SUPPLEMENTAL SIGNING FOR STOP SIGNS - PHASE 2

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J. L. GATTIS, Ph.D., P.E., A. S. BREWER,
S. PERUMALLA, and LYNETTE K. DUNCAN

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J. L. Gattis, A. S. Brewer, S. Perumalla, and Lynette K. Duncan

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University of Arkansas
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DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the information presented herein. This report does not constitute a standard, specification, or regulation.

SUPPLEMENTAL SIGNING FOR STOP SIGNS - PHASE 2

by
J. L. Gattis, Ph.D., P.E., A. S. Brewer, S. Perumalla,
Mack-Blackwell Transportation Center,
and
Lynette K. Duncan, Center for Statistical Consulting,
University of Arkansas

CHAPTER 1
INTRODUCTION

Signs warning motorists that "traffic on the cross street does not stop" can be found at some stop-controlled intersections. These CROSS TRAFFIC signs have been installed to furnish an extra warning at intersections where motorists on the stop-controlled approaches may incorrectly assume that the major crossing or through street traffic also has STOP signs.

SIGN HISTORY

Until recently, the *Manual on Uniform Traffic Control Devices* (MUTCD) did not include a CROSS TRAFFIC sign. Instead, these signs were devised independently in various parts of the country. With the absence of national control or coordination, it is not surprising that the CROSS TRAFFIC signs that evolved lacked a uniform message, color, shape, and placement location.

The December 2000 edition of the *MUTCD (FHWA)* for the first time included a standardized CROSS TRAFFIC DOES NOT STOP (W4-4P) plaque. This sign was shown in Section 2C.27. The sign consisted of words accompanied by a black arrow on a yellow background. The arrow was to point in the direction that through traffic was coming from, not headed toward.

If drivers misinterpreted the arrow-direction convention employed in the 2000 *MUTCD*, then the sign could not only fail to address drivers' incorrect assumptions as intended, but instead could exacerbate the problem. Subsequently, the FHWA proposed a replacement sign in 2002 which had no arrow, for use until the "arrow" issue is resolved, and the 2003 *MUTCD (FHWA)* showed this arrow-less version. While deleting the arrow removes a possible cause of confusion for locations at which only one of the two crossing or perpendicular approaches does not stop, it also removes potentially helpful information. Exhibit 1 presents these two signs, with the 2000 version on the left and the 2003 version on the right.

W4-4P

W4-4p

EXHIBIT 1 Versions of Sign in the 2000 and 2003 *MUTCD*

BACKGROUND AND CONSIDERATIONS

Some drivers on an intersection approach having the STOP sign may mistakenly assume that one or more of the other intersecting approaches also has a STOP sign, and therefore pull out into the path of oncoming vehicles that will not be stopping. At certain stop-controlled intersection locations that seemed to more frequently exhibit this problem behavior, supplemental or additional signs have been installed over the years to warn drivers on the stop-controlled approach.

As they evolved in different locales, these additional signs were not uniform. Rather, a variety of signs were devised to warn drivers on the stop-controlled approach. Some versions of the sign were placed in advance of the intersection, others were located at the intersection, and still other versions were installed as supplemental plaques, below the STOP sign. There also have been a number of different opinions about the use and appropriateness of such signs.

One problematic aspect of the CROSS TRAFFIC sign is the orientation of the arrow. Some drivers may interpret the arrowhead as pointing in the direction that traffic having the right-of-way is headed toward, while other drivers may think the arrowhead is pointing toward the direction that the through traffic is coming from. If both approaches perpendicular to the driver at the STOP sign have the right-of-way and are not required to stop, then arrowheads pointed to the left and right can be interpreted by either of these conventions and still produce the same result -- traffic from (or headed toward) both the left and the right has the right-of-way and will not be stopping. On the other hand, if traffic from one of the two nominally perpendicular approaches has a STOP sign, while the other perpendicular approach has the right-of-way (as shown in Exhibit 2), then a misinterpretation could cause a driver to incorrectly judge which approach would not be stopping.

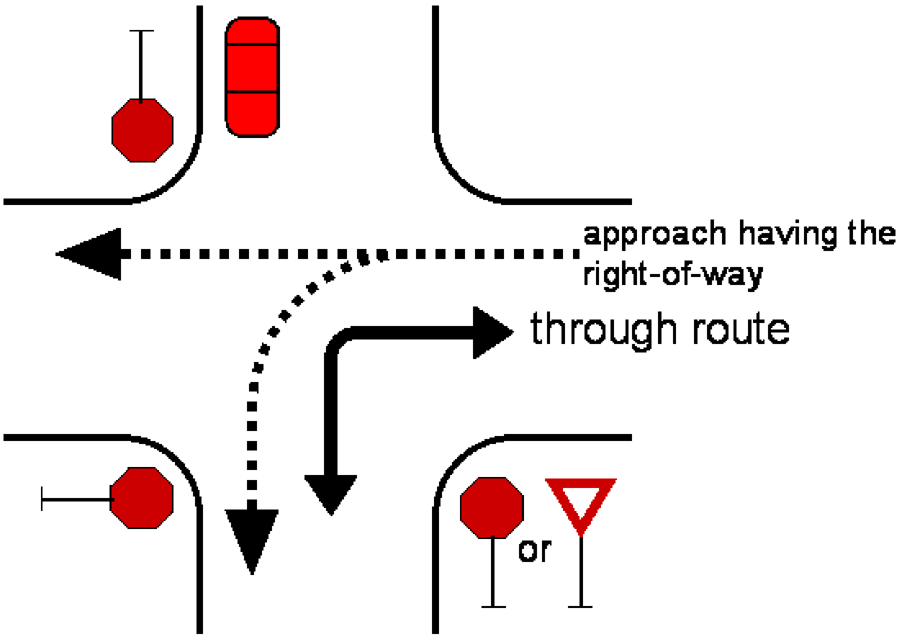


EXHIBIT 2 Only of the Approaches Perpendicular to Stopped Vehicle has a STOP Sign

The sign shown in Exhibit 3 is used in Germany to advise drivers of these types of situations.

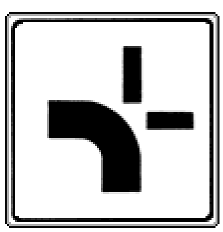


EXHIBIT 3 Sign Used in Germany

PURPOSE OF THIS STUDY

Driver misunderstanding of a CROSS TRAFFIC sign could contribute to the increased possibility of crashes. Therefore, it is desirable to develop an alternative sign with a high level of driver comprehension. In this project, researchers measured and recorded drivers' comprehension of both the CROSS TRAFFIC sign included in the 2000 *MUTCD* and other alternative variations of the sign which had been devised by the researchers and by others.

The scope of the research was restricted to that of drivers having the STOP sign, who are evaluating traffic on nominally perpendicular (or crossing) approaches or legs of the intersection, determining whether or not the vehicles on the perpendicular approaches will also have a STOP sign. It does not address the situation involving one approach having a STOP sign while the opposing or oncoming approach does not.

CHAPTER 2
LITERATURE REVIEW

A search for relevant literature was performed. Documents that reported surveys of practitioners, crash studies, comprehension tests, and sign testing methods were reviewed.

SURVEYS OF PRACTICE

Several studies have reported the state practices of traffic engineers and various agencies throughout the U.S. and Canada concerning the use of supplemental signs at stop-controlled intersections. The studies document the many versions of supplemental signs in use at stop-controlled intersections.

A study by Bowman developed a database of and categories for supplemental warning devices which are used by various agencies across the U.S., but are not in the *Manual on Uniform Traffic Control Devices* (MUTCD). The presentation of each category of supplemental warning devices included a summary description and a diagram. The report presented various signs which indicated that traffic from one or more conflicting directions at a stop-controlled intersection does not stop. Documentation of the background or effectiveness of CROSS TRAFFIC signs was outside the scope of the report (Bowman 1993 p. 37).

Gattis surveyed the use of the CROSS TRAFFIC DOES NOT STOP and other similar supplemental traffic control devices. Of the more than 300 respondents, approximately 40 % indicated that they did use supplemental STOP sign control devices in advance of or at the intersection to warn motorists they were at a two-way stop rather than an all-way stop (Gattis 1996). A few variations of the supplemental sign included arrows with a word legend. Some showed a double-ended arrow, while others used two separate arrows, one in each direction. The following lists some of the reported supplemental sign message variations.

CAUTION - CROSS TRAFFIC DOES NOT STOP (used by Ligon et al. in FHWA report)
NOTICE: CROSS ST. TRAFFIC WILL NOT STOP effective date (for 4-WAY removal)
CROSS ROAD (or STREET) TRAFFIC DOES NOT STOP
CROSS TRAFFIC DOES NOT STOP
WATCH FOR CROSS TRAFFIC
WATCH FOR THRU TRAFFIC
WATCH OPPOSING TRAFFIC
ALL TRAFFIC DOES NOT STOP
SIDE STREET TRAFFIC DOES NOT STOP
THRU TRAFFIC DOES NOT STOP
YOU STOP, THEY DO NOT....on other street THEY STOP, YOU DO NOT
name of road NO LONGER STOPS

name of road TRAFFIC DOES NOT STOP
name of road DOES NOT STOP
TRAFFIC ON name of road DOES NOT STOP
TRAFFIC FROM N, S, E, W direction DOES NOT STOP
TRAFFIC FROM left or right DOES NOT STOP
ONCOMING TRAFFIC DOES NOT STOP
YIELD TO ALL ONCOMING TRAFFIC
OPPOSING LEFT TURN TRAFFIC DOES NOT STOP
ACCESS ROAD TRAFFIC DOES NOT STOP
NOT A 4-WAY STOP

The report catalogued a number of reasons for installing CROSS TRAFFIC signs. Although common threads link many of the reasons given for installing the signs, each reason reflects a different set of circumstances. The identified situations or reasons given for using these traffic control devices (TCDs) were grouped into three general categories (Gattis 1995 p.45).

Category 1: Changing the assignment of right-of-way

1. converting an all-way to a 2-way stop
2. switching the approaches that have to stop at an existing 2-way stop

Category 2: Unexpected or uncommon geometric/operational characteristics

3. traffic is not required to stop on one or more uphill intersection approaches, because after stopping in snow and ice, it is difficult to make an uphill start
4. due to the opening of a new roadway, an existing T-intersection was converted to a 4-leg intersection
5. the presence of a railroad grade crossing on one of the intersection approaches makes it undesirable to have that approach stop, while traffic conditions dictate that all other intersection approaches do stop

Category 3: Driver behavior

6. driver misperception at a 2-way stop that the through road also has a STOP when in fact it does not have a STOP
7. observed disregard of an existing STOP sign

Reasons given by those objecting to the use of these signs included the existing standard signs were adequate; the CROSS TRAFFIC DOES NOT STOP sign was not a [then] 1988 MUTCD-standard sign; and the potential for driver confusion and liability (Gattis 1995 p.45). Some who used the supplemental signs did not think they were particularly effective.

Picha et al. conducted a survey among various state departments of transportation (DOT) and Texas DOT (TxDOT) traffic engineers. They found a wide variety of supplemental signs in use in different TxDOT districts and among nine state DOTs. To address problematic intersections, TxDOT engineers generally first installed a supplemental sign rather than beacons or signals (Picha 1996 p. 12). Of those responding to the survey, 46% indicated that the MUTCD should adopt a uniform treatment for TWSC intersections, compared to 36% who indicated that no standard was necessary, and 18% who were not sure. However, "the respondents indicated that a more uniform treatment should be adopted for only problematic, or 'specialized,' intersections, where high crash frequencies are prevalent and/or where drivers may expect all directions to stop." Almost all of the respondents (92%) indicated that they preferred a rectangular-shaped sign, and 50% preferred black letters on a white background (Picha 1996 p. 13). Eighty-nine percent of the respondents preferred that the supplemental plaque be mounted below the STOP sign.

STUDIES OF CRASHES AND CONFLICTS

Studies that have analyzed stop-controlled intersection crash data have discussed the potential causes of crashes, and the effectiveness of supplemental signs to reduce STOP sign violations. The studies found various potential reasons for crashes at stop-controlled intersections, and conflicting results of the effectiveness of the supplemental signs.

Causes of Crashes and Treatments

Ligon et al. examined crash data before and after the conversion of a multi-way stop-controlled intersection to a TWSC intersection. The results from the study were inconclusive. The authors stated that accidents can increase as a direct result of the conversion of multi-way stop-control to TWSC at some intersections (Ligon 1984 p.39). The percentage of sites that experienced a decrease in crashes was greater where supplemental signs were used than at sites where no supplemental signs were used. The report also stated "However, what cannot be ascertained is what further increase in accidents might have occurred if the signs were not used" (Ligon 1984 p. 41).

Chalupnik (1998) analyzed Minnesota crash data from low volume (500 vehicles per day or less), four-leg intersections with stop, yield, or no control. All 25 intersections included in the study were categorized as "low speed" intersections (30 mph) or "high speed" intersections (55 mph). The results showed that for low speed intersections, intersections with no control and yield-control experienced a greater number of crashes than at intersections with stop-control. No direct correlation could be found for type of intersection control at high speed intersections.

A study by Retting et al. of various two-way stop-controlled (TWSC) intersections in four U.S. cities found that STOP sign violations accounted for about 70 % of all crashes, most of which were angle collisions (Retting 2002 p. 1, 4), but only about 17 % of the crashes involved drivers who did not stop. About two-thirds of the STOP sign violation crashes involved drivers who claimed to have stopped before entering the intersection. The most common reasons drivers cited for proceeding into oncoming traffic after stopping were that they did not see the oncoming vehicle (44 %), their view of cross traffic was obstructed (16 %), or they incorrectly judged the intent of the cross traffic vehicle (7 %).

Different findings were reported in a study of rural stop-controlled intersections conducted by Stokes et al. Their data indicated that a majority of the crashes did not appear to be directly related to STOP sign violations (Stokes 2000 p. 28). Instead, most of the crashes appeared to caused by drivers entering the major road and not accelerating quickly enough to avoid being struck by major road vehicles. The authors suggested that drivers on the minor road either did not see oncoming vehicles or failed to accurately estimate the speeds of oncoming vehicles on the major road. Stokes et al. stated that effective treatments to this "fail-to-yield" problem include reducing the speed of vehicles on the major road, such as advance warning signs and reduced-speed zones. The authors did not mention of other possible factors, such as the possibility of drivers misinterpreting the right-of-way assignment at intersections.

The Gattis study used before-and-after crash data from seven agencies to assess the effectiveness of the CROSS TRAFFIC supplemental signs. At three intersections, the supplemental signs were effective in reducing crash rates, two intersections offered no clear results, and the supplemental signs seemed to have been ineffective at two intersections (Gattis 1995 p.46). Gattis provided several possible reasons for crashes at intersections with the supplemental signs.

1. The line-of-sight of some drivers on the minor approaches may be blocked -- contributing factors may include drivers not adequately "looking around" the vehicle door posts, intersection skew, or the presence of other vehicles.
2. Some drivers overlook plainly visible oncoming through roadway vehicles, and background "visual clutter" compounds this oversight problem.
3. Some drivers incorrectly assume that cross traffic is supposed to stop at "normal" intersections. Unusual right of way arrangements at some intersections can violate driver expectancy.

Crash Risk and Driver Age

Studies have examined relationships between driver age and crashes at stop-controlled intersections. In general, younger and older drivers are disproportionately at fault or involved in crashes at stop-controlled intersections, particularly in STOP sign violations (Retting 2002 p. 6; Stokes 2000 p. 11; Ford 2000 p. 1).

One such study conducted by Preusser et al. found that failure to obey traffic control, such as stop or yield control, accounted for more than half of all fatal crashes for drivers 75 and older

(Preusser 1997 pp. 157-158). For stop-controlled intersections, drivers 85 and up are almost 62 times at risk of a fatal crash than drivers age 40 to 49. Failure to obey traffic controls appears to be related to situations where the older driver must evaluate changing information from the left and right periphery before pulling out into the intersection. Recommended countermeasures include simplifying those situations where older drivers must make decisions based on "dynamic, time-dependent information coming from their periphery;" converting non-signalized intersections to all-way stop-control; and utilizing intersections with one-way streets on all approaches.

Traffic Conflict Study

To gain insight into driver behavior at stop-controlled intersections, Picha et al. studied six TWSC intersections: three with no supplemental signs and three with supplemental signs. A video camera attached to a raised pole was used to record erratic maneuvers, which were classified by traffic conflicts. A video ground-mounted camera was used to record the viewing behavior of drivers, as defined by head movements to the left and right. No correlation was found between driver understanding of right-of-way conditions and head movements (Picha 1996 pp. 48-49).

Picha et al. described five factors contributing to the observed traffic conflicts (Picha 1996 pp. 57-59).

Driver Behavior Characteristics

The authors hypothesized that driver impatience may have been a contributing factor to traffic conflicts at the TWSC intersections. They reported that almost two-thirds of the conflicts involved drivers waiting less than 10 seconds to proceed into or across the major street. Many of the conflicts were caused by drivers either accepting insufficient gaps in the major street traffic or improperly proceeding into or across the major street with sufficient gaps.

Geometric Features

The geometry of the intersection, especially the presence of wide shoulders and left-turn bays on the major street, was found to contribute to a number of conflicts. At sites with wide shoulders, many drivers made smaller gaps acceptable by turning onto the major street and using the shoulder as an acceleration lane. Such maneuvers increased the number of conflicts. The authors also stated that the presence of left-turn bays at one site helped create situations during which high-profile vehicles in the left-turn bay produced a "screening effect," interfering with the line-of-sight of drivers on the minor street scanning the major street.

Traffic Characteristics

The authors commented that higher volumes increased the number of vehicle interactions, which in turn increased the conflict frequency. A higher percentage of trucks, with their reduced acceleration capabilities, also increased conflict frequency.

Traffic Control Characteristics

The authors stated that the use of TCDs at intersections in a system should be consistent with driver expectations. “If a TWSC intersection is located along a roadway system where other intersections of state-maintained roadways are signalized or are four-way stop-controlled intersections, driver expectancy may be violated.” This occurred at one site where almost all the other intersections on the road system were four-way stop-controlled, with red flashing intersection control beacons. At the exception site, approximately 20 vehicles (less than 1%) on the major street were observed to completely stop at the intersection during an 11-hour period.

Environmental Conditions

Environmental conditions such as the location of the sun or adverse weather conditions were hypothesized to contribute to conflict frequency. The study did not examine effects of environmental conditions.

STUDIES OF COMPREHENSION

The effects of a driver misunderstanding the intent of a traffic control device vary with the situation. Obviously, one would expect misunderstanding a red signal to have a greater potential for harm than misunderstanding a “no parking” prohibition.

The question of what level of driver comprehension is needed before a TCD can be considered effective is an elusive one. A digest of a passage from a study (Womack et al. 1993) of traffic control device comprehension follows.

> Previous research has not provided conclusive evidence that correlates accident potential to the driver’s understanding of a traffic control device. During this research, it became clear that a threshold value would have little practical use.

Although comprehension and preference studies have been conducted for a wide variety of traffic signs, few studies have included the CROSS TRAFFIC DOES NOT STOP supplemental sign. The studies that did include the CROSS TRAFFIC sign have shown somewhat mixed results.

Driver Understanding and Preferences

The study conducted by Ligon et al. included a comprehension and preference test of various supplemental signs, shown in Exhibit 4. The CROSS TRAFFIC DOES NOT STOP supplemental sign received the highest comprehension score (96.1 %), while the NO LONGER FOUR-WAY supplemental sign received the lowest (87.6 %). The most preferred version had the black CAUTION on a yellow background, separated from the black CROSS TRAFFIC DOES NOT STOP on a white background (Ligon 1984 pp. 45, 46).

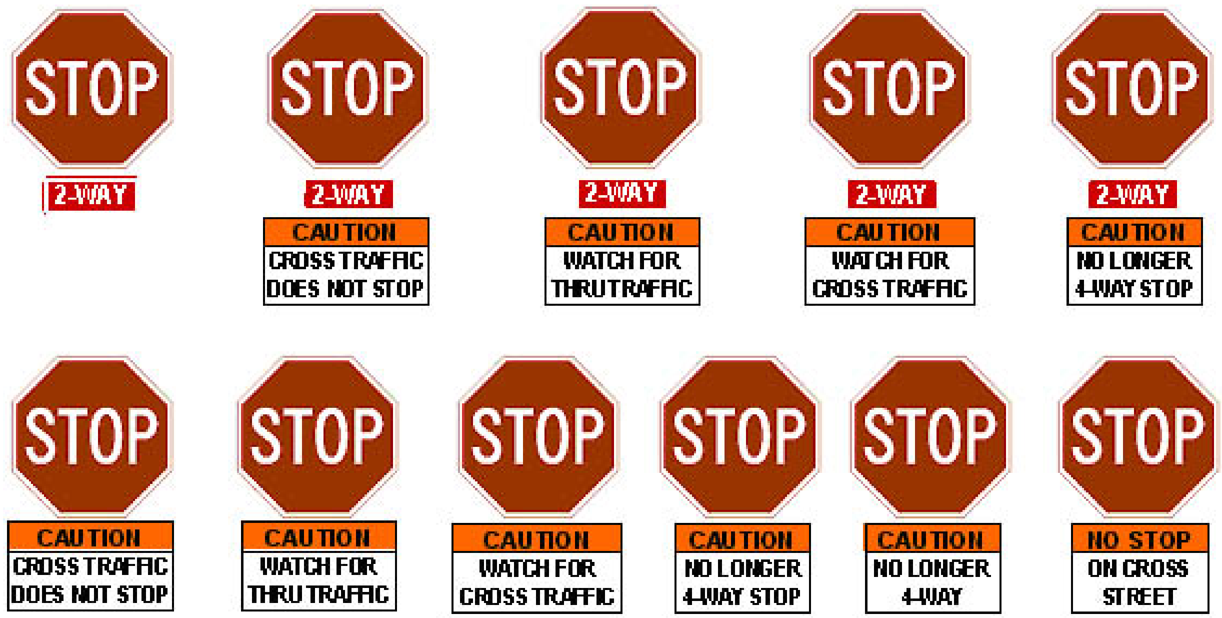


EXHIBIT 4 Supplementary Signs (Ligon 1984 p. 42)

Hawkins tested driver comprehension of four warning signs and their alternatives (these did not included STOP signs). The alternatives consisted of various supplemental signs, including words and arrows. Hawkins found that driver comprehension scores were higher for warning signs with supplemental plaques, with the exception of the distance supplemental plaques for the advance pedestrian crossing sign (Hawkins 1994 pp.6-11).

Over 2000 people from five states responded to a survey Picha et al. had mailed. The survey contained a two-part assessment of the CROSS TRAFFIC DOES NOT STOP supplemental signs, measuring driver comprehension of right-of-way concepts at a TWSC intersection, and asking drivers which supplemental sign alternative best conveyed the message that traffic on the major approaches has the right-of-way. Most (90 to 95%) of the respondents understood the concept of right-of-way, and 70 to 75% were “never” unsure of right-of-way conditions at a TWSC intersection (Picha 1996 p. 26). When asked to express a preference, 58% of respondents chose the word/symbol combination sign over the word sign (37%) and the symbol sign (5%). When asked if the respondent believed it necessary to supplement the STOP sign with another sign to convey right of way conditions at a TWSC intersection, 50% replied "No," 44% replied "Yes," and 6% replied "Not Sure." When asked to illustrate a message that could be more effective than those already shown, approximately 35% included words "cross traffic" in combination with arrows and/or with the words "does not stop," "caution," or "has the right of way."

Picha et al. used a video survey instrument to investigate driver understanding of four traffic control treatments to assign the right-of-way at a TWSC intersection. The four traffic control treatments were (Picha 1996 p. 31-33):

- STOP sign with overhead flashing beacons;
- STOP sign with stop bar;
- STOP sign alone; and
- STOP sign with CROSS TRAFFIC DOES NOT STOP supplemental sign mounted below.

The participants viewed one scenario seen from the driver's perspective approaching a TWSC intersection. The video showed the traffic control device; panned left and right, simulating the behavior of checking for traffic; and while panning left, showed a vehicle approaching the intersection but yet not indicating whether or not it would stop. The overhead flashing beacons scored the poorest (72% indicated comprehension of the right of way conditions), and the supplemental CROSS TRAFFIC DOES NOT STOP sign scored the highest with 89% (Picha 1996 p. 39).

Age and Driver Understanding

The results of the study by Dewar et al. showed that for 10 of 19 modified, redesigned, or novel symbol signs, comprehension was poorer for drivers age 60 and older than for younger drivers.

Ford et al. examined teenage drivers' comprehension of selected traffic control devices. The survey involved 260 teenage drivers in Texas who had not yet received any formal education about TCDs (Ford 2000 p. 2). They categorized the comprehension levels as follows (Ford 2000 p. 9):

- TCDs are understood (correct response rate greater than 80%);
- TCDs are with potential difficulty to understand (correct response rate between 80 and 60%); and
- TCDs are most commonly misunderstood (correct response rate less than 60%).

The study concluded that in general, teenage drivers had difficulty comprehending TCDs. The respondents understood (as determined by a correct response rate greater than 80%) only nine out of 53 TCDs in the study. The STOP sign with CROSS TRAFFIC DOES NOT STOP/double-ended arrow supplemental sign had a correct response rate between 60 and 80%, which indicated that the teenage respondents had some difficulty understanding the sign (Ford 2000 pp. 3, 5, 10).

DEVELOPING AND TESTING SIGNS

The two main methods used to examine the driver comprehension of traffic signs are the open-ended format and the multiple-choice format. Each method has advantages and disadvantages which not only have been noted in engineering studies but also have been the focus of behavioral scientists and human factors specialists (Dewar 1997 p.16). The multiple-choice method is more commonly used because it is generally less time consuming, less expensive, and requires less effort to perform than the open-ended method (Young p. 294). However, little research was found pertaining to comprehension testing of multiple alternatives of a particular traffic sign.

Principles for Effective Signs

Dewar et al. recommended principles and criteria to consider when developing or improving a sign (Dewar 1997 p. 208).

- Comprehension: The message must be readily understandable, or the user will not know whether or how to respond to it. If the meaning of the message is not immediately understood driver, error or delay can result.
- Legibility Distance: The critical features of a symbol sign must be legible from as far away as possible so that drivers have time to take the necessary action.
- Glance Legibility: A symbol should be legible when seen for a very brief time. When in heavy high-speed traffic and/or in unfamiliar settings, drivers often have little time to extract information needed from signs. Additionally, at busy urban locations, signs may be seen only briefly when they are obscured by objects such as large vehicles, trees or other signs.
- Reaction Time: For a sign to be effective, its message must be understood quickly. Drivers often have only a second or two to interpret and respond to it.
- Conspicuity: A sign must command attentions or be easily detected by the person who needs the information.
- Learnability: Symbol messages must be readily understood, or at least easily learned and remembered.

- Relevance: The information on the sign should be easily ignored if it is irrelevant for the driver.
- Clarity: The action to be taken in response to the message must be immediately obvious.
- Distinctiveness: Symbol messages should be easily distinguished from other symbols in the system.
- Uniformity: Signs must share the basic characteristics of other signs of similar type (e.g., color and shape) and be consistent in design from one locale to another.

Dewar et al. stated that generally the two most important measures of a sign's effectiveness are comprehension and legibility distance (Dewar 1997 p. 208).

Dewar et al. also provided recommendations to enhance the comprehension of traffic symbol signs. The authors stated that the "acceptable" levels of comprehension for symbol signs are somewhat arbitrary and depend on the consequences of failure to understand the message (Dewar 1997 p. 222). It was suggested that for regulatory and warning symbol signs, a minimum of 80% average comprehension with no lower than 70% comprehension in any one driver group (young, 18-39; middle age, 40-59; and older, 60+) may be acceptable (Dewar 1997 p. 222).

Review of Methods Used in Past Studies

In their study of procedures for conversion of four-way stop-controlled intersections to TWSC intersections, Ligon et al. (1984) conducted a comprehension and preference test of 11 CROSS TRAFFIC supplemental signs. After briefly describing the scenario and showing a slide of a four-way stop-controlled intersection being converted into a TWSC intersection, the participants were shown the 11 supplemental signs on slides one at a time, and were asked to answer the multiple-choice questionnaire designed to test the comprehension of the meaning of each sign. Each of seven groups was shown the slides in a different order and received a different sequence of multiple-choice questions. The multiple-choice questions included one correct, two incorrect (i.e., distracter), and one "not certain" choice. The various sequences of the questions involved different wording of the correct response and different wording of the distracters. After the 11 signs were shown, the participants were asked which three signs were most preferred, which of the three preferred signs he or she would recommend, and given a space to include any suggestions.

Paniati employed an open-ended testing method to examine the comprehension of four work zone traffic control symbol signs and their alternatives. A total of 32 respondents were shown the 14 symbol signs separately in random order, and were given unlimited time to respond. The criteria for assessing the responses (Paniati 1989 p. 50) were:

- Correct: The response demonstrated a clear understanding of the intended meaning of the sign;

- Substantially Correct: The response was not exact, but did indicate a reasonable understanding of the sign meaning; and
- Incorrect: The response demonstrated a lack of understanding of the intended meaning.

Paniati used the Cochran Q-test to determine whether the correct response rates differed significantly among themselves. In this data analysis, Paniati combined the correct and substantially correct responses and considered them to be correct (Paniati 1989 p. 51).

Hawkins' study (1994) of four warning signs and their alternatives with and without supplemental plaques used the multiple-choice format to measure driver comprehension of each sign. Each question included one correct, two incorrect, and one "not sure" answer. Each set of signs, three in total, was given to a separate sample of drivers.

A study conducted by Dewar et al. included examining drivers' comprehension of 86 traffic symbol signs from the 1988 MUTCD (phase 1) and 13 modified and redesigned symbol signs (phase 2). A total of 480 drivers were surveyed for phase 1 of the study (Dewar 1997 p. 57). The subjects viewed each sign for 30 to 40 seconds, wrote the sign's meaning in the answer booklet, and immediately indicated their familiarity with that sign using a five-point rating scale (Dewar 2001 p. 37). The open-ended questionnaire responses were scored as correct, partially correct, or incorrect. The response was considered incorrect when no answer was given. Responses scored as correct and partially correct were combined and considered to be correct in the data analysis. The authors stated that this procedure is commonly used in research on traffic sign symbol comprehension because even drivers who give a partially correct response have an adequate understanding of the general nature of the message (Dewar 2001 p. 38). To test the quality of the grading done by the research assistant, 60 test booklets were scored by both the research assistant and the principal investigator (Dewar 1997 p. 63). Since agreement between judges was high (95 %), the research assistant scored the comprehension test data.

The study by Ford et al. (2000) employed the multiple-choice method for evaluating teenage driver comprehension. The multiple-choice questionnaire developed closely resembled the tests taken by teenage driver-education students in Texas.

Comparing Open-Ended with Multiple-Choice Format

A few studies have been structured to compare and contrast the results from multiple-choice and open-ended formats.

Stokes

The study conducted by Stokes et al. used both the multiple-choice and open-ended format to examine driver comprehension. Twenty-five warning signs that were currently in use in Kansas were evaluated. The authors studied driver comprehension through the use of a multiple-choice questionnaire which included one correct, two incorrect, and one "not sure" answer. Each question had space for comments. To compensate for the potential bias in the multiple-choice survey results, the authors administered an open-ended questionnaire showing six of the warning signs to a separate sample of drivers.

To compare the results from the multiple-choice and open-ended survey formats, Stokes et al. used Tukey's test to determine if the responses from the two survey formats were significantly different. The results, shown in Exhibit 5, indicated that all six selected signs had a higher correct response rate for the multiple-choice format than for the open-ended format.

EXHIBIT 5 Comparison of Multiple-Choice and Open-Ended Questionnaire Response Rates (Stokes et al. 1996 p. 39)

Warning Sign	Percent Correct Multiple-choice	Percent Correct Open-Ended
Divided Highway Ends (W6-2)	78.8	63.6
School Zone (S1-1)	71.1	45.5
Side Road (W2-2)	92.8	50.5
Added Lane (W4-3)	86.9	13.6
Parallel RR Advance Warning (W10-3)	93.0	59.1
Workers Ahead (W21-1a)	92.0	77.3
Totals	85.8	51.5

The authors suggested that some respondents might have guessed or deduced the correct answers from the possible choices provided on the multiple-choice survey. Also, the results implied that the multiple-choice survey might overstate the general population's understanding of some warning signs (Stokes 1996 p. 39).

Wolff

Wolff et al. conducted a study that examined multiple factors of symbol sign comprehension testing methods. This study examined two factors involved in the evaluation of pictorial symbol comprehension: context (absence vs. presence of photographs depicting the probable environments where a symbol would be seen) and test method (multiple-choice with less vs. more plausible distracter alternatives vs. open-ended). Thirty-three various pictorial symbols (7 pharmaceutical, 21 industrial safety, and 5 from various categories) were selected.

The experiment was a 2 (Context: absent vs. present) x 3 (Test Method: less vs. more plausible multiple-choice distracters vs. open-ended) factorial design. The 211 participants were assigned to the two main factors about equally. Answers were scored as correct (1) or incorrect (0). If the judges disagreed in the scoring of an open-ended test response, an average score of 0.5 was used.

The results, using a 3 x 2 ANOVA test, showed a significant main effect of test method, $F(2, 64) = 41.81$, $MSE = 0.045$, $p < 0.0001$ (Wolff 1998 p. 181). Using Tukey's HSD test to compare the means (Exhibit 6, Wolff 1998 p. 181) showed the multiple-choice test with less plausible distracters produced significantly higher comprehension scores ($p < 0.05$) than the tests using either the more plausible multiple-choice distracters or the open-ended method. The latter two means did not significantly differ.

EXHIBIT 6 Mean Proportion Correct as a Function of External Context and Test Method

	Test Method			
External	Multiple-Choice		Open-Ended	Mean
Context	Less Plausible	More Plausible		
Absent	0.88	0.57	0.55	0.67
Present	0.93	0.70	0.64	0.75
Mean	0.90	0.64	0.59	

The ANOVA test also showed a significant main effect of context, $F(1,32) = 14.95$, $MSE = 0.025$, $p < 0.001$. The mean of context present (0.75) was significantly higher than the mean with no context present (0.67). The interaction between context and test method was not significant, $F(2,64) = 2.71$, $MSE = 0.010$, $p < 0.07$. The means show that context had a positive effect for all test methods, but its effect was smaller for the less plausible multiple-choice test.

The mean of the less plausible multiple-choice test was about 30% higher than the more plausible multiple-choice test or the open-ended test. Wolff et al. suggested that the less plausible multiple-choice test gives an inflated measure of the symbols' actual comprehensibility (Wolff 1998 p. 182). The authors cautioned that although the mean of the more plausible multiple-choice test and the open-ended test were not significantly different, direct comparisons cannot be made and that the open-ended test is still the most preferred method (Wolff 1998 p. 183).

Young

Because of the time-consuming nature of the open-ended method, a study conducted by Young et al. examined two different rating methods of safety symbols to approximate open-ended comprehension results. The first method had participants estimate the percentage of the population that would correctly interpret a symbol's meaning. The second method involved showing participants a symbol and it's meaning, and having them rate the correspondence between the two.

Fifty participants were first given the open-ended questionnaire of 50 different safety symbols in random order. Each response was scored as correct or incorrect. Following this, the participants were asked, "What percentage of the general population do you think would correctly interpret the meaning of this symbol?" Later, using a different booklet, the participants were provided each symbol with its actual meaning and asked, "To what extent does the symbol convey the meaning of the text?" Participants used a rating scale from 0 to 100%.

Young et al. found that the correlation between the open-ended scores and the prediction scores was high ($r = 0.79$, $p < 0.001$). However, the results indicated to the authors that the respondents tended to overestimate population comprehension when it should be low and underestimate it when it should be high (Young 2000 p. 4-295). The authors also stated that the results demonstrated that participants grossly misestimated population comprehension for some pictorials, especially the poorly understood symbols. Young et al. attributed this phenomenon by pointing out that since the prediction questionnaire was not given with the actual meaning of each symbol, participants may have provided higher predicted population scores for some symbols they assumed they understood when in fact they did not (Young 2000 p. 4-296). The authors recommended that this problem may be prevented by providing participants with the symbol's actual meaning.

Correlation between the open-ended scores and the correspondence scores was also high ($r = 0.93$, $p < 0.001$). The authors stated that the results indicated the participants were generally more accurate in their assessments of correspondence than they were when attempting to predict population comprehension (Young 2000 p. 4-296). Young et al. pointed out that one problem associated with this procedure is that since participants are not required to provide a definition of a symbol, this procedure did not objectively demonstrate the true level of understanding possessed by any given participant (Young 2000 p. 4-297). Another problem is that, unlike the prediction ratings, "it is difficult to predict how many people will correctly interpret a symbol in an open-ended test based solely on correspondence ratings." Therefore, the authors stated, the correspondence rating method can be considered as a rough guide to potential performance for a symbol.

Young et al. also noted that the study used the same participants for both rating methods (Young 2000 p. 4-297). Therefore, correlation between the two different methods would be expectedly higher than if two different samples were used for each method. The authors stated that these two methods are not adequate replacements for open-ended testing. However, "they can be beneficial in the development/prototype stages, when multiple versions of the same symbol may require evaluation" (Young 2000 p. 4-297).

Testing Considerations

It is important to recognize the limitations of any survey format which evaluates driver comprehension. The following concerns were discussed by Stokes et al., Ford et al., Dewar et al., and Wolff et al.

- The reading or educational level may effect the participant's choices for a multiple-choice test, or the participant may have trouble thinking of the appropriate word(s) in an open-ended test (Ford, Dewar).
- The multiple-choice format does not allow the participants to develop their own explanation of the sign (Ford, Stokes, and Wolff).
- The type of distracters selected for a multiple-choice test can significantly affect comprehension scores. Test developers may have a difficult time identifying plausible distracters due to the sometimes subtle nature of low-plausibility distracters (Wolff).
- The participant can correctly answer a multiple-choice question simply by guessing: with four alternatives, the participant has a 25% chance of guessing the correct answer (Wolff).
- It is difficult to assess critical confusions with the multiple-choice format. A critical confusion indicated by an incorrect response is extremely important to detect because it could lead to inappropriate or unsafe behavior. However, inserting an incorrect alternative into a multiple-choice test which would indicate critical confusion (such as the opposite of the correct response) might give away the correct answer to respondents who might not otherwise have known the answer ("test-wiseness"). To obscure or make it more difficult for a "test-wise" participant to detect the correct answer, the researcher would have to increase the number of opposite or negative alternatives. However, this would call unfair attention to the opposites or negatives, which would affect the researcher's ability to measure the level of critical confusions. "Detection of critical confusions might be readily accomplished only in open-ended tests (Wolff)."
- Scoring criteria for the open-ended format can be somewhat arbitrary (Dewar).
- Lack of context may underestimate driver comprehension of signs (Dewar).
- Assessing driver comprehension of a sign does not necessarily correlate with the actual driving response (proper or improper) with respect to that sign (Ford, Stokes, and Wolff).

Wolff et al. recommended using open-ended testing with appropriate context when evaluating comprehensibility of symbols (Wolff 1998 p. 185). Some useful guidelines when scoring open-ended tests to reduce the likelihood of biased scores are provided (Wolff 1998 p. 185).

- Have more than one judge score the answers so that reliability can be measured.
- Use independent judges who have not engaged in cross-discussion during the scoring process and who have no stake in the outcome.
- Decide on the scoring criteria and what kinds of answers are acceptable ahead of time. A lenient criterion based on whether the respondent shows basic understanding of the symbol is more appropriate than a strict verbatim criterion because people will use different wording to convey similar answers.
- If possible, the judges should score the answers blindly; that is, they should not know which particular symbol is being answered.
- Judges should look for and record the kinds of errors people make, with particular attention to critical confusions.

CHAPTER 3
DATA COLLECTION AND REDUCTION

The researchers administered the survey to test drivers' reactions to both the CROSS TRAFFIC DOES NOT STOP SIGN (with one directional arrow) from the 2000 *MUTCD* and five alternative signs. One person administered the survey to individual subjects, while a second person recorded the subjects' age group (between 16 and 24 years, or 25 and older), gender, and responses.

When evaluating responses to surveys similar to those administered during this project, it is not uncommon to test whether the subjects gave a "correct response" or "understood" the intended meaning of the sign. However, perhaps there is merit to at the end of the study letting the way that most drivers interpret a sign define what the correct understanding is.

For this study, the initial hypothesis was the majority of drivers would understand the arrow to be pointing in the direction that through, non-stopping traffic was headed toward, not coming from. Therefore, for the purpose of conducting this study, the "correct understanding" of the sign alternatives coincided with the direction the arrowhead pointed toward. The one exception to this was that the correct meaning of the sign from the 2000 *MUTCD* was taken to be as stated in the Manual, namely, the arrow was pointing in the direction that through, non-stopping traffic was coming from.

SURVEY ADMINISTRATION

Four separate groups of surveys were administered. Exhibit 7 shows the signs tested in each survey group.

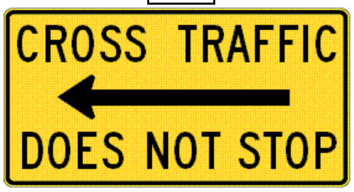
The first survey group considered three signs, the one from the 2000 *MUTCD* and two alternatives. Three different orders or sequences of signs were rotated among the subjects.

Based on comments the subjects made during the first group of surveys, a second group of surveys was created and administered. Each participant in this survey viewed one of two sequences of signs.

Again, from comments the subjects made during the second survey group, a third survey was devised. Later, a fourth survey was administered. Both the third survey group and the fourth survey group viewed only one sign.

The surveys were administered at three locations: an outdoor farmers' market, the entry to a student union food court, and the entry to an engineering building. While two of the three locations were on a university campus, many of the surveys were taken during the second summer semester and during freshmen orientation. Thus, the proportion of students in the survey was small, and some subjects were parents of incoming freshmen, from outside of the area.

A



B

C

Group 1 signs

A

D

Group 2 signs

E

Group 3 sign

F

Group 4 sign

EXHIBIT 7 Sign Alternatives Tested

SURVEY PROCEDURE

A series of slides on a computer screen and a small-scale model intersection were used to administer the survey. The slide presentation began with an introductory statement, followed by a video clip taken from inside a vehicle that showed a vehicle approaching and then stopping at a STOP sign. When the actual intersection was videoed, the back side of the STOP sign on the opposite approach was covered with an oversized black square. Combined with shadows, this made it impossible for the subjects viewing the video clip to ascertain the presence of the sign on the opposing approach. In addition, the vegetation on the approach selected for taping obscured the driver's view of the area where any STOP signs would have been located on the perpendicular street. The third slide explained that drivers could not determine by looking whether or not STOP signs were present on any of the other three approaches.

Then, subjects were presented with slides showing the sign from the 2000 *MUTCD* and alternative signs, and asked, with reference to the scale model intersection at their side, which vehicle or vehicles would not be stopping. On the scale model, a different color miniature car was placed on each intersection approach. If those administering the survey were unsure of a subjects' response, the response was verified by asking the subject to state the color of the vehicle on the approach they were indicating. Finally, subjects expressed which of the signs they had just been shown was easiest to understand. Exhibit 8 shows a survey in progress.

EXHIBIT 8 Survey in Progress

Very few subjects seemed unable to grasp the concept, or stated that they did not understand the signs being tested. Responses from the subjects were entered as an “X”.

DATA REDUCTION

The format of the form used to record the subjects’ responses facilitated data entry into a spreadsheet. Subjects were scored as to how their response compared with (or how well they understood) the intended meaning of the sign.

Two forms of “partially correct” (i.e., technically incorrect) responses received a special coding. Both involved a subject correctly identifying the vehicle that according to the sign would not be stopping, but then also including vehicles that actually would be stopping. The rational for this “partially correct” coding was that if the driver assumed a vehicle would not be stopping but it actually did stop, while the answer was technically incorrect, the chief negative impact would be increased delay but probably not a serious crash. If the response included both a correct and an incorrect perpendicular-street vehicle, it was coded as 3. If the response included both a correct and an incorrect perpendicular-street vehicle, and an incorrect vehicle on the opposite side of the intersection, it was coded as 2.

Correct responses were coded as 4. Incorrect responses where the result of the error would result in a vehicle conflict that could lead to a collision (e.g., right angle crash) were coded as 1. Responses of “do not know” were coded as 0.

CHAPTER 4
DATA ANALYSIS AND RESULTS

The comments received and insight gained during the tests of possible alternatives to the CROSS TRAFFIC sign in the 2000 MUTCD let to the development of additional alternatives. Four separate groups of surveys were conducted.

FOUR DIFFERENT SURVEY GROUPS

After each of the survey groups was completed, initial summary and descriptive statistics were found for each survey group. A statistical analysis was then conducted.

First Group Survey

Signs A, B, and C were tested. The order or sequence of the three signs that the test subjects viewed was varied (e.g., A-B-C, B-C-A, C-A-B). One sequence was shown to 40 subjects, a second sequence to 36 subjects, and the third to 35 subjects. The proportions of correct answers or correct plus technically incorrect responses varied according to the order in which the signs were shown.

There were 111 responses in the first group surveyed. Of these, 74 were from men and 37 from women. In general, males showed less comprehension of the intended meaning than did females. Those under 25 had poorer comprehension.

The values in Exhibit 9 show that few the test subjects correctly understood the exact meaning of sign A, the version from the 2000 *MUTCD*. However, almost 2/3 either gave a correct or a "technically incorrect" response (e.g., combining the number of 4, 3, and 2 responses). But this percentage is less than the percent of those subjects who correctly (response 4) identified the intended meaning of the alternative signs B and C. The percentages of those understanding B was slightly higher than those understanding C.

Difference in understanding the intended sign meaning by gender (female vs. male) and by age (16-24, or 25 and over) were analyzed using Pearson's chi-square test. Initially, each of the three "versions" or sequences of this survey group was analyzed separately. The exact p-values for the chi-square tests for each version were all greater than 0.01; therefore, the analysis proceeded with combining the three versions. It was concluded that there were no significant differences in understanding between the genders, while differences in understanding by age group for signs B and C were borderline.

EXHIBIT 9 Totals from First Survey Group

		Sign A #	Sign A %	Sign B #	Sign B %	Sign C #	Sign C %
Correct responses (i.e., 4)		4	4	93	84	88	79
by Gender	Female	2	5	34	92	32	86
	Male	2	3	59	80	56	76
by Age	under 25	1	5	17	77	15	68
	25 and older	3	3	76	85	73	82
Partially correct responses (i.e., 3 or 2)		65	59	5	5	9	8
by Gender	Female	20	54	1	3	2	5
	Male	45	61	4	5	7	9
by Age	under 25	13	59	2	9	3	14
	25 and older	52	58	3	3	6	7
Correct + Partially correct responses (i.e., 4, 3, or 2)		69	62	98	88	97	87
by Gender	Female	22	59	35	95	34	92
	Male	47	64	63	85	63	85
by Age	under 25	14	64	19	86	18	82
	25 and older	55	62	79	89	79	89
Incorrect responses (i.e., 1 or 0)		42	38	13	12	14	13
by Gender	Female	15	41	2	5	3	8
	Male	27	36	11	15	11	15
by Age	under 25	8	36	3	14	4	18
	25 and older	34	38	10	11	10	11

NOTES: number of females = 37, number of males = 74
number age 16-25 = 22, number 25 or over = 89

Repeated measures logistic regression was used to test if there was a significant difference in the percent of correct answers across the three signs while accounting for the fact that the same subject assessed all three signs. The logistic regression was run twice: first with 4 being correct and 0, 1, 2, or 3 being incorrect, and then with 4, 3, or 2 being correct and 0 or 1 being incorrect. In both cases, a difference was evident. Least squares means were used to determine which of the signs differed significantly; by both indices of understanding, there was no statistical difference in understanding between signs B and C, while the understanding of sign A was significantly less than that of both signs B and C.

While administering the tests, some subjects made unsolicited remarks about the arrows used on signs B and C. Some found the added complexity of the arrow or the street outline employed on these signs to be confusing, compared with the arrow in sign A.

Second Group Survey

Based on comments received during the first group survey, sign D was created with a message similar to that of sign B and C, but with the simple arrow of sign A. The second survey tested and compared drivers' understanding of two signs, A and D.

Two versions or sequences of signs shown to the test subjects: A-D and D-A. Pearson's chi-square test indicated the sequence of the signs did not affect the responses.

In the second survey, there were 60 subjects, 34 women and 26 men. Exhibit 10 shows that as with the first group survey, women exhibited better comprehension of the intended meaning than men did, and those under 25 had poorer comprehension. Testing with Pearson's chi-square, there were no significant differences in responses from females or males, but again the responses from those under 25 were marginally less correct than those from those in the 25-and-over age group.

Repeated measures logistic regression was used to test if there was a significant difference in the percent of correct answers between the two signs while accounting for the fact that the same subject assessed both signs. The logistic regression was run twice: first with only those responses coded as 4 being correct and 0, 1, 2, or 3 being incorrect, and then with 4, 3, or 2 being correct and 0 or 1 being incorrect. By either measure of what constituted understanding the sign, sign D had a higher proportion of correct responses. With $\alpha = 0.10$, the differences were significant.

While administering these surveys, as with the first group survey, test subjects offered unsolicited remarks about the arrows on the signs. This time, a few stated that although the words in sign D referred to traffic from the right, the arrow made them want to look toward the left.

Third Survey Group

Based on comments made during the second survey group, sign E was devised. The arrow was shortened and positioned to the right side of the sign. This was done to test whether this treatment reduced the tendency of some to view the arrow as indicating the direction that traffic was coming from.

The third survey tested only sign E, but included a follow-up question about the subject's understanding of directional arrows. There were 40 subjects, 11 females and 29 males. Of these 40, 11 were less than 25 years old. Chi-square tests found no significant difference in understanding between genders or between age groups.

EXHIBIT 10 Totals from Second Group Survey

		Sign A #	Sign A %	Sign D #	Sign D %
Correct responses (i.e., 4)		2	3	47	78
by Gender	Female	1	3	30	88
	Male	1	4	17	65
by Age	under 25	0	0	4	50
	25 and older	2	4	43	83
Partially correct responses (i.e., 3 or 2)		43	72	5	8
by Gender	Female	25	74	2	6
	Male	18	69	3	12
by Age	under 25	4	50	2	25
	25 and older	39	75	3	6
Correct + Partially correct responses (i.e., 4, 3, or 2)		45	75	52	87
by Gender	Female	26	76	32	94
	Male	19	73	20	77
by Age	under 25	4	50	6	75
	25 and older	41	79	46	88
Incorrect responses (i.e., 1 or 0)		15	25	8	13
by Gender	Female	8	24	2	6
	Male	7	27	6	23
by Age	under 25	4	50	2	25
	25 and older	11	21	6	12

NOTES: number of females = 34, number of males = 26
number age 16-25 = 8, number 25 or over = 52

Exhibit 11 presents totals from the third group survey. The understanding of sign E was compared with that of both sign A and sign D, using Pearson's chi-square test. By either measure of what constituted understanding (response = 4, or response = 4, 3, or 2) the sign, sign E had a statistically significant higher proportion of correct responses than did sign A. Although the proportions of those understanding the meaning of sign E (response 4 = 85% , responses 4/3/2 = 93%) was greater than those for sign D (response 4 = 78% , responses 4/3/2 = 87%), the differences were not statistically significant. Also, the subjects' understanding of sign E was not statistically different from their understanding of signs B and C.

To gain more insight into how drivers initially interpret the directional arrows employed on CROSS TRAFFIC signs, at the end of the survey subjects were asked the following.

Now, think back --- after you had taken a few moments to determine what the sign meant, did you conclude that the arrow was ---

(a) pointing in the direction that vehicles were coming from, or

(b) pointing in the direction that vehicles were traveling toward?

Slightly more than 2/3 responded they had concluded the arrow was pointing in the direction that vehicles were traveling toward, the supporting the previously stated hypothesis.

EXHIBIT 11 Totals from Third Group and Fourth Group Survey

		Sign E		Sign F	
		#	%	#	%
Correct responses (i.e., 4)		34	85	56	66
by Gender	Male	25	86	27	64
	Female	9	82	29	67
by Age	under 25	9	82	10	53
	25 and older	25	86	25	86
Partially correct responses (i.e., 3 or 2)		3	8	25	29
by Gender	Male	1	3	13	31
	Female	2	18	12	28
by Age	under 25	0	0	9	47
	25 and older	3	10	16	24
Correct + Partially correct responses (i.e., 4, 3, or 2)		37	93	81	95
by Gender	Male	26	90	40	95
	Female	11	100	41	95
by Age	under 25	9	82	19	100
	25 and older	28	97	62	94
Incorrect responses (i.e., 1 or 0)		3	8	4	5
by Gender	Male	3	10	2	5
	Female	0	0	2	5
by Age	under 25	2	18	0	0
	25 and older	1	3	4	6

NOTES: Third Group, Sign E: number of females = 11, number of males = 29
number age 16-25 = 11, number 25 or over = 29
Fourth Group, Sign F: number of females = 43, number of males = 42
number age 16-25 = 19, number 25 or over = 66

Fourth Survey Group

Sign F was created for the fourth group. It incorporated a schematic drawing of the intersection in perspective. There were 85 subjects, 43 females and 42 males. Of these, 19 were less than 25 years old. Chi-square tests found no significant difference in understanding between genders or between age groups. The results were not significantly different from those of Sign E (see Exhibit 11).

Exhibit 12 presents the results from each of the alternative signs that was tested.

EXHIBIT 12 Comparing Totals for the Alternative Signs

		Sign B		Sign C		Sign D		Sign E		Sign F	
		#	%	#	%	#	%	#	%	#	%
Correct responses (i.e., 4)		93	84	88	79	47	78	34	85	56	66
by Gender	Female	34	92	32	86	30	88	25	86	27	64
	Male	59	80	56	76	17	65	9	82	29	67
by Age	under 25	17	77	15	68	4	50	9	82	10	53
	25 and older	76	85	73	82	43	83	25	86	25	86
Partially correct response (i.e., 3 or 2)		5	5	9	8	5	8	3	8	25	29
by Gender	Female	1	3	2	5	2	6	1	3	13	31
	Male	4	5	7	9	3	12	2	18	12	28
by Age	under 25	2	9	3	14	2	25	0	0	9	47
	25 and older	3	3	6	7	3	6	3	10	16	24
Correct + Partially correct responses (i.e., 4, 3, or 2)		98	88	97	87	52	87	37	93	81	95
by Gender	Female	35	95	34	92	32	94	26	90	40	95
	Male	63	85	63	85	20	77	11	100	41	95
by Age	under 25	19	86	18	82	6	75	9	82	19	100
	25 and older	79	89	79	89	46	88	28	97	62	94
Incorrect responses (i.e., 1 or 0)		13	12	14	13	8	13	3	8	4	5
by Gender	Female	2	5	3	8	2	6	3	10	2	5
	Male	11	15	11	15	6	23	0	0	2	5
by Age	under 25	3	14	4	18	2	25	2	18	0	0
	25 and older	10	11	10	11	6	12	1	3	4	6

Sign Preferences During Surveys

The researchers also asked subjects which sign they preferred. For Group 1 (signs A, B, and C), about 2/3 preferred sign A, yet they had trouble understanding the meaning of sign A. Sign B was preferred by 13%, and sign C by 14% of the subjects.

When shown the Group 2 signs (A and D), 52% preferred sign A (the version in the 2000 *MUTCD*) and 42% preferred sign B. Again, sign preference was not well correlated with sign understanding.

OBSERVATIONS AND COMMENTS DURING THE SURVEY

During the survey, a few subjects offered unsolicited comments. Many of these were related to the use of the arrows. After viewing the version of the sign with the words “cross traffic” (i.e., not the alternatives with the words “right” or “left”), it was not uncommon for a subject to state that the arrow should have an arrowhead on both ends. It seemed in spite of having an arrow with only one arrowhead, that the words “cross traffic” caused many to conclude that vehicles from either perpendicular approach would not be stopping. An infrequently encountered misunderstanding was that “cross traffic” meant vehicles from the opposite approach.

A minority of the respondents thought the arrow pointed in the direction that vehicles were coming form. The majority thought that the arrow pointed in the direction that vehicles were traveling toward.

It appeared to the survey administrators that many of the subjects had some difficulty with the concept of an intersection at which one perpendicular traffic flow has the right-of-way while the other perpendicular flow has a STOP sign. It also seemed that the subjects had widely varying ability to deal with graphical communication, such as arrowheads and street outlines.

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CHAPTER 5
CONCLUSION

A series of surveys was performed to compare understanding of the CROSS TRAFFIC DOES NOT STOP sign from the 2000 *MUTCD* with understanding of a number of proposed alternative versions of the sign. All of the tested signs were applicable to four-leg intersections where only traffic from one perpendicular approach has the right-of-way, and the other three approaches have a STOP sign. Survey subjects were shown a computer file which included a video clip made from the inside of a vehicle approaching a STOP sign, followed by pictures of the various CROSS TRAFFIC sign alternatives. Subjects also referred to a scale model intersection having a different color car on each of the four approaches.

Although many subjects expressed a preference for the sign from the 2000 *MUTCD*, they also had less understanding of this sign than they did the alternatives. During the last survey group, slightly more than 2/3 responded they had concluded the arrow was pointing in the direction that vehicles were traveling toward, not coming from. The findings can be summarized as follows.

- The intended meaning for Sign A in the 2000 *MUTCD* was correctly understood by few.
- In all cases, the level of comprehension of the sign from the 2000 *MUTCD* was significantly less than that of the alternatives.
- There was not a great difference in the comprehension of any alternative. Comprehension of Sign B was slightly better than the comprehension than Sign C. Signs E and F fared slightly better than Sign D.

Considering both the correct responses and the correct + partially correct responses, Sign E (with the shorter arrow) had a slight edge over versions B, C, D, and F, but its level of comprehension was not statistically different from that of the other alternatives.

Some test subjects offered unsolicited comments. Although subject comments and surveyor impressions were not formally studied, the surveyors did come away with three impressions.

1. Some drivers understand the directional arrows on CROSS TRAFFIC signs to indicate the direction traffic is coming from, although more drivers think it indicates the direction traffic is headed.
2. A number of drivers were challenged to make sense of graphical communication on the signs they were presented with.
3. Although not quantified, there appeared to be a wide range of levels of driver understanding. Some subjects appeared to readily grasp the concept, were quite confident,

and understood the sign meaning in the way that the majority of subjects did. Others were more hesitant or puzzled by the concept. Perhaps some drivers recalled previous experience with such right-of-way assignment schemes.

4. Intersections of the type that were the subject of this study, having two opposing approaches with dissimilar traffic controls (one approach having STOP, the opposite approach having the right-of-way) seemed to be inherently more problematic than intersections with a typical right-of-way assignment scheme. This arrangement does not conform to the right-of-way assignment patterns that drivers usually encounter, and therefore may to some degree violate the expectations of some drivers.

Additional testing of a larger sample would be desirable before considering or adopting any of these alternative CROSS TRAFFIC DOES NOT STOP signs.

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