULTS

The data analysis was performed to answer two specific questions:

1. Are older drivers significantly different from younger drivers in terms of the following signal comprehension criteria?

   a. Understanding of the concept of a protected left-turn movement, e.g., percentage of subjects giving the correct response (no. 5) to stimuli nos. 2, 5, 8, and 15.

   b. Understanding of the concept of a permitted left-turn movement, e.g., percentage of subjects giving the correct response (no. 4) to stimuli nos. 9, 10, 16, 6, 14, 12, and 3.

   c. Potentially dangerous misunderstanding of permitted movements, e.g., believes that the permitted configurations provide protection, e.g., percentage of subjects giving incorrect response (no. 5) to stimuli nos. 9, 10, 16, 6, 14, 12, and 3.

   d. Misunderstanding of protected movements—would stop (unnecessarily) and wait (unnecessarily) for gap in traffic, e.g., percentage of subjects giving incorrect response (no. 6) to stimuli nos. 2, 5, 8, and 15.

   e. Misunderstanding of protected movement—would wait (unnecessarily) for gap in traffic, e.g., percentage of subjects giving incorrect response (no. 4) to stimuli nos. 2, 5, 8, and 15.

2. Is there a relatively small number of older drivers who are responsible for a relatively large percentage of the errors? That is, are 90 percent of the older driver errors made by 10 percent of the sample, while 90 percent of the younger driver errors are made by 50 percent of the sample? If so, it would suggest that either selective reeducation or better driver testing would be appropriate for these problem drivers.

In addition, the data provide some insight into the effect of supplementary signing on signal comprehension and the level of comprehension associated with the permitted signal configurations used by Delaware, Washington State, and Michigan.

Table 4 presents a complete tabulation of the subject responses. The first column contains the stimulus number and an abbreviated description of the stimulus. DH indicates a 5-lens doghouse configuration; 3, 4, and 5 ST refers to a 3-, 4-, or 5-lens stacked configuration. See table 3 for a more detailed description of the stimuli conditions. The seven response choices are listed across the top of the table. The cell entries are the percentage of subjects in each age group that provided that response. For example, the 1 in the upper left-hand cell indicates that 1 percent of the drivers under age 65 indicated that they would stop or remain stopped in response to a green arrow signal over the left traffic lane. The most correct response for each

Table 4. Percent distribution of subject responses (subject n = 121 < 65, 126 > 65+).

| Stimulus # | Response | | (1) Stop or remain stopped | | (2) Proceed straight | | (3) Proceed straight or turn right | | (4) Turn left when there is a large enough gap in oncoming traffic | | (5) Turn left without stopping because you have the right of way | | (6) Stop, but can turn **left** when there is large enough gap in oncoming traffic | | (7) Stop, but can turn **right** when there is large enough gap in oncoming traffic | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Signal/Lane | Subject Age | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ |
| 2 DH | G Arrow | Left | 1 | 5 | 1 | 2 | 1 | 1 | 8 | 8 | 84 | 82 | 5 | 21 | | |
| | R Ball | Center | 97 | 96 | 3 | 2 | | | 1 | | | 2 | | | | |
| | R Ball | Right | 31 | 40 | | 2 | 3 | 2 | | 1 | | | | | 66 | 55 |
| 5 DH | G Arrow | Left | | | 1 | 1 | | 2 | 8 | 18 | 88 | 74 | 3 | 4 | | |
| | G Ball | Center | 2 | 2 | 97 | 91 | 2 | 5 | | 1 | | | | | | |
| | G Ball | Right | | 1 | 14 | 18 | 86 | 74 | | 1 | | | | | | 6 |
| 8 DH & Sign | G Arrow | Left | 1 | 1 | | | | | 21 | 23 | 57 | 41 | 22 | 34 | | 1 |
| | R Ball | Center | 98 | 95 | 3 | 1 | | | | 1 | | | | 2 | | 1 |
| | R Ball | Right | 36 | 45 | 1 | 2 | 2 | 2 | | | | | | 1 | 62 | 50 |
| 15 4 St | G Arrow | Left | | 2 | | | | 1 | 5 | 15 | 93 | 79 | 1 | 3 | | |
| | R Ball | Center | 98 | 99 | 1 | | | | | 1 | | | | | | |
| | R Ball | Right | 35 | 43 | 1 | | 3 | 1 | | | | | 1 | 1 | 60 | 55 |

Shading indicates statistical significance at the 0.01 level.

Table 4. Percent distribution of subject responses (subject n = 121 < 65, 126 > 65+) (continued).

| Stimulus # | Response | | (1) Stop or remain stopped | | (2) Proceed straight | | (3) Proceed straight or turn right | | (4) Turn left when there is a large enough gap in oncoming traffic | | (5) Turn left without stopping because you have the right of way | | (6) Stop, but can turn **left** when there is large enough gap in oncoming traffic | | (7) Stop, but can turn **right** when there is large enough gap in oncoming traffic | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Signal/Lane | Subject Age | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ |
| 9 DH | | Left | 8 | 19 | | 1 | | | 55 | 44 | 5 | 12 | 32 | 21 | | 2 |
| | G Ball | Center | 3 | 2 | 95 | 94 | 3 | 2 | | 1 | | 1 | | | | |
| | G Ball | Right | 1 | | 14 | 16 | 84 | 79 | | | | 1 | | | 2 | 4 |
| 10 DH | G Ball | Left | 12 | 20 | | 2 | | | 58 | 44 | 4 | 10 | 26 | 21 | | 2 |
| | | Center | 1 | 3 | 98 | 91 | 2 | 4 | | 1 | | 1 | | | | |
| | G Ball | Right | | 1 | 13 | 17 | 85 | 80 | | 1 | | | | | 2 | 2 |
| 16 DH | G Ball | Left | 7 | 12 | | 2 | 1 | 1 | 65 | 38 | 4 | 20 | 23 | 23 | | 2 |
| | | Center | 5 | 2 | 93 | 98 | 2 | | | | | | | | | |
| | G Ball | Right | 1 | 1 | 14 | 21 | 82 | 74 | | | 1 | | | | 3 | 4 |
| 6 DH & Sign | G Ball | Left | 2 | 7 | | 1 | | 1 | 54 | 52 | 2 | 7 | 41 | 29 | 1 | 1 |
| | | Center | 2 | 6 | 96 | 88 | 2 | 4 | | 1 | | | | 1 | | |
| | G Ball | Right | | 1 | 15 | 18 | 84 | 77 | | 1 | | 1 | | | 1 | 2 |

**Shading indicates statistical significance at the 0.01 level.**

Table 4. Percent distribution of subject responses (subject n = 121 < 65, 126 > 65+) (continued).

| Stimulus # | Response / Signal | Lane | (1) Stop or remain stopped | | (2) Proceed straight | | (3) Proceed straight or turn right | | (4) Turn left when there is a large enough gap in oncoming traffic | | (5) Turn left without stopping because you have the right of way | | (6) Stop, but can turn **left** when there is large enough gap in oncoming traffic | | (7) Stop, but can turn **right** when there is large enough gap in oncoming traffic | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Subject Age | | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ |
| 14 DH & Sign | G Ball | Left | 3 | 8 | | | | 1 | 57 | 46 | 5 | 10 | 35 | 34 | | 1 |
| | | Center | 3 | 5 | 95 | 90 | 1 | 4 | | 1 | | | 1 | | | |
| | G Ball | Right | 1 | 2 | 12 | 19 | 85 | 72 | | 1 | | 2 | | 1 | 2 | 4 |
| 12 4 St | G Ball | Left | 1 | 6 | | 2 | 1 | 3 | 62 | 52 | 14 | 19 | 22 | 17 | | |
| | G Ball | Center | 3 | 4 | 96 | 91 | 1 | 4 | | 1 | 1 | | | | | |
| | G Ball | Right | | 1 | 11 | 20 | 87 | 74 | | | | 2 | | | 3 | 4 |
| 3 3 St | G Ball | Left | 3 | 4 | 1 | 2 | | 2 | 60 | 58 | 9 | 7 | 27 | 24 | | |
| | | Center | 5 | 4 | 93 | 93 | 1 | 2 | 1 | | | | | 1 | | |
| | G Ball | Right | 3 | 1 | 14 | 18 | 81 | 75 | | | | | | | 2 | 6 |
| 4 5 St | R Arrow (flashing) | Left | 34 | 44 | | | | | 7 | 18 | 1 | 1 | 58 | 36 | 1 | 2 |
| | G Ball | Center | 2 | 3 | 98 | 94 | | 3 | | | | | | | | |
| | G Ball | Right | 1 | 1 | 17 | 24 | 82 | 72 | | 1 | | 1 | | 1 | 1 | |

Shading indicates statistical significance at the 0.01 level.

Table 4. Percent distribution of subject responses (subject n = 121 < 65, 126 > 65+) (continued).

| Stimulus # | Response | | (1) Stop or remain stopped | | (2) Proceed straight | | (3) Proceed straight or turn right | | (4) Turn left when there is a large enough gap in oncoming traffic | | (5) Turn left without stopping because you have the right of way | | (6) Stop, but can turn **left** when there is large enough gap in oncoming traffic | | (7) Stop, but can turn **right** when there is large enough gap in oncoming traffic | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Signal/Lane | Subject Age | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ |
| 7 5 St | Y Ball (flashing) | Left | 12 | 16 | | | | | 47 | 44 | 3 | | 39 | 40 | | |
| | G Ball | Center | 4 | 5 | 95 | 91 | 1 | 3 | | | | | | | | |
| | G Ball | Right | 1 | 1 | 15 | 18 | 84 | 79 | | | | | | | | 1 |
| 11 5 St | R Ball (flashing) | Left | 32 | 41 | | | | 1 | 8 | 10 | | 2 | 59 | 47 | 1 | 1 |
| | G Ball | Center | 4 | 4 | 94 | 93 | 1 | 2 | | | | | 1 | 1 | | |
| | G Ball | Right | 1 | 2 | 14 | 18 | 83 | 77 | | | | | | | 3 | 3 |
| 1 5 St | R Ball | Left | 98 | 94 | | | | | 1 | 3 | 1 | 1 | 1 | 2 | | |
| | R Ball | Center | 100 | 98 | | 2 | | | | | | | | | | |
| | R Ball | Right | 38 | 44 | | | 3 | 6 | | | | | | | 60 | 50 |
| 13 3 St | R Ball | Left | 92 | 82 | | | | | 3 | 8 | | | 5 | 9 | | |
| | | Center | 98 | 96 | | 2 | | | | 1 | | | | | 1 | 1 |
| | R Ball | Right | 31 | 37 | 1 | | 2 | 4 | | 2 | | 1 | | 2 | 65 | 53 |

**Shading indicates statistical significance at the 0.01 level.**

stimulus condition/lane of travel has a double box. When the differences between the percentage of older drivers and the percentage of older drivers and the percentage of younger drivers providing the correct response is statistically significant, the double box has been shaded. Statistical significance was determined using a Chi-square and a probability level of ≤ 0.01.

The first four stimuli listed (nos. 2, 5, 8 and 15) were for protected left-turn movement situations. The correct response for this situation is no. 5. In three of the four situations, the older drivers provided significantly fewer correct responses than the younger drivers. The older drivers apparently do not understand that the green arrow provides for a protected movement. They tended to indicate that they would either stop and turn when there was a gap in traffic (response no. 6) or turn only when there was a gap in traffic (response no. 4). It is interesting that the advisory sign R10-12 LEFT TURN MUST YIELD ON GREEN (ball) produced confusion for both age groups (stimulus no. 8). Both groups were more likely to wait for a gap in traffic when the sign was included. In these four situations, both age groups performed very similarly when specifying movements for both the center and right lanes. Both groups also failed to understand that they could turn right on red after stopping in the right lane (response no. 7). Although older drivers failed to do so more frequently than younger drivers, the differences were not significant.

The next seven stimulus conditions (nos. 9, 10, 16, 6, 14, 12, and 3) depicted permitted left-turn movements. The correct response for these situations was no. 4. Although older drivers again had a lower percentage of correct responses in all seven situations, the differences were significant in only one case (no. 16). The incorrect responses selected by both older and younger drivers are especially interesting. Depending on the specific stimulus configuration, between 17 and 34 percent of the older drivers and 23 to 41 percent of the younger drivers indicated that they would stop before turning left (response no. 6). Perhaps even more surprising is that between 4 and 20 percent of the older drivers and 1 and 12 percent of the younger drivers would stop and remain stopped when confronted with a permitted green ball left-turn indication. The highest levels of this type of incorrect response were made to stimulus no. 10, which depicted the permitted movement following a protected movement (i.e., the pre-stimulus scene had an amber arrow). Although not necessarily hazardous behavior, both of these responses could result in rear-end accidents and would seriously reduce intersection capacity.

The most potentially dangerous misinterpretation of a permitted signal situation is for drivers to believe that it is actually a protected situation and that they have the right of way. A surprising number of drivers in both groups indicated that they would turn without stopping because they have the right of way (response no. 5). Stimulus no. 12 was the most misunderstood. Stimulus no. 12 showed three red balls changing to three green balls, one for each of the three traffic lanes. The left lane had a 4-lens stacked signal head with an unlit left arrow. Fourteen percent of the younger drivers and 19 percent of the older drivers indicated that they would turn left without stopping because they have the right of way (response no. 5). This is an alarmingly high percentage of both driver groups who do not understand the permitted left-turn signal in this configuration. Stimuli nos. 6 and 9 depict identical signalization scenes—an amber arrow over the left lane changing to a green ball. Stimulus no. 6 has the LEFT TURN MUST YIELD ON GREEN (ball) sign. The addition of the sign produced a small decrease of 3 to 4 percentage points in the number of older and younger drivers choosing response no. 5. In fact, stimulus no. 6 had the lowest percentage of drivers choosing the potentially dangerous response (2 percent of the younger drivers and 7 percent of the older drivers). However, stimulus no. 6 also had very high percentages of both age groups indicating that they would stop before turning left into a suitable gap (41 percent of the younger drivers and 29 percent of the older drivers). This was also the response frequently chosen when the same sign was shown with the protected green arrow signal (stimulus no. 16). It is clear that the LEFT TURN MUST YIELD ON GREEN sign does not improve the driver's understanding of the protected/permitted left-turn signalization.

The next three stimulus conditions (nos. 4, 7, and 11) show the special permitted signalization configurations used by Delaware, Washington State, and Michigan. Although there is no reason to believe that the test subjects—since they lived in Virginia, Maryland, and New York—were familiar with these configurations, they were included to see if they had any intrinsic meaning that made them more effective than the current standards.

- Delaware uses a flashing red arrow to indicate a permitted left-turn movement. However, traffic must stop before turning. Fifty-eight percent of the younger drivers and 36 percent of the older drivers selected the correct response (no. 6). This difference between the two age groups is statistically significant. However, most of the remaining drivers (32 percent of the younger group and 44 percent of the older group) indicated that they would stop or remain stopped. This is the highest percentage of that response provided to any of the permitted left-turn signals.

- Washington State uses a flashing amber ball to indicate a permitted left-turn movement. Although slightly less than half of the drivers provided the correct response (no. 4), most of the remainder indicated they would turn left into an acceptable gap after stopping. Although 12 percent of the younger drivers and 16 percent of the older drivers indicated they would stop or remain stopped, very few (3 percent of the younger drivers) confused this permitted indication with a protected movement. In this respect, the Washington State flashing amber ball was better than any of the standard permitted signal displays.

- The Michigan permitted left-turn signal display is a flashing red ball. Although about half of both age groups correctly indicated that they would stop and turn when there was a large enough gap (response no. 6), about a third of each group indicated that they would stop or remain stopped (response no. 1). As was the case with both the Delaware and Washington State permitted displays, almost none of the drivers confused the Michigan permitted signal with a protected phase (response no. 5).

The last two stimulus conditions (nos. 1 and 13) showed all red indications and were included as "distractors" among the test cases. Stimulus no. 1 had three separate signal heads, one over each lane. The left lane had a 5-lens stacked signal with unlit turn arrows. Stimulus no. 13 had two separate 3-lens signals with the through lane and the left-turn lane sharing one signal. Although most of the drivers provided correct responses to these stimuli, it is interesting that 8 percent of the younger drivers and 17 percent of the older drivers indicated they would either turn left when there was a large enough gap (response no. 4) or stop and then turn left (response no. 6) when faced with a shared 3-lens signal over the left-turn lane (stimulus no. 13). Apparently some drivers do not understand that the signal controls all lane movements, including those in the left-turn lane.

## AGGREGATED DATA

The preceding discussion addressed the subject responses to each of the signalization scenes individually. In three of the four protected left-turn situations, older drivers provided significantly fewer correct responses than younger drivers. In one of the seven permitted left-turn situations, older drivers performed significantly worse. This section aggregates the individual test scenarios and discusses the results in terms of percentage of correct responses to different categories of test scenes and the distribution of the number of correct responses by age category.

Table 5 shows the percentage of young and old subjects providing correct responses to all 16 of the left-turn scenes. The table shows the percentage of each group that provides from 3 to 16 correct answers. The younger drivers got an average of 10.85 (68 percent) correct, while the older drivers got an average of 8.90 (55 percent) correct. As shown, this difference is significant at the 0.0005 level.

Table 6 shows the percentage of young and old subjects providing from 0 to 4 correct responses to the four scenes involving <u>protected left-turn movements</u>. The younger drivers got an average of 3.23 (81 percent) correct, while the older drivers got 2.56 (64 percent) correct. This difference is significant at the 0.0005 level.

Table 7 shows the percentage of young and old subjects providing from 0 to 7 correct responses to the seven scenes involving standard <u>permitted left-turn signals</u>. The younger drivers got an average of 4.09 (58 percent) correct, while the older drivers got 3.33 (48 percent) correct. This difference is significant at the 0.01 level.

The differences between younger and older drivers, relative to understanding the left-turn signalization, is also apparent in situations involving right-turn and through-movement signalization. Table 8 shows the percentage of drivers responding correctly to the 16 right-turn scenes. The younger drivers got an average of 12.35 (77 percent) correct, while the older drivers got 10.96 (68 percent) correct. This difference is significant at the 0.027 level. Most of the errors by both age groups involve subjects not realizing that both turn right and proceed straight from the right-most lane were correct as well as those who did not realize that they could turn right on red. However, neither response would result in especially dangerous driving behavior.

Table 9 shows the percentage of drivers responding correctly to the 16 through-lane scenes. The mean number correct for the younger drivers was 15.40 (96 percent), while the older drivers got 14.98 (94 percent) correct. Although this difference is significant at the 0.047 level, it does not represent a very meaningful difference.

Table 5. Percentage of young and old subjects providing number of correct responses to all left-turn scenes.

| Percentage of subjects responding correctly to | Young (n=121) | Old (n=126) |
|---|---|---|
| 0 Questions | 0 | 0 |
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 3 | 0 | 2 |
| 4 | 1 | 4 |
| 5 | 5 | 10 |
| 6 | 5 | 8 |
| 7 | 7 | 10 |
| 8 | 11 | 14 |
| 9 | 5 | 14 |
| 10 | 8 | 6 |
| 11 | 12 | 11 |
| 12 | 12 | 10 |
| 13 | 12 | 5 |
| 14 | 10 | 4 |
| 15 | 6 | 2 |
| 16 | 7 | 2 |
| Mean number correct | 10.85 | 8.90 |
| Standard deviation | 3.14 | 2.98 |
| Standard error | 0.29 | 0.27 |
| t-value (pooled variance) | 5.02 | |
| 2-tail probability | < 0.0005 | |

Table 6. Percentage of young and old subjects providing number of correct responses to "protected" and left-turn scenes.

| Percentage of subjects responding correctly to | Young (n=121) | Old (n=126) |
|---|---|---|
| 0 Questions | 2 | 12 |
| 1 | 3 | 10 |
| 2 | 13 | 17 |
| 3 | 31 | 35 |
| 4 | 51 | 27 |
| Mean number correct | 3.23 | 2.56 |
| Standard deviation | 0.97 | 1.31 |
| Standard error | 0.09 | 0.12 |
| t-value (pooled variance) | 4.63 | |
| 2-tail probability | < 0.0005 | |

Table 7. Percentage of young and old subjects providing number of correct responses to "permitted" left-turn scenes.

| Percentage of subjects responding correctly to | Young (n=121) | Old (n=126) |
|---|---|---|
| 0 Questions | 8 | 13 |
| 1 | 16 | 13 |
| 2 | 7 | 13 |
| 3 | 7 | 15 |
| 4 | 11 | 13 |
| 5 | 14 | 13 |
| 6 | 15 | 13 |
| 7 | 22 | 7 |
| Mean number correct | 4.09 | 3.33 |
| Standard deviation | 2.43 | 2.18 |
| Standard error | 0.22 | 0.19 |
| t-value (pooled variance) | 2.61 | |
| 2-tail probability | 0.010 | |

Table 8. Percentage of young and old subjects providing number of correct responses to all right-turn scenes.

| Percentage of subjects responding correctly to | Young (n=121) | Old (n=126) |
|---|---|---|
| 0 Questions | 7 | 7 |
| 1 | 0 | 4 |
| 2 | 1 | 2 |
| 3 | 1 | 2 |
| 4 | 0 | 1 |
| 5 | 2 | 2 |
| 6 | 2 | 1 |
| 7 | 1 | 2 |
| 8 | 2 | 6 |
| 9 | 2 | 2 |
| 10 | 3 | 5 |
| 11 | 13 | 10 |
| 12 | 2 | 5 |
| 13 | 7 | 13 |
| 14 | 7 | 7 |
| 15 | 16 | 15 |
| 16 | 34 | 17 |
| Mean number correct | 12.35 | 10.96 |
| Standard deviation | 4.68 | 5.07 |
| Standard error | 0.43 | 0.45 |
| t-value (pooled variance) | 2.23 | |
| 2-tail probability | 0.027 | |

Table 9. Percentage of young and old subjects providing number of correct responses to all through-lane scenes.

| Percentage of subjects responding correctly to | Young (n=121) | Old (n=126) |
|---|---|---|
| 0 Questions | 0 | 0 |
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 3 | 0 | 0 |
| 4 | 0 | 0 |
| 5 | 0 | 0 |
| 6 | 1 | 0 |
| 7 | 0 | 1 |
| 8 | 0 | 0 |
| 9 | 1 | 2 |
| 10 | 1 | 2 |
| 11 | 2 | 3 |
| 12 | 1 | 2 |
| 13 | 1 | 6 |
| 14 | 5 | 10 |
| 15 | 17 | 13 |
| 16 | 72 | 62 |
| Mean number correct | 15.40 | 14.98 |
| Standard deviation | 1.48 | 1.77 |
| Standard error | 0.13 | 0.16 |
| t-value (separated variance) | 2.00 | |
| 2-tail probability | 0.047 | |

To determine if there is a relationship between age and signal comprehension, scatter plots and regression statistics were computed. The results of these runs for the entire subject group (n=247) and for all subjects age 65 and older (n=126) are shown in table 10. For all test situations, there is a small negative correlation between subject age and the number of correct responses, i.e., older subjects tend to have a slightly lower level of signal comprehension. For the entire sample, the correlation ranged from -0.311 for all left-turn situations combined to -0.114 for the right-turn situations. As shown by the R-squared values, these correlations indicated that age accounts for less than 10 percent of the variance in comprehension scores.

Within the sample of older drivers, the correlations are even smaller, ranging from a high of -0.137 for the permitted left-turn situations to a low of -0.017 for the middle-lane situations. The R-squared values indicate that age accounts for less than 2 percent of the variance in the test scenes. This indicates that the older old drivers do not tend to have lower comprehension levels than the younger old drivers.

Table 10. Correlations between subject age and number of correct responses.

| Test Scene | No. of Scenes | All Subjects (n=247) | | Subjects over 65 years (n=126) | |
|---|---|---|---|---|---|
| | | Correlation | R-Squared | Correlation | R-Squared |
| Protected left-turn situations | 4 | -0.305 | 0.093 | -0.064 | 0.004 |
| Permitted left-turn situations | 7 | -0.144 | 0.021 | -0.137 | 0.019 |
| All left-turn situations | 16 | -0.311 | 0.097 | -0.120 | 0.014 |
| Middle lane situations | 16 | -0.143 | 0.020 | -0.017 | 0.000 |
| Right-turn situations | 16 | -0.114 | 0.013 | -0.097 | 0.009 |
| All situations | 48 | -0.251 | 0.063 | -0.126 | 0.016 |

## CONCLUSIONS

This study shows conclusively that older drivers do not understand the protected/ permitted left-turn signalization as well as younger drivers. However, the most important finding is that *neither* group has an acceptable level of comprehension associated with left-turn signalization. It would be inappropriate to develop countermeasures targeted only at older drivers. Instead, efforts should be directed toward improving the comprehension levels of the entire driving population.

# 6. DEVELOPMENT AND EVALUATION OF A PEDESTRIAN SIGNAL EDUCATIONAL PLACARD

## BACKGROUND

The purpose of the Pedestrian Signal Educational Placard Study was to determine if pedestrian comprehension of and compliance with the pedestrian signals could be improved by installing a placard explaining the three phases of the pedestrian signal. Many different versions of the placards have been tried in a number of different cities. Typically, the wording used on these educational placards was developed using a combination of engineering judgment and group consensus. A variety of different areas—large cities, towns, and suburban locations—have installed educational placards. Although most places that have installed the placards report that they are pleased with the result, there have been no rigorous evaluations of placard effectiveness.

This study was conducted to accomplish two objectives. The first was to experimentally develop the wording/phrases to be used on a pedestrian signal educational placard. A description follows of the procedures used to develop the wording for the placard. The second objective was to experimentally demonstrate the effect of the signal educational placard on pedestrian comprehension and/or compliance. The results of the field evaluation are also described.

## PLACARD DEVELOPMENT

### Focus Group/Workshop

A combination focus group and workshop was conducted with 13 participants in Baltimore, MD. The purpose of the meeting was to find out what pedestrians think the pedestrian signals actually mean. Another aim was to gather opinions about how best to format the information to appear on the instructional placard. The placard would eventually be used in an open field test to study compliance with and comprehension of the pedestrian signal. Six men and seven women ranging in age from 19 to 62 years old took part in the 2 hours of activities. An incentive of $30 was given at the conclusion of the meeting.

At the beginning of the workshop, a brief presentation was made by the moderator to explain the concept of a focus group and how the workshop would operate. An overview of the subject matter was presented to include the purpose of the research project, the use of the instructional placard, word choices, placement of the information on the sign, and other sign-related elements.

The first activity consisted of having the participants write their own meanings for the three phases of the pedestrian signal. This was an independent activity and prior discussions did not include any actual meanings, so the subjects responded strictly from their own knowledge and/or opinion. A sheet with both a word and a symbol placard was distributed. Blank space was provided and the participants were instructed to fill in what they thought each signal phase meant.

All 13 participants understood the meaning of the word and symbol WALK phase of the pedestrian signal. They scored nearly as well on the STEADY DON'T WALK phase with only one potentially incorrect response that could lead to a dangerous action. The FLASHING DON'T WALK phase was the most misunderstood. Only two people knew the correct meaning for both word and symbol signs; five answered just partially correct for the word sign and three for the symbol sign. A total of 11 responses could have led to dangerous action: 7 were for the symbol sign and 4 were for the word sign. Three responses were completely incorrect, of which two were for the word sign.

At the conclusion of the first activity, the moderator explained the actual meaning of each phase of the pedestrian signal and circulated a number of different copies of instructional placards that are now, or have been, used by different States. Optional information, such as "watch for turning vehicles," was reviewed.

The next part of the workshop was a "design-a-sign" activity. Here the participants were given three envelopes each that contained precut messages for each signal phase. The messages were all words that are currently used on instructional placards throughout the United States and Canada. The participants were also given a 20- by 28-cm (8- by 11-in) copy of a blank placard. They were instructed to open one envelope at a time and read all the message choices. They were then asked to tape the best meaning or combination of meanings in the space next to each phase of the sign. This was done for all three phases of the word sign. The activity was repeated using a blank symbol placard with the same message choices.

While there were no clear cut "winning messages" for any of the phases, there were certain trends. The most frequently selected messages were used for the questionnaires that were later distributed at various locations in several cities.

The last portion of the focus group/workshop dealt with a number of issues that would improve the legibility of, and attention to, the instructional placard. Twelve participants were asked for their preference by a simple show of hands regarding the following questions. Examples of each of the choices were shown.

1. Do you prefer highlighting of key words on the sign? (dark background behind words such as DON'T START). All 12 participants preferred highlighting.

2. Do you think the word FLASHING should appear above or below the message DON'T CROSS? Eight preferred above; four preferred below the message.

3. Do you prefer the word STEADY or SOLID above the message DON'T CROSS? Ten preferred the word STEADY and four preferred the word SOLID.

4. Do you like a sign with the colors green for the WALK, orange for the FLASHING DON'T WALK, and red for the STEADY DON'T WALK phases, or do you prefer white for the WALK and orange for the two DON'T WALK phases? Nine preferred the green, orange, and red combination, while four chose the white and orange combination.

5. Which do you like best, the use of DO NOT or DON'T? Ten participants chose DO NOT and two preferred DON'T.

6. Do you think additional information such as WATCH FOR TURNING VEHICLES should appear on the WALK phase? Of the 12 people, 10 responded that they did like additional information.

7. Do you prefer the phrase WATCH FOR versus LOOK FOR? Nine people preferred WATCH FOR and three people thought LOOK FOR was best.

8. Which type of signs do you prefer—words or symbols? There was a unanimous vote of 12 for symbol signs.

**DMV Questionnaires**

The information from the focus group/workshop was reviewed and a questionnaire was developed for use at Division of Motor Vehicle (DMV) offices in Fredericksburg and Northern Virginia. The purpose of the questionnaire was to find out what pedestrians think is the best way to explain the real meanings of the pedestrian signal phases.

Two pilot test questionnaires were prepared. They were conducted at the DMV in Fredericksburg, VA, with 11 people taking the first test and another 11 people taking the second test.

For the first questionnaire, the subjects reviewed a sample placard with a description of the meaning of, and actions necessary for, each phase of the signal. A separate page was used for each signal phase with six message choices for the WALK phase and eight choices each for the FLASHING DON'T WALK and STEADY DON'T WALK phases. Under each choice was space for the subjects to rank order the messages. At the bottom of each signal phase page, there was room for the subjects to write in their own suggested meaning. Of the 11 pilot tests conducted, only 3 suggested meanings were given. For the FLASHING DON'T WALK phase, one person thought it should read IF STARTED DO NOT CONTINUE, RESUME FROM THE POSITION FROM WHERE STARTED. For the STEADY DON'T WALK phase, one person thought it should just say DON'T WALK, and another person thought it should say ENTER AT OWN RISK.

A second pilot test was developed that allowed the subjects to better address the rating system of choice. Participants reviewed the exact same message choices, however, this time they circled the number 1 for "very good," 2 for "good," 3 for "fair," 4 for "poor," and 5 for "very poor." Due to a lack of message suggestions from the subjects who took the first test, that portion was deleted on the second test.

From the mixed results of the pilot tests, a revised questionnaire was developed with the same basic five-point scale. Two message choices for the FLASHING DON'T WALK and the STEADY DON'T WALK phases were eliminated based on poor scores. The words DO NOT START were added to IF IN CROSSWALK CONTINUE message for the FLASHING DON'T WALK phase.

Twenty-five questionnaires were administered at DMV offices in Northern Virginia. Thirteen men and twelve women participated, ranging in age from 24 to 80 years old. One-half of the total group were age 60 or older.

A number of issues developed at this point regarding the format of the questionnaire. Many of the participants did not seem to grasp the concept of the instructional placard as an actual sign that correlated with the pedestrian signal and its three phases.

A revised questionnaire was developed that allowed the participants to have a full-page sample of the instructional placard at hand to refer to during the test. The directions and signal phase meanings were also streamlined.

In addition, the subjects were rating many of the message choices very favorably and it was thought that some messages would work better in conjunction with other messages when creating a full sign with all three phases included. Therefore, another activity was included at the end of the test that had the subjects select their best choice from the available messages for each phase of the signal. A large placard illustration was provided with space for the participants to write in their choice.

Twenty-five of the new questionnaires were completed at DMV offices in Fairfax and Fredericksburg, VA. Eleven men and fourteen women participated. The age range of the subjects was from 21 to 58 years old.

Further eliminations of definitions were made based on the results of the revised questionnaire. For the WALK phase, YOU MAY START CROSSING THE ROADWAY IN THE CROSSWALK AND IN THE DIRECTION OF THE SIGNAL scored the poorest and was chosen as the favorite meaning by only one person. START CROSSING also ranked poorly and was not selected as the best choice by anyone. These two definitions were dropped from the study. The word "cars" was substituted for "vehicles" so that OK TO CROSS WATCH FOR TURNING CARS and START CROSSING WATCH FOR TURNING CARS could be tested more consistently.

For the FLASHING DON'T WALK phase of the test, the message—IF YOU ARE CROSSING THE ROAD WHEN THIS SIGNAL APPEARS, YOU MAY CONTINUE TO CROSS. IF YOU HAVE NOT YET STARTED TO CROSS, DO NOT ENTER THE ROADWAY—was also eliminated because of how poorly it ranked and the fact that none of the subjects chose it as the best definition.

It was appropriate to drop two definition choices from the STEADY DON'T WALK phase of the questionnaire. WAIT ON CURB ranked the poorest and was not chosen as a favorite meaning. Although DO NOT START—WAIT FOR THE WALK SIGNAL ranked fairly well, it was chosen only twice as a favorite message. And referring back to the focus group/workshop, the conjugation of "do not" was substituted so that DO NOT CROSS WAIT ON CURB and DO NOT CROSS were used in the next version of the questionnaire. This permitted uniformity throughout the test on that issue.

By eliminating the least popular responses, the next version of the questionnaire consisted of four message choices for the WALK phase and five message choices each for the FLASHING DON'T WALK and the STEADY DON'T WALK phases of the instructional placard. Twenty-six additional questionnaires were administered at the Fairfax, VA, DMV.

A final questionnaire was prepared using the three best definitions for each phase of the pedestrian signal. A combination of the ranking and first preference scores was used.

Another layout of the questionnaire was pilot tested at a DMV office in Northern Virginia and was found to work somewhat better. The instructions remained the same, but the placement of the message choices and the five-point rating scale were placed horizontally on the page.

Sixty of the final questionnaires were administered at various locations in Buffalo, NY. Of the 60 tests, 32 were taken by subjects age 60 or older.

Table 11 shows the average rank for each of the message choices as well as the percentage of the subjects who selected each message as their first choice. The columns labeled "Older" give the values for the 32 subjects who were age 60 or older. The "All Ages" column represents all 60 subjects. Both CROSS WITH CAUTION and OK TO CROSS, WATCH FOR TURNING CARS did very well as WALK phase messages. Because the caution regarding turning vehicles is not universally applicable at all signalized intersections and because of possible legal implications, it was decided to proceed with the most highly ranked message, CROSS WITH CAUTION. The best messages for the other two signal phases were more convincing winners.

## RESULTS/CONCLUSIONS

The final recommendations are based on the focus group discussions and the series of questionnaires administered to 225 drivers at four Virginia DMV offices. The recommended format for the pedestrian signal education placard is shown in figure 2.

Table 11. Message choices by signal phase.

| | Average Rank | | First Choice, % | |
|---|---|---|---|---|
| WALK Phase Definitions | Older | All Ages | Older | All Ages |
| 1. Cross with Caution | 1.68 | 1.85 | 42 | 43 |
| 2. OK to Cross. Watch for Turning Cars | 1.75 | 1.96 | 42 | 40 |
| 3. OK to Cross | 2.59 | 2.88 | 16 | 17 |
| | | | | |
| Flashing DON'T WALK Phase Definitions | | | | |
| 1. Do Not Start. If in Crosswalk Continue | 1.62 | 2.11 | 58 | 49 |
| 2. Do Not Enter Crosswalk. If in Crosswalk Continue. | 2.43 | 2.61 | 19 | 29 |
| 3. Finish Crossing if Started. Do Not Start. | 2.12 | 2.53 | 23 | 22 |
| | | | | |
| Steady DON'T WALK Phase Definitions | | | | |
| 1. Do Not Enter Crosswalk | 1.75 | 2.05 | 19 | 13 |
| 2. Do Not Cross. Wait for Walk Signal. | 1.46 | 1.75 | 32 | 38 |
| 3. Do Not Cross | 1.43 | 1.68 | 49 | 49 |

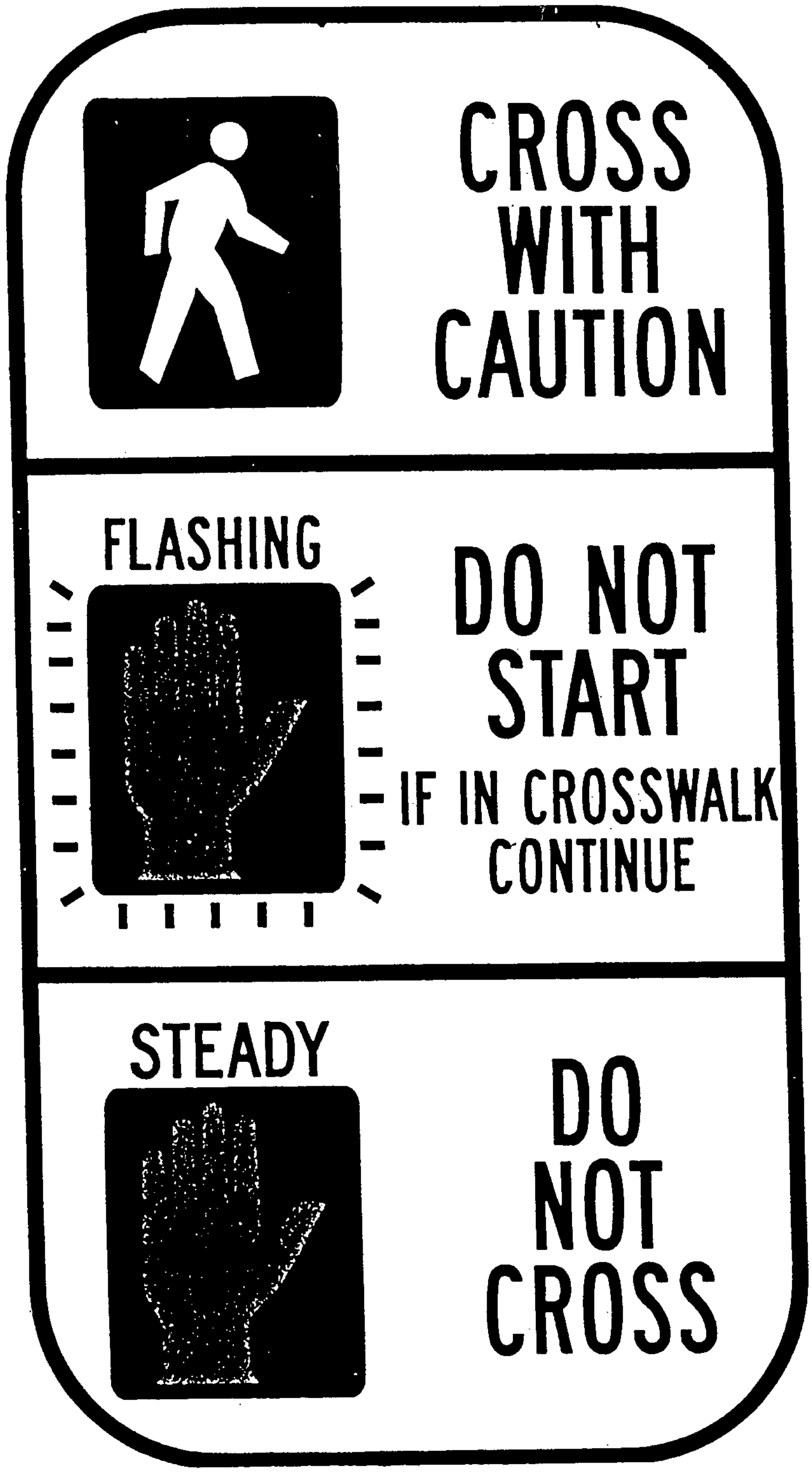



Figure 2. Recommended format for an educational placard.

## FIELD EVALUATION OF THE PEDESTRIAN SIGNAL EDUCATION PLACARD

The pedestrian signal education placards were installed at six intersections, two in each of three cities: Baltimore, MD; Buffalo, NY; and Richmond, VA. Six similar locations, at least 10 blocks from the experimental sites, were also selected to serve as control locations and received no treatment. These 12 locations included 3 with symbolic pedestrian symbols and 9 with word signals. Seven were on major arterials, four were on collector distributors, and one was on a local street. All of the roadways were between 10.7 and 16.8 m (35 and 55 ft) wide and had two or three through-traffic lanes. None had medians. Three had pedestrian-actuated pedestrian signals, while nine did not. All 12 locations had marked crosswalks; 9 were of the standard configuration, while 3 had high-visibility markings. Half of the locations included a one-way street.

The six experimental locations typically had one placard installed at each crosswalk approach. The number of placards installed was limited by the number of available mounting locations. The placards were placed 122 cm (48 in) from the sidewalk facing pedestrians approaching each crosswalk. Of the 6 experimental sites, 2 had 11 placards and 7, 8, 10, and 12 placards were mounted at 1 location each. Signal timing at the sites was as follows:

| | |
|---|---|
| WALK time: | 9 to 63 s |
| Flashing DON'T WALK time: | 5 to 22 s |
| Steady DON'T WALK time: | 28 to 86 s |

The hypothesized effects of installing the pedestrian education placards were that they would result in an increased understanding of the pedestrian signal phasing and increased compliance.

Pedestrian signal compliance was measured by counting the number of pedestrians crossing on each phase (WALK, flashing DON'T WALK, and steady DON'T WALK) for a minimum of 50 signal cycles at each experimental and control location. This was done before the placards were installed and during an equal number of cycles about 30 days after the placards were installed. A total of 2,071 pedestrians were observed at the experimental sites and 2,272 at the control sites. The distribution of the pedestrians observed across the three signal phases is presented in table 12. The table shows the percentage of pedestrians at each experimental site and each control site that started to cross during each of the three signal phases. In addition, a cumulative total for all six experimental sites and all six control sites is shown. If the placards produced the desired effect, we would expect more pedestrians to cross during the WALK phase and fewer to start crossing during both the flashing DON'T WALK and steady DON'T WALK phases. As is evident from the figures shown, no such effect is indicated. Three of the experimental sites did show a slight increase in the percentage of pedestrians crossing on the WALK signal. However, two sites showed a decrease and the cumulative total for all experimental sites indicated a 2-percent *reduction* in the number of pedestrians crossing during the WALK phase. The control sites showed similar variability, three increased percentages, two decreased percentages, and one site with no change. Overall, the control sites showed a 2-percent *increase* in the number of pedestrians crossing during the WALK phase.

The changes in the percentage of pedestrians crossing during the flashing DON'T WALK and steady DON'T WALK phases show the same trends evident in the WALK cycle. Of all the distributions shown, only the changes found at the control sites—Baltimore Site 2 with an 8-percent increase during the WALK phase and Buffalo Site 3 with a 13-percent decrease during the WALK phase—were significant at the 0.01 level (t-test).

Additional analyses revealed no differences in signal compliance by age or sex. It appears that pedestrian crossing behavior is influenced by factors other than the signal phase, i.e., the presence of traffic. The fact that fewer pedestrians cross during the flashing DON'T WALK than during the steady DON'T WALK is probably because the flashing DON'T WALK indication is of a shorter duration so there is less opportunity for pedestrians to cross.

Because pedestrian signal compliance is dependent on a variety of factors, specifically the presence or absence of approaching traffic, other pedestrians, etc., additional analyses of compliance behavior were conducted. Rather than base the analysis on the percentage of pedestrians observed, it was decided to consider compliance or noncompliance during each signal cycle as the basic unit of analysis. A cycle-by-cycle analysis was performed to identify the percentage of signal cycles when no noncompliance occurred (i.e., no pedestrians started to cross).

If pedestrians never started to cross during the flashing DON'T WALK or the steady DON'T WALK, then 100 percent of the cycles would have full compliance. As is evident in table 13, this is very rarely the case. The experimental sites in the "before" phase had compliance percentages for the flashing DON'T WALK that varied from 86 to 100 percent. In the "after" phase at the experimental sites, the percentage of compliance to both phases increased in two cases, decreased in four cases, and showed no change at one site (Baltimore Site 1). Across all experimental sites, there was a 4-percent *decrease*. The control sites showed similar changes with an overall 2-percent decrease. During the steady DON'T WALK phase, both the experimental and the control sites showed similar changes in the percentage of signal cycles with no noncompliance. None of the changes in compliance behavior shown in table 12 is significant at the 0.01 level (t-test).

The pedestrian signal compliance data indicates that the pedestrian education placards failed to produce the desired change in pedestrian behavior. Additional analyses were conducted on the information provided by pedestrian crossings at both the experimental and the control locations. During the before and after phases of the study, 30 pedestrians at each experimental and each control site were interviewed to determine their understanding of the 3 pedestrian signal phases. There were a total of 720 pedestrians (30 at each of 6 experimental and 6 control sites before and after). The results of these interviews are shown in table 14. It is evident that a relatively high percentage of the pedestrians understand the meaning of both the WALK and steady DON'T WALK phases. It is also evident that the pedestrians interviewed *do not* understand the meaning of the flashing DON'T WALK phase.

Perhaps the most interesting finding from the subject interviews was the lack of comprehension associated with the flashing DON'T WALK phase. To determine the nature of this lack of comprehension, the subject responses were recoded to indicate the level of comprehension along three different levels of meaning: (1) whether the pedestrians indicated an understanding that the flashing DON'T WALK phase is different from the steady DON'T WALK phase; (2) whether the pedestrians indicated that they would behave any differently in response to the flashing DON'T WALK as opposed to the steady DON'T WALK; and (3) whether the pedestrians understood that there was a "clearance aspect" associated with the flashing DON'T WALK, i.e., that the signal was going to change. It was hypothesized that the placards may have produced a change in one or more of these aspects of understanding the flashing DON'T WALK, even though no changes in crossing behavior or overall comprehension were found.

Table 15 shows the percentage of pedestrians who indicated that they understood that there was a difference between the two DON'T WALK phases. There is a lot of variability across sites with no change at one experimental site, an improvement of 10 percentage points at one experimental site, and a decrease at all other sites. Of all the changes indicated, only the 18-percentage-point decrease across all control sites combined is statistically significant. Apparently the placard did not improve pedestrian understanding of the fact that the steady DON'T WALK phase is different from the flashing DON'T WALK phase.

Table 16 shows the percentage of pedestrians who indicated that they walk differently when the flashing DON'T WALK is on. Typically, they said they would "stop," "wait," "not start," "hurry up," "not go," or "not walk" when the DON'T WALK began to flash. Although there is some variability across sites, the totals for all experimental and control sites, both before and after placard installation, are remarkably similar. None of the differences shown are statistically significant. Apparently the placard had no effect on this aspect of signal-phase understanding.

Table 17 shows the percentage of pedestrians demonstrating an understanding of the clearance aspect of the flashing DON'T WALK signal. As was the case in the previous two tables, the results are not supportive of an improvement attributable to the placard. There was no change at one experimental site, a relatively small increase in understanding at two experimental sites, and unexplained decreases at three experimental sites and all of the control sites. Only the difference indicated for all control sites combined was found to be statistically significant.

## FIELD TEST RESULTS/CONCLUSIONS OF THE FIELD EVALUATION

In this field test at six experimental locations in three cities, the pedestrian signal education placard failed to produce a change in pedestrian crossing behavior, pedestrian signal compliance, or pedestrian signal-phase comprehension. The placards were in place for 30 to 45 days between the collection of "before" and "after" data. During the "after" interviews, it was found that only 28.9 percent of the pedestrians interviewed indicated that they had actually seen the placards at the intersection. It is not known, of course, if this is an accurate indication of the number of people who actually saw the placard. Analyses of the differences between the behavior and comprehension of those who reported seeing the placard and those who said they had not seen the placard found no differences. It may be that a positive effect may accrue if the placards are in place for a longer time so that more pedestrians may actually read them.

## COMPREHENSION TESTING OF THE PEDESTRIAN SIGNAL EDUCATION PLACARD

Because of the somewhat disappointing results of the field evaluation of the pedestrian signal education placard, it was decided to conduct an additional experiment to see if exposure to the placard could increase understanding of the pedestrian signal phasing. Because only 28.9 percent of the pedestrians interviewed during the field study reported that they had seen the placard, this seemed to be a reasonable next step.

A simple before-and-after testing procedure was used. Subjects were given a questionnaire to test their understanding of the WALK, flashing DON'T WALK, and steady DON'T WALK signal phases. A copy of that questionnaire is included as figure 3. The subjects were then handed one of the placards and were asked to study it. After several minutes, the experimenter took the placard back and administered another questionnaire. The subjects were selected from individuals waiting in DMV offices in Buffalo, NY; Fairfax, VA; and Edgewood, MD. Thirty subjects were tested at each location, except for Buffalo where 32 subjects were tested.

The results of the testing are shown in table 18. The first question concerns the meaning of the WALK indication. The test subjects generally understood the meaning of the WALK signal (question 1) and little improvement was noted, except in Edgewood where there was a 30-percent increase in comprehension level. Overall, there was a significant 12-percent increase in comprehension. The subjects also tended to understand the meaning of the steady DON'T WALK signal (question 2) and no improvement was found, again except in Edgewood where there was a 27-percent improvement. Across all sites this produced a 9-percent improvement. The test subjects tended to understand the meaning of the flashing DON'T WALK when they were standing on the curb—even in Edgewood (question 3). There were slight improvements in Fairfax and Edgewood, but a slight decrease in Buffalo. The comprehension level increased overall by 2 percent.

A major source of confusion regarding the pedestrian signal phasing involves the meaning of the flashing DON'T WALK when one is in the street (question 4). Exposure to the placard increased comprehension by 10 percent in Fairfax, 13 percent in Edgewood, and 6 percent in Buffalo. Across all sites, this accounted for a significant 10-percent increase in signal comprehension.

The McNemar test for the significance of changes was used to compare the before and after responses. Since the frequencies of changed responses were small, the binomial distribution was used to compute probabilities. Using a two-tailed test, there were significant differences for question 1 at Edgewood, and for questions 1 and 4 for all locations combined.

## RESULTS/CONCLUSIONS

The wording for a pedestrian signal-phase education placard was developed using focus groups and a series of questionnaires administered to a total of 225 drivers at 4 different DMV offices in Virginia and New York. The newly developed placard was installed at six intersections in Virginia, Maryland, and New York. Observational studies of more than 4,300 pedestrians during 600 signal cycles found no change in pedestrian signal compliance. Pedestrian crossing behavior appears to be more affected by the presence or absence of traffic than it is by the signal indication. If they can safely cross, they will do so regardless of the signal. Interviews conducted with 720 pedestrians at the test and control locations found no increase in the pedestrians' comprehension of the signal phasing. However, less than one-third of the pedestrians interviewed actually saw the placard at the intersections. As a followup activity, questionnaires were administered to 92 subjects at DMV's in New York, Maryland, and Virginia. It was found that exposure to the placard resulted in a significant increase in understanding of the phases of the pedestrian signal.

It is believed that the lack of effect found in the field study was due to the relatively small number of placards installed (eight at each of six intersections) and the relatively short time between signal installation and testing (30 to 45 days). Based on the positive results of the questionnaire, exposure to the placard can produce a change in understanding. The phrasing of the message for the placard developed for this project was based on quantitative procedures using a relatively large number of subjects. It is recommended that local engineers who wish to install signal education placards use this wording.

Subject No._________
Location __________
Age _____ Sex _____
B _____ A ______

## PEDESTRIAN SIGNAL STUDY

We would like you to answer several questions about pedestrian signals like these:


When you are <u>at the curb</u> and ready to cross, what does it <u>mean</u> when the WALK signal is on? Choose the one best answer.

_____ You can cross without worrying about turning vehicles.
_____ You can cross if you hurry.
_____ You can cross with caution.
_____ You should wait for the light to change.

When you are <u>at the curb</u> and ready to cross, what does it <u>mean</u> when the WALK signal turns off and the DON'T WALK signal starts flashing? Choose the one best answer.

_____ You can cross because there is still enough time.
_____ You should watch for turning vehicles before crossing.
_____ You should hurry across the street.
_____ You should not start crossing.

When you are <u>at the curb</u> and ready to cross, what does it <u>mean</u> when the DON'T WALK signal stops flashing and stays on steady? Choose the one best answer.

_____ You should not cross.
_____ You can cross if you hurry.
_____ You should watch for turning vehicles before crossing.
_____ You should look both ways before crossing.

When you have already started <u>crossing the street</u>, what does it <u>mean</u> when the WALK signal turns off and the DON'T WALK signal starts flashing? Choose the one best answer.

_____ You should go back to the curb.
_____ You should continue crossing.
_____ You should run or walk faster.
_____ You should stop where you are and wait.

Figure 3. Pedestrian signal comprehension questionnaire.

Table 12. Pedestrian crossing behavior—percentage of all pedestrians crossing by signal phase.

| Location | Signal Phase | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | WALK | | | Flashing DON'T WALK | | | Steady DON'T WALK | | |
| | Before | After | Change in % | Before | After | Change in % | Before | After | Change in % |
| **Experimental Sites** | | | | | | | | | |
| Baltimore Site 1 | 61 | 64 | +3 | 6 | 12 | +6 | 33 | 24 | -9 |
| Baltimore Site 3 | 63 | 55 | -8 | 3 | 4 | +1 | 34 | 41 | +7 |
| Richmond Site 8 | 22 | 22 | 0 | 5 | 4 | -1 | 73 | 74 | +1 |
| Richmond Site 10 | 45 | 41 | -4 | 4 | 8 | +4 | 51 | 51 | 0 |
| Buffalo Site 1 | 49 | 52 | +3 | 3 | 0 | -3 | 49 | 48 | -1 |
| Buffalo Site 2 | 13 | 14 | +1 | 0 | 0 | 0 | 87 | 86 | -1 |
| All Experimental Sites (n = 2,071 pedestrians) | 44 | 42 | -2 | 4 | 5 | +1 | 53 | 53 | 0 |
| **Control Sites** | | | | | | | | | |
| Baltimore Site 2 | 59 | 67 | +8* | 3 | 6 | +3 | 39 | 27 | -12 |
| Baltimore Site 4 | 48 | 56 | +8 | 6 | 7 | +1 | 45 | 36 | -9 |
| Richmond Site 7 | 43 | 46 | +3 | 3 | 4 | +1 | 54 | 50 | -4 |
| Richmond Site 9 | 30 | 30 | 0 | 5 | 8 | +3 | 65 | 62 | -3 |
| Buffalo Site 3 | 30 | 17 | -13* | 3 | 0 | -3 | 67 | 83 | +16 |
| Buffalo Site 4 | 39 | 29 | -10 | 1 | 1 | 0 | 60 | 71 | +11 |
| All Control Sites (n = 2,272 pedestrians) | 43 | 45 | +2 | 4 | 5 | +1 | 53 | 51 | -2 |

* Denotes differences between before and after that are significant at the 0.01 level.

Table 13. Pedestrian signal compliance—percentage of signal cycles with full compliance with flashing DON'T WALK and steady DON'T WALK signals.

| Location | Signal Phase | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Flashing DON'T WALK | | | Steady DON'T WALK | | | Both Flashing and Steady | | |
| | Before | After | % change | Before | After | % change | Before | After | % change |
| **Experimental Sites** | | | | | | | | | |
| Baltimore Site 1 | 92 | 83 | -9* | 63 | 67 | +4 | 59 | 59 | 0 |
| Baltimore Site 3 | 88 | 91 | +3 | 50 | 36 | -14 | 46 | 33 | -13 |
| Richmond Site 8 | 89 | 90 | +1 | 9 | 8 | -1 | 9 | 7 | -2 |
| Richmond Site 10 | 90 | 77 | -13 | 6 | 10 | +4 | 6 | 10 | +4 |
| Buffalo Site 1 | 93 | 100 | +7 | 39 | 32 | -7 | 39 | 32 | -7 |
| Buffalo Site 2 | 100 | 100 | 0 | 9 | 10 | +1 | 9 | 10 | +1 |
| All Experimental Sites (n = 686 pedestrians) | 92 | 91 | -1 | 29 | 26 | -3 | 28 | 24 | -4 |
| **Control Sites** | | | | | | | | | |
| Baltimore Site 2 | 91 | 84 | -7 | 26 | 50 | +24 | 23 | 41 | +17 |
| Baltimore Site 4 | 77 | 77 | 0 | 30 | 36 | +6 | 21 | 25 | +4 |
| Richmond Site 7 | 92 | 88 | -4 | 23 | 9 | -14 | 23 | 9 | -14 |
| Richmond Site 9 | 93 | 84 | -9 | 13 | 12 | -1 | 13 | 8 | -5 |
| Buffalo Site 3 | 95 | 100 | +5 | 28 | 15 | -13 | 23 | 15 | -8 |
| Buffalo Site 4 | 98 | 98 | 0 | 29 | 24 | -5 | 27 | 23 | -4 |
| All Control Sites (n = 721 pedestrians) | 92 | 89 | -3 | 25 | 24 | -1 | 22 | 20 | -2 |

* Denotes differences between before and after that are significant at the 0.01 level.

Table 14. Signal phase comprehension—percentage of subjects indicating understanding of WALK, flashing DON'T WALK, and steady DON'T WALK signal indications.

| Location | Signal Phase | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | WALK | | | Flashing DON'T WALK | | | Steady DON'T WALK | | |
| | Before | After | Change in % | Before | After | Change in % | Before | After | Change in % |
| **Experimental Sites** | | | | | | | | | |
| Baltimore Site 1 | 93 | 100 | +7 | 50 | 23 | -27 | 90 | 100 | +10 |
| Baltimore Site 3 | 100 | 100 | 0 | 57 | 17 | -40* | 100 | 100 | 0 |
| Richmond Site 8 | 97 | 93 | -4 | 10 | 0 | -10 | 90 | 77 | -13 |
| Richmond Site 10 | 100 | 100 | 0 | 7 | 10 | +3 | 87 | 83 | -4 |
| Buffalo Site 1 | 100 | 100 | 0 | 27 | 13 | -14 | 100 | 100 | 0 |
| Buffalo Site 2 | 100 | 100 | 0 | 10 | 20 | +10 | 100 | 100 | 0 |
| All Experimental Sites (n = 360 pedestrians) | 98 | 99 | +1 | 27 | 14 | -13* | 94 | 93 | -1 |
| **Control Sites** | | | | | | | | | |
| Baltimore Site 2 | 100 | 97 | -3 | 57 | 20 | -37* | 97 | 93 | -4 |
| Baltimore Site 4 | 97 | 97 | 0 | 70 | 33 | -37* | 93 | 97 | +4 |
| Richmond Site 7 | 100 | 100 | 0 | 7 | 0 | -7 | 87 | 80 | -7 |
| Richmond Site 9 | 97 | 100 | +3 | 7 | 7 | 0 | 93 | 63 | -30* |
| Buffalo Site 3 | 100 | 100 | 0 | 13 | 0 | -13 | 100 | 100 | 0 |
| Buffalo Site 4 | 100 | 100 | 0 | 17 | 10 | -7 | 100 | 100 | 0 |
| All Control Sites (n = 360 pedestrians) | 99 | 99 | 0 | 28 | 12 | -16* | 95 | 89 | -6 |

* Denotes differences between before and after that are significant at the 0.01 level.

Table 15. Signal comprehension—percentage of subjects indicating a difference between flashing DON'T WALK and steady DON'T WALK signal phases.

| Location | Before | After | Change in % |
|---|---|---|---|
| **Experimental Sites** | | | |
| Baltimore Site 1 | 100 | 100 | 0 |
| Baltimore Site 3 | 100 | 79 | -21 |
| Richmond Site 8 | 70 | 54 | -16 |
| Richmond Site 10 | 68 | 63 | -5 |
| Buffalo Site 1 | 63 | 73 | +10 |
| Buffalo Site 2 | 52 | 41 | -11 |
| All Experimental Sites (n = 360 pedestrians) | 76 | 67 | -9 |
| | | | |
| **Control Sites** | | | |
| Baltimore Site 2 | 100 | 89 | -11 |
| Baltimore Site 4 | 96 | 95 | -1 |
| Richmond Site 7 | 61 | 35 | -26 |
| Richmond Site 9 | 89 | 54 | -35* |
| Buffalo Site 3 | 73 | 58 | -15 |
| Buffalo Site 4 | 70 | 46 | -24 |
| All Control Sites (n = 360 pedestrians) | 82 | 64 | -18* |

* Denotes differences between before and after that are significant at the 0.01 level.

Table 16. Signal comprehension—percentage of subjects indicating a difference in walking behavior during flashing DON'T WALK and steady DON'T WALK signal phases.

| Location | Before | After | Change in % |
|---|---|---|---|
| **Experimental Sites** | | | |
| Baltimore Site 1 | 57 | 37 | -20 |
| Baltimore Site 3 | 59 | 59 | 0 |
| Richmond Site 8 | 46 | 45 | -1 |
| Richmond Site 10 | 48 | 45 | -3 |
| Buffalo Site 1 | 76 | 48 | -28 |
| Buffalo Site 2 | 59 | 85 | +26 |
| All Experimental Sites | 58 | 54 | -4 |
| | | | |
| **Control Sites** | | | |
| Baltimore Site 2 | 57 | 28 | -29 |
| Baltimore Site 4 | 70 | 62 | -8 |
| Richmond Site 7 | 44 | 54 | +10 |
| Richmond Site 9 | 42 | 56 | +14 |
| Buffalo Site 3 | 58 | 58 | 0 |
| Buffalo Site 4 | 62 | 71 | +9 |
| All Control Sites | 56 | 54 | -2 |

Table 17. Percentage of subjects indicating an understanding of the clearance aspect of the flashing DON'T WALK phase.

| Location | Before | After | Change in % |
|---|---|---|---|
| **Experimental Sites** | | | |
| Baltimore Site 1 | 100 | 100 | 0 |
| Baltimore Site 3 | 100 | 80 | -20 |
| Richmond Site 8 | 74 | 57 | -17 |
| Richmond Site 10 | 71 | 77 | +6 |
| Buffalo Site 1 | 65 | 73 | +8 |
| Buffalo Site 2 | 58 | 45 | -13 |
| All Experimental Sites | 78 | 70 | -8 |
| | | | |
| **Control Sites** | | | |
| Baltimore Site 2 | 100 | 93 | -7 |
| Baltimore Site 4 | 96 | 90 | -6 |
| Richmond Site 7 | 64 | 46 | -18 |
| Richmond Site 9 | 89 | 67 | -22 |
| Buffalo Site 3 | 73 | 59 | -14 |
| Buffalo Site 4 | 68 | 48 | -20 |
| All Control Sites | 82 | 66 | -16* |

* Denotes differences between before and after that are significant at the 0.01 level.

Table 18. Percentage of subjects providing correct responses to pedestrian signal phase questions.

| Location/Before-After | Question Number* | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Fairfax, VA | | | | |
| Before | 97 | 97 | 93 | 57 |
| After | 100 | 97 | 97 | 67 |
| Edgewood, MD | | | | |
| Before | 63** | 53 | 83 | 30 |
| After | 93 | 80 | 90 | 43 |
| Buffalo, NY | | | | |
| Before | 75 | 81 | 94 | 44 |
| After | 78 | 81 | 91 | 50 |
| All Locations | | | | |
| Before | 78 | 77 | 90 | 43 |
| After | 90 | 86 | 92 | 53 |
| % Improvement | 12** | 9 | 2 | 10** |

* See figure 3.

** Denotes differences between before and after that are significant at the 0.05 level.

# 7. THE TRAFFIC SIGNAL RESPONSES AND STOPPING BEHAVIOR OF OLDER DRIVERS

A controlled field experiment was conducted to study the decision/reaction times and deceleration rate characteristics of older drivers. In the experiment, subjects drove through a test course where their responses to standard traffic signals could be measured. Instrumentation was installed to determine accelerator and brake pedal applications as well as vehicle acceleration and deceleration characteristics. By having the subjects drive their own vehicle, it was felt that more realistic results would be obtained because the subject would not have to drive an unfamiliar instrumented test vehicle. The traffic signal responses, decision/reaction times, and deceleration rate characteristics of a sample of older drivers were compared with a sample of younger drivers.

The discussion that follows addresses specific topics:

RESEARCH PROCEDURE
- Test Location
- Subject Recruitment
- Subject Testing
- Test Instrumentation
- Traffic Signal Control and Display Subsystem
- Onboard Vehicle Instrumentation System
- Data Collection Subsystem

RESULTS
- Data Reduction/Pre-analysis
- Pretest Screening Measures
- Signal Response Characteristics
- Braking Decision Times
- Deceleration Rate Characteristics

## RESEARCH PROCEDURE

A former military housing complex on the Aberdeen (MD) Proving Ground (APG) property was selected as the test site because of its proximity to the Combat Systems Training Activity (CSTA). CSTA provided the vehicle instrumentation.

The test site consisted of several neighborhood streets that circled a park-like setting. The available roadway made up two squares, one inside the other. The inner road was reached by narrower connecting roads. The few existing buildings were either vacant or used for administrative functions. The project team used a room in one of the buildings to welcome test subjects and to administer vision and nondriving tests. The only traffic in the area was in the southeast quadrant of the neighborhood. Police barricades were used to keep the public off of the driving course.

The test site was designed to approximate a typical roadway setting. Double solid center lines, stop bars, and traffic signals were installed. Stop signs were already in place and were also used for the driving test. All testing was conducted during daylight hours so overhead lighting was not necessary.

**Subject Recruitment**

To recruit the more than 80 subjects who were eventually tested, a comprehensive approach was used. Posters and flyers were circulated at senior centers, churches, Rotaries, Masons, VFW, DMV, laundromats, the APG Post, local factories, and shopping centers. Project announcements were placed in local newspapers. A Project Statement was written for the flyer to introduce the study to the public. It was also used to pre-screen respondents on the telephone.

A screening form was developed for use on the telephone (and eventually for partial subject documentation) to handle the response to the advertising. Subjects were required to have a valid driver's license, own or have regular use of a car or van no older than a 1980 model, and drive at least once a week. Subjects were scheduled for weekdays between 8 a.m. and 4 p.m. Reminder calls were made 1 week in advance and again the day before each subject's appointment. Only two people failed to appear; most of the subjects were on time or early for their appointment.

**Subject Pretesting**

A Titmus vision tester was used to determine a subject's acuity for both eyes at a distance. The minimum passing score was established as 20/70 (the legal limit in Maryland is 20/40). Color discrimination for distance was also tested.

A simple reaction-time tester was used to measure, in 1/100 of a second, the subject's ability to detect a blue light illuminating; a green light's intensity; and general identification of red, blue, and green lights activated in random order. The test device consisted of a stimulus box (where the light came through), a lever pad (where the subject could depress the appropriate lever), and a control box with timer. The researcher was instructed to notify the team if any subject seemed confused or unable to respond in a reasonable period of time. Only one subject showed unusually slow reaction times (she was taking medication) and was dropped from the study.

The paper-and-pencil driver survey was a two-page questionnaire that asked the subjects to respond to questions about when, where, why, and how often they drive. It also included a self-rating section that asked the subjects to critique their own driving abilities. Two questions appeared on the survey that specifically asked the drivers about the amber phase of the traffic signal: what the amber light means to them and how they respond to it.

Because most of the subjects were recruited over the telephone, the researcher conducted a brief driving test with each subject before any of the above-mentioned activities to ensure the safety of all involved. To be subtle about the purpose of this test, it was tied into the installation of the equipment in the subject's vehicle. Shortly after arrival, each subject was asked to drive his or her vehicle to the road test site with the researcher riding along. During the drive, the researcher gave verbal directions to the site and observed the subject's ability to listen, follow instructions, and get a sense of each subject's general cognitive abilities. Since a number of the subjects had some hearing loss, the drive helped the researcher prepare for the volume level she would need during the actual test. Also, a rapport was established between the participant and the researcher.

**Subject Testing**

COMSIS and CSTA were responsible for planning and programming the field hardware (traffic switches and cable) and software (computer program). The Maryland State Highway Administration loaned the project team four standard traffic signals with 203-mm (8-in) lenses that were used throughout the testing period.

Three basic post-mounted, vertical traffic signals with 203-mm (8-in) lenses and visors (hoods) were installed. A computer program was developed to randomize both the occurrence of the signal changing from green to amber and the duration of the amber "on" timing at each signal.

The driving course was designed so each subject could drive the course in about 15 minutes, passing through each of the three traffic signals five times. Three stop signs were incorporated into the driving course as distractors. Turning movements left and right, U-turns, and use of turn signals were also written into the program of events.

The researcher used a script with each subject when instructions were given, thus providing consistency throughout the study.

A two-way radio provided communication between the researchers and the CSTA instrumentation van technicians. It was used to communicate the start and end of the test, the start and end of each driving course loop, and any unusual activity on or near the course for safety purposes. This was done succinctly so as to be neither threatening nor distracting.

The complete procedure with all equipment was pilot tested over several days.

Subjects had been notified in advance that their vehicle would be equipped with several devices for the purpose of recording information about their driving performance. They were shown pictures of the instrumentation equipment that would be installed on their vehicle. They were told that two boxes approximately 0.3 m by 0.6 m (1 ft by 2 ft) would be placed in the back seat and trunk of their vehicle. One of the boxes housed the batteries/power source and the other held the telemetry equipment needed to send information to the computer.

Two pieces of conductive aluminum tape were installed onto the brake and accelerator pedals. A conductive piece of copper ribbon was also applied to the subject's shoe to make a switch closure with the accelerator and brake pedals, allowing driving behavior to be recorded.

Each participant was allotted a 2-h block of time. Subjects were welcomed by the two researchers who would conduct all of the activities. The first researcher gave the subjects a brochure describing the equipment that would be installed on their vehicles. The second researcher escorted the subjects back to their vehicles and briefly described the study. The script for this explanation is as follows:

> This is a study of driver behavior. We want to find out how drivers react to different kinds of traffic signals and stop signs. This is not a driving test. We are not testing you or your driving. First we will go over to the test course and I'll show you what it looks like. After you've seen the setup, we'll have your car equipped while you're taking a vision test and filling out a driving survey.

Subjects were then asked to drive to the equipment installation staging area and the driving pre-test was conducted. Once there, the researcher and subjects got out of the vehicle. The researcher quickly checked for any damage to the subjects' vehicles at the points where the equipment would be installed. For the protection of all parties, any scratches or dents were pointed out in advance of instrumentation. At the same time, the researcher showed the subjects exactly where the devices would be placed on the vehicle.

The second researcher then drove the subjects back to the office, where the first researcher conducted the vision test, the laboratory reaction-time test, and the driver survey.

After the vehicle was equipped, the second researcher drove the subjects back to their cars. The researcher showed the subjects a sample of the conductive tape strip to be applied to their shoes. At the staging area, the subjects examined their equipped vehicle and waited to have the tape strip applied to their shoes.

Notations were made about the time of day, the weather, and the foot the subject used for braking. After a few final checks of the equipment and communication system, subjects were instructed to drive to the start of the course, stop their vehicle, put the car in park, and listen to instructions. Below is the script that was used for all of the test subjects.

> We are going to drive through the driving course five times. Please use your turn signals. I will tell you which way to go, whether to turn right or turn left, make a U-turn, or go straight. I will ask you to drive at a specific speed from time to time. I will also ask you to maintain that speed. As we drive, sometimes the traffic signals will change and sometimes they won't. If the amber signal goes on, respond as you normally would. If you feel you have time to stop before the intersection, please try to do so. If you feel you don't have time to stop before the

> intersection, that's fine, too. It's okay to go through the amber light if you can't or don't choose to stop. We don't expect you to do a panic stop or lock up your brakes. We want you to react and stop as you normally would when you see traffic signals and stop signs on regular roads. As we approach each signal, plan on going straight at the signal. I won't suddenly ask you to turn right or left. We will always be going straight at the signal so do not slow down to try to anticipate a last second turning instruction. There won't be any. Are there any questions? Are you ready to begin?

After the final verbal signal from the instrumentation van, subjects were told to "accelerate to 48 km/h (30 mi/h), and to maintain that speed." They were also reminded to go straight at the traffic signal. If the signal changed to amber and subjects stopped, they were instructed to wait at the signal until it changed to green again. This was important in keeping subjects thinking in the "real driving world." At this point, the researcher gave directions for approaching the next traffic signal.

The program for "amber on," "no amber/remain green," and "distance to the signal before amber on" consisted of a different random order for each subject. The researcher did not know what the order would be and therefore made no anticipatory body movements.

The researcher had an onboard speedometer to monitor the subject's speed. Any driver speed adjustments were requested in a friendly and nonthreatening manner. For example, if the subject had not attained 48 km/h (30 mi/h) by the time the signal was "tripped," the researcher would say, "Let's try to go just a little faster" or "I'll let you know when you've reached 48 km/h (30 mi/h) next time." No matter what maneuver the subject executed (stopped or passed through the amber signal), the researcher always responded very casually with, "That's fine" or "All right, very good."

The subject drove two complete course loops at 48 km/h (30 mi/h) passing through three traffic signals and two stop signs for each loop. At the beginning of the third loop, the subject was asked, again, to stop and listen to the following directions:

> For the next several signals, we're going to do something a little different. I'm going to ask you to go 32 km/h (20 mi/h). If the traffic signals change to amber, we'd like you to stop before the intersection if at all possible. But again, we do not expect you to do a panic stop or lock up your brakes. Do you understand? Do you have any questions? Are you ready to begin?

After a signal from the instrumentation van, subjects started the third driving loop, following these instructions for one loop of the driving course, passing through or stopping at three traffic signals and two stop signs. It became obvious that maintaining 32 km/h (20 mi/h) was more difficult than 48 km/h (30 mi/h) and more assistance was necessary from the researcher monitoring the onboard speedometer.

The 32-km/h (20-mi/h) loop served a number of purposes. It was felt that the third loop at a slower speed might help to keep subjects from becoming too familiar with the test. In addition, subjects were asked to brake, if they normally would, for the first two and last two loops, and to brake, if they possibly could, for the third loop. It was felt that the subjects might not "figure out" the purpose of the driving test if there was some variety in the procedure. It also tended to keep the drivers more alert because they could not predict what they might be asked to do.

At the beginning of the fourth loop, the researcher told the subjects to resume driving at 48 km/h (30 mi/h) and if the signal changed, to stop before the intersection if they chose to. This pattern was repeated for the fifth and final loop.

Some of the subjects seemed anxious, especially if they did not stop when the traffic signal changed from green to amber. In such cases, the researcher reminded subjects that they were not being tested, but rather "normal driving behavior was being studied." They were also told repeatedly that they were "doing just fine."

After the fifth loop, a final check was made with the instrumentation van. If additional trials were necessary, instructions were repeated and an additional loop or two was completed. If no extra trials were necessary, subjects were instructed to drive back to the office for payment while the equipment was removed from the vehicle.

Finally, subjects were escorted back to the equipment installation staging area to examine the condition of their vehicle. There was no damage to any of the vehicles that were equipped for the entire project.

A total of 81 subjects participated in the study. The age and gender breakdown of the subjects is shown in table 19. Subsequent analyses will focus on the differences between older drivers (age 65+) and younger drivers (those age 64 and younger).

**Test Instrumentation**

The data acquisition system, shown in figure 4, consisted of instrumentation to monitor, control, and record test vehicle characteristics, driver reactions, and test conditions. The system comprised three subsystems: a traffic signal control and display component, an onboard vehicle instrumentation component, and a data collection component. Table 20 lists the major components. A description of each subsystem follows.

**Traffic Signal Control and Display Subsystem**

Three traffic signals were used for this subsystem. The signals were on loan from the Maryland State Highway Administration for the duration of the test. The signal heads were standard, pole-mount red-green-amber (RGA) models with 203-mm (8-in) lenses, "poly" housings, and sun shields. Each light housed three 60W, 120-VAC bulbs. The green lens was located approximately 2.75 m (9 ft) above the road surface. Power at each signal light was supplied by generator. The signals were mounted on frames

Table 19. Participating subjects by age and gender.

| Age | Male | Female |
|---|---|---|
| 71 and older | 7 | 5 |
| 65-70 | 12 | 13 |
| 60-64 | 8 | 6 |
| 50-59 | 8 | 12 |
| 40-49 | 3 | 3 |
| under 40 | 2 | 2 |
| TOTAL | 40 | 41 |

made of 102-mm (4-in) schedule 40 polyvinyl chloride (PVC) pipe. The frames were designed to allow rapid setup and teardown each day.

Signals were controlled by a network of relays connected via hardwire to a single PC-mounted data acquisition and control board. The PC board included eight isolated digital inputs and eight relay outputs. Each signal head operated independently and was activated by one or two of the PC board relays based on a timing algorithm. These relay closures allowed a 16- to 18-VDC power supply to flow through the coils of two additional relays at each signal head. The two relays at each signal head were then used to switch the 120-VAC power to the individual signal lights. The design of this circuit allowed only one signal head bulb to be on at any given time. The signal controls were carried to the signal head relays over six-conductor telephone wire. This configuration allowed the use of modular telephone jacks and plugs for rapid daily deployment and storage. The maximum distance of the signal heads from the control PC was approximately 244 m (800 ft).

For each signal, a tapeswitch was placed 91.5 m (300 ft) before the signal. This signal provided a contact closure signal to the data acquisition board for signal identification and timing purposes. This signal was passed using the six-conductor wire as well.

The PC board was programmed in BASICA. For each subject session, the software provided a randomized presentation order and online accounting of individual trial completion and requirements for reruns. The program also provided a running description of each test case parameter (i.e., amber delay, amber on, and red on time) and event-specific information about which tapeswitch was activated, the trial number, and the condition of the relevant signal lights on the computer monitor in the test van. In addition, the speed of the vehicle was displayed after the tapeswitch was triggered for each trial. Each time a subject vehicle passed the tapeswitch, the time-coded event was captured by the signal control PC. After logging this event, the signal

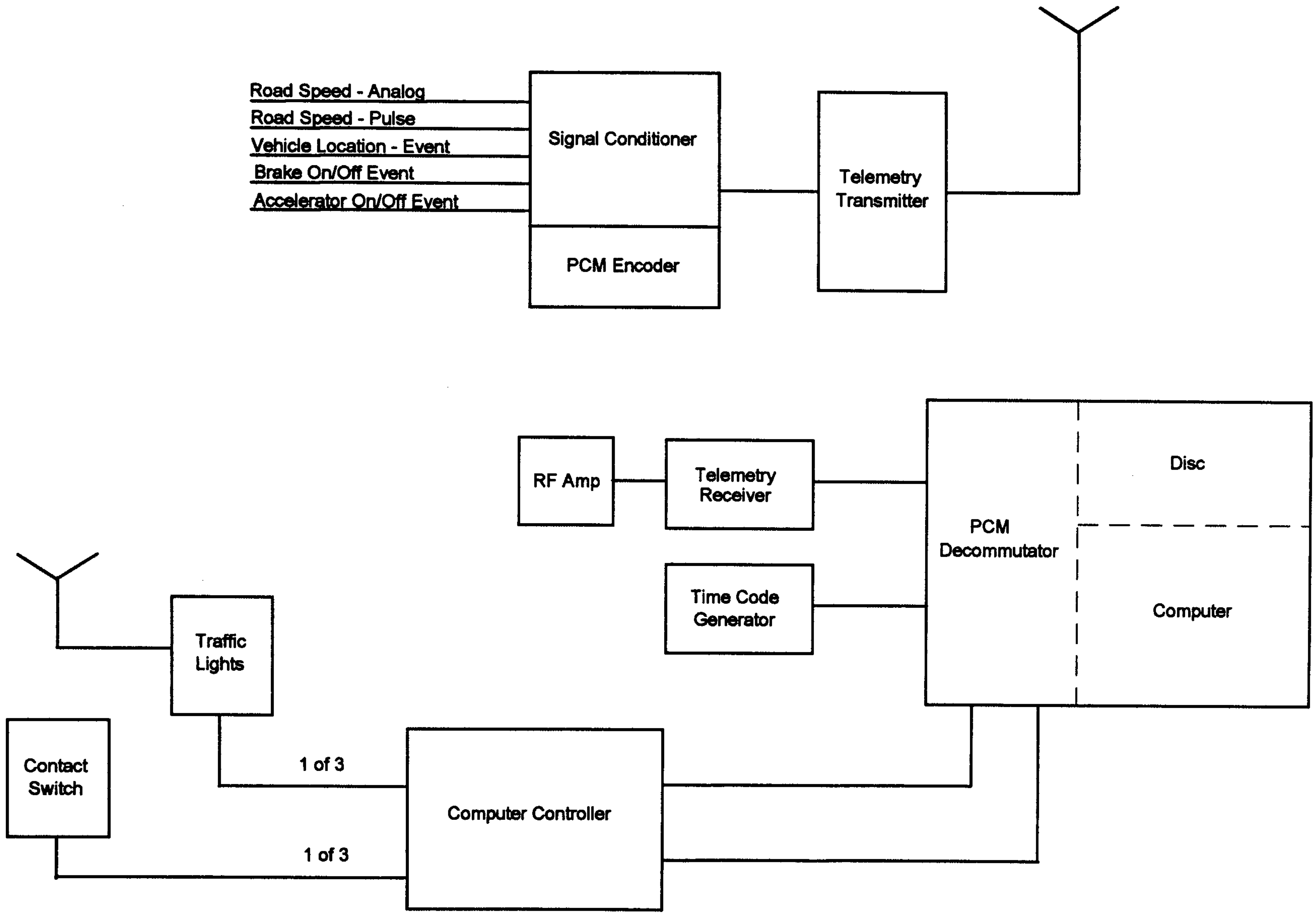



Figure 4. Driver reaction study instrumentation system.

Table 20. Driver reaction study instrumentation.

| Name | Manufacturer | Model |
|---|---|---|
| Signal Conditioner | Metraplex | 760 |
| Telemetry Transmitter | Conic | 702 |
| Antennas | Andrew | 55070-17 |
| RF Amplifier | Hewlett-Packard | 8449B |
| Telemetry Receiver | Scientific Atlanta | 410WA |
| PCM Decommutator/ Computer/Disc | VEDA | ITAS-10 |
| Computer Controller | Zenith | 248 |
| Road Speed Transducer | Correvit | CVS-2 |
| Vehicle Location Event | Sick-Optic | WL-20 |
| Brake Event | CSTA | NMN |
| Accelerator Event | CSTA | NMN |
| Data Acquisition/ Control Board | Advantech | PCL-725 |

control PC polled CSTA's data collection computer for the speed of the vehicle at that instant. Using the speed and the known distance of the vehicle, the delay time for the amber signal was calculated and used to control the presentation parameters of the signals for the experiment. Late in the study, the speed information coming from the CSTA computer was found to be highly susceptible to fluctuations that, in some cases, changed the values by up to 100 percent (i.e., 32 km/h [20 mi/h] appeared as nearly 64 km/h [40 mi/h]). This unanticipated fluctuation affected the signal timing algorithm and the test cases used as the basis for comparison among subject trials.

The test cases for the experiment were designed around the amber delay time (i.e., the time before a vehicle was expected to reach the signal that the amber was activated). The study was originally designed to consist of four test cases, with one case maintaining the green light for the trial. The other cases kept a constant value for amber duration and red duration, but varied the amber delay. Initially, these delay parameters were set to 2, 3, and 4 s. An inadvertent change to the parameters early in the study changed them to 3, 3, and 4 s and modified one amber duration parameter to 4 s. A later correction returned the amber duration to 3 s and revised the amber delays to 3, 3.5, and 4 s. However, the erratic ground speed information provided by the CSTA instrumentation caused the actual amber delay times to vary from trial to trial. The data analysis focused on actual, as opposed to planned, amber delays. The 3-s amber duration was chosen to be consistent with the planned approach speeds. A survey of actual amber times in the Aberdeen area showed that the test subjects are exposed to amber durations between 3.43 s and 4.88 s.

**Onboard Vehicle Instrumentation Subsystem**

The onboard vehicle instrumentation subsystem allowed driver performance data to be collected while subjects drove their own vehicles around the test course. This subsystem collected real-time information on vehicle and driver conditions during the trials and relayed it to the data collection subsystem in the instrumentation van by microwave radio communications.

The onboard vehicle instrumentation system took approximately 30 to 45 min to install and verify for each subject's vehicle. Removal normally took less than half that time. Power from two deep-cycle marine batteries allowed the system to operate without using the vehicles' own power supply system. The power supply was normally placed in the trunk or rear compartment, while the data control and transmission component electronics were normally placed in the back seat and buckled in for safety. Components requiring outboard mounting, namely data transmission antenna, optical fifth wheel, and photoelectric position locator, were secured with suction cup mounting hardware for rapid attachment and removal.

Central to the data collection system within the vehicle was a PCM encoder that allowed digital information from several input channels within the vehicle to be coded as a digital data word for transmission over the radio link to the data collection subsystem at a rate of approximately 1000 Hz. Five data input channels were used for this subsystem, including:

- Optical Fifth Wheel Speed Sensor.
  - Digital output
  - Analog output
- Photoelectric Position Locator.
- Brake Contact Sensor.
- Accelerator Contact Sensor.
- Study Administrator's Signal Button.

The optical fifth wheel, a Datron Messtechnik Correvit model, uses a pulse counting system that provides 400 pulses/m (or once every ¼ cm). It was used to record information on speed and distance as well as deceleration for the subject trials. Analog data were also sent to the data recording van as a backup to the digital distance information. This analog signal was used in calculating the signal timing parameters as well. The photoelectric position locator was used to provide a redundant indication of the point of tapeswitch activation. Retroreflective targets, measuring 0.19 $m^2$ (2 $ft^2$), were placed parallel to the tapeswitches to ensure that a pulse of sufficient length would be recognized by the data collection system when the vehicles passed this point. The brake and accelerator contact sensors provided information about the position of the driver's foot (or feet in the case of drivers who used both feet to control the pedals) before and during deceleration. These sensors consisted of a pair of contacts (conductive aluminum tape) placed in two strips across the respective pedals and tailored for individual pedals and driver foot placement characteristics. In addition, the driver's shoes were fitted with a small piece of conductive copper cloth (used in military applications for electromagnetic interference shielding) that would close the circuit between the two conductive strips each time the driver's shoes were placed across them. These contact sensors provided acceptable shoe presence detection, but no indication of the force with which the brake or accelerator pedals were being depressed. The researcher who rode with each subject controlled a signal button to inform the data collection system operator of the subject's imminent approach to a given signal light. This kept data recording to a minimum for data volume control purposes and provided a reliable indication of subject location to the data collection system operator who often had limited or no visual contact with the subject vehicle during a test session.

**Data Collection Subsystem**

The data collection system was located in a CSTA Instrumentation Van (CIV) parked centrally to the signal head locations to facilitate minimal control and power cable lengths during the study. The CIV was a self-contained van with an onboard diesel generator for power. Within the van were computer racks and electronics storage, assembly, and operation space for all phases of test instrumentation in remote locations. The data collection system consisted of several components for performing the required activities. A microwave band radio receiver was used to receive the real-time data from the subject vehicle at about 400 samples per second. A time code generator was used to provide highly accurate timing information to the data collection computer. A PCM decommutator was used to decode the transmitted information from the vehicle for logging as a binary data word on the data collection computer. A data collection computer tapped the signals from the traffic signal-head activation events, provided some simplistic processing and display of the pertinent information, and temporarily stored the digital information from the onboard vehicle sensors and signal heads to a RAM file for later downloading onto floppy disks. This computer also provided the analog speed information to the traffic signal control computer for signal timing. Two-way voice radios were also available within the CIV for study personnel coordination and emergency communication with the CSTA instrumentation offices, located about 8 km (5 mi) away.

During the study execution, one person was located in the CIV at all times to control the data collection instrumentation. This person was responsible for starting and stopping the data collection process as the subjects approached and passed each signal, respectively. This person also started the signal timing routine that operated essentially unattended after that unless a trial had to be repeated. He was also responsible for instructing the computer to repeat any required trials. At the end of a given subject session, this person downloaded the data from the data collection computer onto floppy disks for backup storage and further data reduction off line.

## RESULTS

### Data Reduction/Pre-Analysis

As described in the preceding discussion of research procedures, an enormous amount of data was recorded every one-hundredth of a second. CSTA did not have the capability to generate files for a mainframe computer, so all data files were sent to the Center for Applied Research (CAR) in compressed format on 88.9-mm (3.5-in) diskettes for a personal computer.

There were 81 subjects, each with 15 data files, for a total of 1,290 data files. Each data file consisted of 800 to 1,100 records representing one trial. Each record had 220 columns and 22 variables. This accounted for 1,392,940 records or 30,644,680 variables or 306,446,800 columns of data.

The data files were uncompressed and checked for errors. These included tapeswitch errors, data transmission errors, other equipment errors, and human errors. The onset of data collection was inconsistent for the various runs within subjects and between subjects. Data collected before 91.5 m (300 ft) from a signal were eliminated. The optical trigger to start the distance counter did not always operate. Sometimes the signal switches indicated that more than one signal was operating. Occasionally, electrical pulses invalidated the data from the trial. All these errors had to be checked for and eliminated from the data base.

About 80 percent of the data records were usable. The data records were reduced, reformatted, and rewritten so the data could be analyzed. There are 86 data files, 1 file per subject, and each record consists of 10 variables. These variables are trial number, time from data collection onset (hundredths of seconds), speed (fps [ft/s]), deceleration (ft/s/s), distance from tape switch (ft), accelerator on/off, brake on/off, signal (light 1, 2, or 3), amber on/off, and red on/off. Because all the runs made by each subject did not produce usable data, the number of subjects in each analysis varies. The discussion that follows involves a detailed analysis of this data set.

### Pretest Screening Measures

As described, before participating in the field test, subjects were given a test for visual acuity and color discrimination, three simple reaction time tests, and were asked to complete a brief questionnaire about their driving habits and their driving abilities. The results of this pretest screening is shown in table 21.

The simple reaction time measures were taken using a Lafayette Model 6302B Reaction Time Tester. The first measure, "stimulus on," had the subjects press a telegraph key when a blue stimulus light was turned on. The mean values shown are the total elapsed time (in milliseconds). There were no differences between the younger and the older drivers. The second measure involved having the subjects press a telegraph key when they observed a green stimulus light increase in intensity.

Table 21. Pretest screening measures: young vs. old drivers (age 65+).
(from ABERDN 11.LIS)

| Measure | Young Drivers | | | Old Drivers | | | t-value | d.f. | Prob* |
|---|---|---|---|---|---|---|---|---|---|
| | N | mean | SD | N | mean | SD | | | |
| Reaction Time - Stimulus On (ms) | 39 | 518.08 | 90.85 | 32 | 539.00 | 67.36 | 1.08 | 69 | 0.28 |
| Reaction Time - Intensity Change (ms) | 39 | 445.36 | 64.95 | 32 | 482.97 | 64.72 | 2.43 | 69 | 0.02 |
| Reaction Time - Stimulus ID (ms) | 39 | 756.71 | 142.18 | 32 | 914.56 | 207.52 | 3.64 | 53.4 | 0.001 |
| Visual Acuity: Both Eyes/Far (Titmus acuity test value) | 39 | 27.69 | 15.91 | 32 | 30.50 | 15.64 | 0.75 | 69 | 0.46 |
| Color Discrimination (Titmus color test value) | 39 | 4.69 | 1.30 | 32 | 4.22 | 1.22 | 1.57 | 69 | 0.12 |
| Years Driving | 38 | 34.57 | 10.00 | 32 | 50.19 | 10.71 | 6.29 | 68 | <0.001 |
| Miles Driven per Year | 39 | 4.03 | 1.33 | 32 | 3.47 | 1.37 | 1.74 | 69 | 0.09 |
| Trips per Week | 39 | 2.97 | 1.01 | 32 | 2.66 | 1.23 | 1.19 | 69 | 0.24 |
| Driving Ability/City Streets | 39 | 2.18 | 0.79 | 32 | 2.47 | 0.57 | 1.74 | 69 | 0.09 |
| Driving Ability/Country Roads | 39 | 2.05 | 0.79 | 32 | 2.25 | 0.72 | 1.10 | 69 | 0.28 |
| Driving Ability/Night | 39 | 2.74 | 0.75 | 32 | 2.91 | 0.59 | 1.00 | 69 | 0.32 |
| Driving Ability/Freeways: Light Traffic | 38 | 1.97 | 0.75 | 31 | 2.29 | 0.74 | 1.75 | 67 | 0.08 |
| Driving Ability/Freeways: Rush Hour | 39 | 2.46 | 0.97 | 32 | 2.66 | 0.65 | 1.01 | 66.7 | 0.32 |
| Driving Ability/Poor Weather | 39 | 2.51 | 0.94 | 32 | 2.59 | 0.76 | 0.39 | 69 | 0.70 |

* Shading indicates probability $\leq 0.05$.

This is a somewhat more difficult task and the older drivers were significantly slower by about 10 percent. The last reaction time measure had the subjects press either a blue, red, or green telegraph key, depending on whether a blue, red, or green stimulus light was illuminated. This is a much more difficult task and the older subjects were about 20 percent slower than the younger subjects. The difference is significant at the 0.001 level.

A Titmus vision tester (Model OV-7A) was used to measure the visual acuity and color discrimination ability of each subject. Neither the visual acuity nor the color discrimination of the older subjects was significantly different from that of the younger subjects.

The last part of the pretest screening procedure had the subjects complete a two-page questionnaire about their driving habits and their perceptions of their own driving ability. Not surprisingly, the older drivers (age 65+) had significantly more years of driving experience (50.19 years) than drivers younger than age 65 (34.57 years). The subjects reported miles driven per year on a six-point scale: 1 = < 1610 km (1,000 mi), 2 = 1610 to 8048 km (1,000 to 4,999 mi), 3 = 8050 to 16 098 km (5,000 to 9,999 mi), 4 = 16 100 to 24 148 km (10,000 to 14,999 mi), 5 = 24 150 to 32 198 km (15,000 to 19,999 mi), and 6 = 32 000+ km (20,000+ mi). The older drivers reported slightly fewer miles (mean = 5.6 km [3.47 mi]) than the younger drivers (mean = 6.5 km [4.03 mi]), but this difference is not significant. The subjects reported trips per week on a four-point scale: 1 = less than 5, 2 = 6-10, 3 = 11-15, 4 = 15+. Again, the older drivers reported slightly fewer trips (mean = 3.66) than the younger drivers (mean = 2.97), but the difference is not significant.

The final pretest screening questionnaire item had the subjects rate their driving ability relative to "most other drivers on the road." A five-point scale was used: 1 = excellent, 2 = above average, 3 = average, 4 = below average, and 5 = poor. Subjects were asked to rate their driving ability in six specific conditions: on city streets, on country roads, at night, on freeways with light traffic, on freeways during rush hour, and during poor weather. Although the older subjects rated themselves somewhat lower than the younger subjects in all categories, none of the differences were significant. This is perhaps an indication that the older drivers do not have a realistic self-perception of their declining capabilities. The increased accident involvement of older drivers (Evans, 1991; Gerber, 1990) suggests that there is a decrease in driving ability.

**Signal Response Characteristics**

To compare the initial responses of the subject drivers to the changing signal (amber onset), the total number of signal approaches was divided by the number of signal approaches where the driver stopped. The resulting percentage of stops was compared for drivers age 65 and older and younger drivers. On the 32-km/h (20-mi/h) trials, almost all subjects had three approaches (one had only two approaches). The younger drivers stopped an average of 60.3 percent of the time, while the older drivers stopped 61.1 percent of the time. On the 48-km/h (30-mi/h) trials, almost all subjects had 9 approaches (1 had 8 while 5 subjects had 10 approaches). The younger drivers stopped 44.9 percent of the time, while older drivers stopped 37.6 percent of the time. Neither of these differences is significant (t-test).

Additional analyses of the stopping behavior were conducted by dividing the subjects into four age categories: ≤ 59, 60 to 64, 65 to 69, and 70+. The percentages obtained are shown in table 22. Analysis of variance was used to look for differences between age groups in signal response behavior. No statistically significant effects were found. Because our major interest was in determining if there were any age-related effects in driver signal response behavior, a final analysis procedure was conducted on the two age groups representing the very youngest (under age 60) and the very oldest (over age 70) drivers. By eliminating the middle groups, which may be considered to be neither young nor old, the analysis focuses on the two most extreme groups. The results of this analysis for the 48-km/h (30-mi/h) approaches are shown in table 23.

While 46.88 percent of the drivers under age 60 stopped for the signal, only 32.10 percent of those over age 70 chose to stop. This difference is statistically significant at the 0.03 level. The field procedure was set up so that the subjects would have a real choice between stopping for the light or running the signal. During pilot testing, the time for the signal was varied until an interval (3.0 to 4.9 s) was found that appeared to stop the subjects about half of the time. The other half of the time, the subjects would decide that they were too close to the light to stop and would make a conscious decision to pass through the intersection. Our goal was achieved in that the drivers under age 59 stopped an average of 46.88 percent of the time. Drivers over age 70, however, were more inclined to decide not to stop or to stop an average of only 32.10 percent of the time.

### Braking Decision Characteristics

The field instrumentation allowed the accurate determination of the instant the signal changed to amber, the instant the driver released pressure on the accelerator in response to that signal onset, and the instant the driver applied the brakes to stop for the signal. These three data points were used to compute three values: off-gas reaction time, on-brake reaction time, and decision/response time. Off-gas reaction time is the interval from signal onset to the time the subject lifted his or her foot from the accelerator. On-brake reaction time is the interval from signal onset to the time the subject applied the brakes. Decision/response time is the interval between the time the subject lifted from the gas and applied the brakes. These values were computed for all subjects who were between 3.0 and 4.9 s from the signal when the signal indication changed and who subsequently stopped for the signal. As discussed in the previous section, the subjects stopped in slightly less than half of their trials.

Table 22. Percentage of subjects stopping at signal: by approach speed for four age groups.

| 48 km/h (30 mi/h) | | | | |
|---|---|---|---|---|
| Summary | n | Sum | Mean | Variance |
| ≤59 | 26 | 12.19 | 0.46 | 0.05 |
| 60-64 | 13 | 5.33 | 0.41 | 0.41 |
| 65-69 | 20 | 8.40 | 0.42 | 0.09 |
| 70+ | 16 | 5.13 | 0.32 | 0.03 |
| ANOVA | df | MS | F | P-value |
| Between Groups | 3 | 0.07 | 1.26 | 0.29 |
| Within Groups | 71 | 0.05 | | |
| Total | 74 | | | |
| 32 km/h (20 mi/h) | | | | |
| Summary | n | Sum | Mean | Variance |
| ≤59 | 26 | 15 | 0.57 | 0.12 |
| 60-64 | 13 | 8.50 | 0.65 | 0.07 |
| 65-69 | 20 | 12.66 | 0.63 | 0.92 |
| 70+ | 16 | 9.33 | 0.58 | 0.06 |
| ANOVA | df | MS | F | P-value |
| Between Groups | 3 | 0.02 | 0.25 | 0.85 |
| Within Groups | 71 | 0.09 | | |
| Total | 74 | | | |
| Combined 48 km/h (30 mi/h) and 32 km/h (20 mi/h) | | | | |
| Summary | n | Sum | Mean | Variance |
| ≤59 | 26 | 12.88 | 0.49 | 0.04 |
| 60-64 | 13 | 6.09 | 0.46 | 0.03 |
| 65-69 | 20 | 9.46 | 0.47 | 0.08 |
| 70+ | 16 | 6.18 | 0.38 | 0.03 |
| ANOVA | df | MS | F | P-value |
| Between Groups | 3 | 0.04 | 0.79 | 0.50 |
| Within Groups | 71 | 0.05 | | |
| Total | 74 | | | |

Table 23. Percentage of youngest (under age 60) and oldest (over age 70) subjects stopping at signal on 48-km/h (30-mi/h) approaches.

| t-test: Two Samples Assuming Equal Variances | | |
|---|---|---|
| | ≤59 | 70+ |
| Mean | 0.46 | 0.32 |
| Variance | 0.04 | 0.03 |
| Observations | 26 | 16 |
| Pooled Variance | 0.04 | |
| Hypothesized Mean Difference | 0 | |
| df | 40 | |
| t Stat | 2.23 | |
| P(T≤t) one-tail | 0.01 | |
| t Critical one-tail | 1.68 | |
| P(T≤t) two-tail | 0.03 | |
| t Critical two-tail | 2.02 | |

Table 24 contains driver reaction time comparisons for the older and younger drivers. Trials were conducted at approach speeds of 32 km/h (20 mi/h) and 48 km/h (30 mi/h). These data are presented separately in the table. For analysis purposes, the time the subject's vehicle was from the signal when it changed was divided into two intervals: 3.0 to 3.9 s and 4.0 to 4.9 s. The table shows the number of subjects, mean, 85th percentile, and standard deviation for the various measures for each approach-speed category and approach-distance category. Also shown are t-test values, degrees of freedom, and the probability levels associated with each t-value. In most cases, a t-value based on pooled variance estimates was used. In those cases where there was no homogeneity of variance, the t-value based on separate variance estimates was used. When this was the case, the degrees-of-freedom value was not an even integer. Traditionally, statistical analysis examines the differences between the means of various groups. Age-related factors may affect only a portion of a particular group, i.e., only some of the older subjects may have increased reaction times. This effect may not be sufficient to shift the mean value of the entire group. However, it may be sufficient to alter the extreme values of the group, i.e., the tails of the distribution. Thus, it was decided that the 85th percentile values should be examined. This would allow us to determine if the slowest older drivers are different from the slowest younger drivers. The last column shows a z-ratio that was computed to test for differences between the 85th percentile values shown in the table. This z-ratio was computed using the test statistic

$$\frac{x_{85}-x'_{85}}{1.539\sigma pooled\sqrt{\frac{1}{N}+\frac{1}{N'}}}$$

where:
$x_{85}$ = 85th percentile value of group x
$x'_{85}$ = 85th percentile value of group x'
$\sigma_{pooled}$ = pooled variance
n = number of subjects in group x
n' = number of subjects in group x'

For the differences between the 85th percentile values to be significant at the $p \leq 0.05$ level, the z-ratio must be $\geq 1.96$. All cases of significant differences between means (t-test probability) and 85th percentiles (z-ratio) that are $p \leq 0.05$ are shaded in the table.

The mean off-gas reaction time values ranged from 0.27 to 0.36 s for older drivers across the various speed and distance from signal conditions. Younger drivers varied from 0.30 to 0.37 s across the same conditions. No differences, either apparent or statistically significant, were found. The mean on-brake reaction times also showed no differences between older and younger drivers. Not surprisingly, the computed value for mean decision time was always somewhat slower for the older drivers, but the differences were not significant. The computed decision time values are based on the mean values of each individual trial. Thus, the values shown in the tables do not necessarily equal the difference between the off-gas/on-brake values shown. The total duration of the decision/response time value is relatively short. The relatively short duration of the value suggests that the drivers are doing most of their decisionmaking prior to lifting their foot off the gas. Once they decide to stop, the off-gas to on-brake response is apparently almost automatic.

The 85th percentile values for off-gas reaction times varied from 0.41 to 0.60 s for the older drivers to 0.41 to 0.47 s for the younger drivers. For both age groups, the longest duration off-gas reaction times were associated with the scenario where the subjects had the most time to react, i.e., on 32-km/h (20-mi/h) approaches when they were from 4.0 to 4.9 s from the signal when the amber was displayed. The z-ratio values indicate that there are no significant differences between the 85th percentile off-gas reaction times of the younger and older drivers.

The 85th percentile on-brake reaction times when the subjects were 3.0 to 3.9 s from the signal were 0.77 s for the older drivers and 0.77 s for the younger drivers on the 32-km/h (20-mi/h) approaches. The 48-km/h (30-mi/h) approaches produced 85th percentile on-brake reaction times of 0.74 s for the younger drivers and 0.87 for the older drivers. These differences are not significant. When the subjects were 4.0 to 4.9 s from the light, there were significant differences in 85th percentile on-brake

Table 24. Driver reaction times: young vs. old drivers (age 65+).
(from ABERDN7.LIS)

| Measure | No. of Subjects | | Mean | | 85th Percentile | | Standard Deviation | | t-value | d.f. | Prob | z-ratio* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Y | O | Y | O | Y | O | Y | O | | | | |
| **32-km/h (20-mi/h) Approach** | | | | | | | | | | | | |
| 3.0-3.9 s from Signal | | | | | | | | | | | | |
| Off-Gas Reaction Time | 14 | 13 | 0.34 | 0.32 | 0.41 | 0.41 | 0.11 | 0.11 | 0.46 | 25 | 0.65 | 0.02 |
| On-Brake Reaction Time | 20 | 21 | 0.62 | 0.59 | 0.77 | 0.77 | 0.17 | 0.18 | 0.54 | 39 | 0.59 | 0.05 |
| Decision Time | 14 | 13 | 0.27 | 0.34 | 0.39 | 0.51 | 0.17 | 0.17 | 1.15 | 25 | 0.26 | 1.15 |
| 4.0-4.9 s from Signal | | | | | | | | | | | | |
| Off-Gas Reaction Time | 16 | 10 | 0.35 | 0.36 | 0.47 | 0.60 | 0.16 | 0.20 | 0.02 | 24 | 0.99 | 1.21 |
| On-Brake Reaction Time | 20 | 15 | 0.64 | 0.78 | 0.82 | 1.26 | 0.16 | 0.33 | 1.55 | 18.73 | 0.14 | 3.05 |
| Decision Time | 16 | 10 | 0.33 | 0.48 | 0.50 | 1.38 | 0.13 | 0.49 | 0.93 | 9.75 | 0.38 | 3.65 |
| **48-km/h (30-mi/h) Approach** | | | | | | | | | | | | |
| 3.0-3.9 s from Signal | | | | | | | | | | | | |
| Off-Gas Reaction Time | 27 | 15 | 0.30 | 0.30 | 0.43 | 0.46 | 0.12 | 0.14 | 0.02 | 40 | 0.98 | 0.38 |
| On-Brake Reaction Time | 32 | 25 | 0.61 | 0.63 | 0.74 | 0.87 | 0.19 | 0.19 | 0.45 | 55 | 0.65 | 1.65 |
| Decision Time | 27 | 15 | 0.31 | 0.35 | 0.45 | 0.53 | 0.16 | 0.13 | 0.82 | 40 | 0.42 | 1.04 |
| 4.0-4.9 s from Signal | | | | | | | | | | | | |
| Off-Gas Reaction Time | 26 | 14 | 0.37 | 0.27 | 0.44 | 0.43 | 0.21 | 0.17 | 1.46 | 38 | 0.15 | 0.15 |
| On-Brake Reaction Time | 33 | 27 | 0.68 | 0.73 | 0.92 | 0.95 | 0.23 | 0.21 | 0.79 | 58 | 0.43 | 0.43 |
| Decision Time | 26 | 14 | 0.33 | 0.48 | 0.46 | 0.88 | 0.15 | 0.32 | 1.71 | 16.05 | 0.11 | 3.05 |

* z-ratio ≥ 1.96 = probability ≤ 0.05.

reaction times. On the 32-km/h (20-mi/h) approach, the older subjects' 85th percentile value was 1.26 s, while the younger subjects' was 0.82 s. This difference is significant at the $\leq$ 0.05 level. There was no difference between the older (0.95 s) and younger (0.92 s) drivers on the 48-km/h (30-mi/h) trials.

The 85th percentile decision/response times showed a similar trend. There were no differences between the values when the subjects were closer to the signal (3.0 to 3.9 s) at either approach speed. However, when the subjects were further from the signal (4.0 to 4.9 s) at amber onset, the older drivers had a significantly longer decision/response time (1.38 s at 32 km/h [20 mi/h] and 0.88 s at 48 km/h [30 mi/h]) than the younger drivers (0.50 s at 32 km/h [20 mi/h] and 0.46 s at 48 km/h [30 mi/h]).

The three significant differences in 85th percentile values are all associated with those test scenarios where the subjects were relatively far from the signal (4.0 to 4.9 s) when it changed. Two of the three cases involved the lower approach speed of 32 km/h (20 mi/h). It appears that some older subjects will take longer to react and respond when additional time is available for them to do so. Thus, it does not appear that these differences indicate that older drivers are necessarily reacting inappropriately to the signal.

## Driver Deceleration Rates

The field test instrumentation provided data on the acceleration and deceleration rates of the subject's vehicle throughout the test sequence. Instantaneous deceleration rates were available every 0.01 s. Analysis of this data was conducted to determine if older drivers are less willing to brake hard (and experience high deceleration rates) than younger drivers. Since the need to stop for a changing signal is dependent on both the approach speed and the distance the test vehicle is from the signal at amber onset, the data are aggregated according to both of these parameters. To uncover any differences associated with the duration of the period of maximum deceleration, mean maximum deceleration values were computed for intervals of 0.1, 0.5, and 1.0 s.

Table 25 is formatted like table 24. Number of subjects, means, 15th percentiles, standard deviations, t-values, degrees of freedom, probability values for t-tests, and z-ratios for the 15th percentile values are given. The deceleration rates range from high values, indicating better deceleration rates, to low values, indicating poorer deceleration rates. In order to compare the poorer extremes of the subjects' deceleration rate distributions, it is appropriate to look at the 15th percentile (lower) values. In the previous section that looked at reaction times—where higher values are indicative of poorer performance—the 85th percentiles were used. The deceleration rates shown are in ft/s/s. Since 1 g = 32 ft/s/s, it can be seen that the mean deceleration rates varied from a high of 0.49 g's (15.66 ft/s/s) to a low of 0.33 g's (10.70 ft/s/s).

Table 25. Driver deceleration rates: young (≤ age 65) vs. old drivers (age 65+).
(from ABERDN7.LIS)

| Maximum Deceleration | No. of Subjects | | Mean | | 15th Percentile | | Standard Deviation | | t-value | d.f. | Prob | z-ratio* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Y | O | Y | O | Y | O | Y | O | | | | |
| **32-km/h (20-mi/h) Approach** | ≤ 65 | 65+ | ≤ 65 | 65+ | ≤ 65 | 65+ | ≤ 65 | 65+ | | | | |
| 3.0-3.9 s from Signal | | | | | | | | | | | | |
| Max decel for 0.1 s | 20 | 21 | 14.97 | 15.19 | 12.55 | 12.71 | 2.28 | 2.44 | 0.29 | 39 | 0.77 | 0.15 |
| Max decel for 0.5 s | 20 | 21 | 14.76 | 14.93 | 12.23 | 12.62 | 2.23 | 2.34 | 0.23 | 39 | 0.82 | 0.35 |
| Max decel for 1.0 s | 20 | 21 | 14.30 | 14.28 | 11.99 | 12.26 | 2.05 | 2.08 | 0.02 | 39 | 0.99 | 0.27 |
| 4.0-4.9 s from Signal | | | | | | | | | | | | |
| Max decel for 0.1 s | 20 | 15 | 11.17 | 11.89 | 9.42 | 8.82 | 2.04 | 2.27 | 0.98 | 33 | 0.34 | 0.53 |
| Max decel for 0.5 s | 20 | 15 | 11.00 | 11.67 | 9.25 | 8.76 | 1.95 | 2.24 | 0.95 | 33 | 0.35 | 0.45 |
| Max decel for 1.0 s | 20 | 15 | 10.70 | 11.36 | 8.94 | 8.65 | 1.75 | 2.12 | 1.01 | 33 | 0.32 | 0.28 |
| **48-km/h (30-mi/h) Approach** | | | | | | | | | | | | |
| 3.0-3.9 s from Signal | | | | | | | | | | | | |
| Max decel for 0.1 s | 32 | 25 | 15.66 | 15.58 | 13.98 | 13.52 | 1.55 | 1.75 | 0.20 | 55 | 0.84 | 0.69 |
| Max decel for 0.5 s | 32 | 25 | 15.49 | 15.40 | 13.87 | 13.43 | 1.53 | 1.73 | 0.21 | 55 | 0.83 | 0.67 |
| Max decel for 1.0 s | 32 | 25 | 15.20 | 15.07 | 13.57 | 13.36 | 1.46 | 1.66 | 0.32 | 55 | 0.75 | 0.33 |
| 4.0-4.9 s from Signal | | | | | | | | | | | | |
| Max decel for 0.1 s | 33 | 27 | 12.67 | 12.75 | 10.56 | 11.21 | 2.25 | 1.30 | 0.17 | 52.6 | 0.86 | 0.90 |
| Max decel for 0.5 s | 33 | 27 | 12.51 | 12.60 | 10.39 | 11.01 | 2.25 | 1.30 | 0.18 | 52.7 | 0.86 | 0.82 |
| Max decel for 1.0 s | 33 | 27 | 12.25 | 12.35 | 10.22 | 10.86 | 2.19 | 1.24 | 0.23 | 52.3 | 0.82 | 0.88 |

* z-ratio ≥ 1.96 = probability ≤ 0.05.

Subjects in both age groups stopped the fastest (i.e., experienced the highest deceleration rates) when they were traveling the fastest [48 km/h (30 mi/h)] and when they were closest to the signal when it changed (3.0 to 3.9 s). The mean deceleration rates ranged from 4.60 to 4.78 m/s/s (15.07 to 15.66 ft/s/s). The next highest deceleration rates were associated with the 32-km/h (20-mi/h) approaches, again when the subjects were closest to the signal. These values varied from 4.38 to 4.63 m/s (14.28 to 15.19 ft/s). The 48-km/h (30-mi/h) approaches when 4.0 to 4.9 s from the signal produced the next most severe deceleration rates. These values ranged from 3.74 to 3.89 m/s/s (12.25 to 12.75 ft/s/s). The subjects had the most leisurely deceleration rates when they were going the slowest and were the farthest from the signal. During the 32-km/h (20-mi/h) approaches when 4.0 to 4.9 s from the signal, they decelerated between 3.26 to 3.63 m/s/s (10.70 and 11.89 ft/s/s).

There were no significant differences, either in mean or 15th percentile values, between the older and younger subjects. Apparently, older and younger drivers voluntarily subject themselves to very similar deceleration rates when stopping for a traffic signal. Therefore, it is not necessary to alter amber signal phase timing in order to accommodate older drivers.

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