

Age Differences in Comprehension of Traffic Sign Symbols

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Previous research has shown that drivers, particularly elderly ones, do not understand many of the symbolic traffic signs on U.S. highways. Phase I of this research examined comprehension levels of virtually all (85) of the symbols in the U.S. *Manual on Uniform Traffic Control Devices for Streets and Highways* (FHWA, U.S. Department of Transportation, 1988) as a function of age. Subsequently, new versions of 13 of these symbols and 5 novel symbols were tested. Drivers in Texas, Idaho, and Alberta, Canada, participated in the studies. Of the 85 standard symbols, 16 were understood by more than 95 percent of drivers; however, 10 were understood by less than 40 percent. Older drivers had poorer understanding than younger ones of 39 percent of the symbols examined; for the remainder there were no age differences. In Phase II modifications and redesigns to selected symbols resulted in better understanding of three messages and poorer understanding of four messages. Comprehension of the novel symbols was close to that of the modified and redesigned ones. Again, older drivers had poorer understanding, but there was no systematic relationship between age and changes in comprehension level following revision of the symbols.

The dramatic increase in the proportions of elderly people in U.S. society has been accompanied by tremendous growth in the number of elderly drivers (1). Rosenbloom (1) cites data indicating that the percentage of people in the United States over age 70 years who had drivers licenses doubled from the early 1950s to 1984. The proportion of older drivers will continue to increase because people in U.S. society are very dependent on personal transportation and are unlikely to give up readily the use of their automobiles. As a result of these changes interest in the problems of elderly road users has grown dramatically.

Even though a great deal of research has been done on traffic signs, little is known about their effectiveness for older drivers. Driver age has been a variable of concern in a few studies of sign comprehension, legibility distance, and sign luminance requirements, but a systematic examination of the issue with a large sample of subjects and a wide variety of traffic sign symbols has not been carried out to date.

Pietrucha and Knoblauch (2) carried out an extensive study of the potential deficiencies in approximately 30 U.S. symbols and made recommendations for their improvement. On the basis of existing research they identified deficiencies in understanding symbols that could pose safety or operational problems. Input was gathered from a variety of professionals—traffic engineers, driver educators, and safety specialists—who were asked to comment on any signs that they believed presented problems. Signs with the worst ratings were further studied in the laboratory. Alternative designs of a number of messages were then developed and tested in a driving simulator.

Certain families of signs were found to be quite confusing (e.g., curves versus turns and pedestrian versus school signs). Improvements were effected in fewer than half the new signs, and many were substantially worse.

Relatively few traffic sign studies have analyzed comprehension by driver age. Hulbert et al. (3) examined comprehension of several traffic sign symbols, traffic signals, and pavement markings with a large sample (more than 3,100) of drivers from across the United States using a color film depicting a dynamic roadway situation viewed from a vehicle as it approached a traffic control device. Although only eight symbols were studied, significant age deficits were found for all but one of the signs. The overall level of understanding was 72 percent for those over age 50 years, 70 percent for those under age 24 years, and 79 percent for the 24- to 49-year-old age group. Hulbert and Fowler (4) used the same procedure in a follow-up study to test a different set of traffic control devices, including five traffic sign symbols. Comprehension levels for the 19 devices (10 signs, 3 signals, and 6 pavement markings) were consistently lower for the older (over 50 years old) subjects. Comprehension was generally poor (mean correct understanding below 60 percent) for the symbols, and the older subjects performed significantly worse than those in one or both of the other age groups on three of the five symbols.

In an experiment that examined the effects of driver age on traffic sign symbol recognition Allen et al. (5) used a driving simulator that provided steering and speed control over a dynamic highway scene that included 72 symbolic traffic signs. Subjects "drove" the roadway before and immediately after training and 1 week later. The age groups (21–29, 30–44, 45–59, and 60 years of age and over) were divided into three different training subgroups. One received an education pamphlet explaining the meaning and nature of the signs, another received a review of each sign in the simulator with an educational plaque below it, and the third received a combination of these. Initial knowledge of the symbol signs declined with age. Training, which produced a substantial increase in comprehension for all age groups, did not reduce the age group differences. Recognition errors were reduced from approximately 48 (out of 72) to 23 immediately following training for the oldest group. The corresponding figures for the youngest group were 30 and 4. The authors explained that age differences in symbol recognition could be due in part to a generational effect based on younger drivers' greater exposure to symbol signs through driver education and training.

There is clearly a need for a systematic and comprehensive evaluation of drivers' understanding of the symbols used on highway signs to know where best to concentrate efforts to improve them. The objective of the study described here was to evaluate the level of comprehension of virtually all the symbol highway signs in the U.S. *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD) (6) among young, middle-aged, and older

drivers. The comprehension study described here is one of a comprehensive set of studies that also examined legibility distance under day, night and night-with-glare conditions, reaction time, glance legibility, and conspicuity.

PHASE I

Method

Subjects

The subjects were 480 volunteer licensed drivers, aged 18 to 88 years, solicited from existing subject pools, driver licensing offices, local service clubs, recreational/social organizations for senior citizens, newspaper ads, and personal contact by the experimenters. Subjects were paid \$25.00 for their participation. Approximately equal numbers of male and female participants from four age categories (18–39, 40–59, 60–69, and 70+ years) were tested at each of three locations (Texas, Idaho, and Alberta, Canada).

Apparatus and Materials

The stimuli were 85 color slides of traffic sign symbols in MUTCD (6). The signs tested are listed in Table 1.

A Kodak carousel slide projector (Model 4000) was used to project slides of the traffic signs. Subjects provided information about their driving backgrounds and wrote their responses to each of the signs in a test booklet. Subjects sat at distances from the screen of from 3 to 12 m (9.85 to 39.4 ft). In all cases the signs projected onto the screen were large enough to be seen easily by all subjects from the maximum distance.

Procedure

The test facilities ranged from a small classroom that could accommodate 20 observers to an auditorium that seated 90. All facilities had chairs and tables and adjustable lighting, permitting levels of illumination appropriate for viewing slides clearly while at the same time writing answers in the booklet.

Drivers were tested in groups ranging from 8 to 60. They initially completed the two-page driver background information questionnaire and read the instructions describing the procedure. The subjects viewed signs for 30 to 40 sec each, wrote the sign's meaning in the answer booklet, and immediately indicated their familiarity with that sign using a five-point rating scale (1 = very familiar; 5 = very unfamiliar). Each session was initiated by using a practice sign (No Pedestrians; MUTCD no. R9-3a). Approximately equal numbers of young, middle-aged, and elderly drivers were tested in each of six previously determined random orders of sign presentation. Halfway through the presentation of the slides subjects were given a 15-min break.

Results

The answers were scored as correct (2), partially correct (1), or incorrect (0). The answer was considered incorrect when no response was given. Responses scored as fully correct and partially correct were combined and considered to be correct in the data analysis. This procedure is commonly used in research on traffic sign sym-

bol comprehension because even drivers who give a partially correct response have an adequate understanding of the general nature of the message because there is a close correspondence between a driver's understanding of a symbol's intended meaning and the action that should be taken in response to the symbol when it is seen on the roadway. Reliability between a research assistant and the principal investigator, who each scored 50 test booklets, was very high (95 percent).

The percentage correct for each sign as a function of age is shown in Table 1. It is evident that many symbols are very well understood. More than 95 percent of the drivers sampled understood the following signs: No Right Turn, No U Turn, No Trucks, No Bicycles, No Parking, No Hitchhiking, Deer Crossing, Cattle Crossing, Tractor, Low Vehicle Clearance, Playground, Phone, Fuel, Diesel Fuel, Food, and Railroad Advance Warning. Several, however, were poorly understood. For example, Straight or Left, Large Arrow, Chevron Alignment, Added Lane, Lane Reduction Transition, Double Arrow, Bus Station, Winter Recreation, Shelter, and Amphitheater were understood by fewer than 40 percent of drivers.

Comprehension was examined for each of the sign types separately to determine whether drivers were more knowledgeable about some types of signs than others. Railroad and regulatory signs were best understood (91.2 and 81.4 percent, respectively), whereas school (59.2 percent) and recreation (69.7 percent) signs were the most poorly understood. The levels of understanding for the other categories were as follows: information, 74.7 percent; warning, 75.4 percent; and construction, 76.3 percent. The poor performance on the school signs was due largely to confusion between the School Crossing and the School Advance signs. The data in Table 1 indicate that drivers age 60 years and older had poorer understanding than the young and middle-aged drivers for 33 of the 85 (39 percent) symbols.

The overall level of familiarity with each sign is also shown in Table 1. Some symbols are unfamiliar to most drivers (e.g., National Truck Route, Winter Recreation), whereas others (e.g., No U Turn, Deer Crossing) were very familiar to nearly all drivers. Significant positive correlations ($p < .01$) between familiarity and comprehension occurred for 57 of the 85 signs. Some unfamiliar signs (e.g., Tractor and No Hitchhiking), however, were also well understood, suggesting that they were well designed for comprehension. Age differences in familiarity showed that older drivers were less familiar in general with the symbols used, in spite of their greater driving experience.

Use of the written response technique allowed a determination of the frequency with which certain wrong and partially correct answers were given. The response "road narrows" was given for Lane Reduction Transition 28.4 percent of the time and for Narrow Bridge 28.6 percent of the time. These responses suggest that drivers are unaware of the degree of hazard conveyed by these signs. The Advance Flagging symbol was thought to represent a school crossing guard by 9.1 percent of respondents. One of the symbols giving the greatest difficulty was the snowflake symbol on the Winter Recreation sign, which was thought to indicate snow by 59.2 percent and icy road by 7.9 percent of the sample.

Discussion of Results

The results of the study confirm and extend to a broader range of symbols the findings of other researchers who have reported lower levels of comprehension of traffic sign symbols among older drivers. Symbols that are seen regularly and with which drivers are

familiar, including many of the regulatory and warning signs, are generally well understood. However, it is evident that many symbols on today's highways are poorly understood, especially by older drivers. Results of the study, including the types of errors made and comments from participants, help to identify possible improvements that could be incorporated into redesign of existing symbols and the development of new symbols. These findings also suggest the need for a public education campaign to inform drivers, especially older ones, of the meanings of poorly understood symbols and provided the basis for Phase II of the study.

PHASE II

Our objective was to examine the level of understanding of modified and redesigned versions of 13 of the standard symbols tested in Phase I and the level of understanding of five novel symbol messages among drivers of different ages. The selection of signs for modification and redesign was based on results of the Phase I comprehension and legibility distance studies and on focus group dis-

cussions and input from the project researchers and graphics design consultants.

Method

Subjects

The subjects were 219 volunteer licensed drivers aged 18 years or older in Texas, Idaho, and Alberta, Canada, recruited in the same manner as for Phase I. Subjects were paid \$10.00 for their participation. The profile of participants by age, gender, and location was essentially the same as that of Phase I participants.

Stimuli

The stimuli were 19 color slides of traffic sign symbols. Seven were modified versions and seven were redesigned versions of signs used

TABLE 1 Comprehension of Standard Symbols as Function of Age (Phase I)

AGE		18-39	40-59	60-69	70+	Total	Familiarity**
<u>Sign Name and MUTCD#</u>							
No right turn	R3-1	99	96	95	92	96.9	1.44
No U turn	R3-4	99	98	95	94	97.9	1.23
Straight or left (lane control)	R3-6	22	10	19	13	16.0	2.18
Keep right *	R4-7	89	88	83	62	85.8	2.10
No trucks	R5-2	99	98	100	87	97.1	1.91
No bicycles	R5-6	99	97	98	96	97.8	1.86
No parking	R8-3a	98	97	94	89	95.4	1.38
No hitchhiking	R9-4a	99	95	98	89	95.8	3.32
National network route	R14-4	55	69	55	48	61.0	4.45
National network prohibited	R14-5	76	81	81	70	77.7	3.80
Mandatory seat belt *	R16-1	96	87	54	39	74.4	3.45
Right turn	W1-1R	91	93	94	89	91.7	1.76
Right curve *	W1-2R	97	96	94	89	94.9	1.62
Right reverse turn	W1-3R	78	68	71	72	70.4	2.24
Right reverse curve	W1-4R	74	71	65	61	69.2	1.88
Winding road (right)	W1-5R	96	93	94	92	94.0	1.22
Large arrow	W1-6	35	41	43	38	38.9	2.19

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TABLE 1 (continued)

AGE		18-39	40-59	60-69	70+	Total	Familiarity**
<u>Sign Name and MUTCD#</u>							
Double head arrow *	W1-7	81	67	59	49	68.1	2.74
Chevron alignment	W1-8	44	32	26	23	36.8	3.56
Cross road *	W2-1	98	95	86	81	92.9	1.98
Side road (right, 90 deg)	W2-2	89	88	86	80	87.4	2.16
Side road (right, 45 deg)	W2-3	71	74	80	63	72.5	2.64
T symbol *	W2-4	88	80	64	68	78.1	2.21
Y symbol	W2-5	91	87	83	77	86.6	3.07
Stop ahead *	W3-1a	98	93	83	82	90.2	1.93
Yield ahead *	W3-2a	93	84	50	47	75.8	3.00
Signal ahead *	W3-3	99	89	78	71	87.3	1.41
Merge *	W4-1	93	93	86	82	90.0	1.97
Added lane*	W4-3	37	27	15	8	25.5	2.82
Lane reduction transition	W4-2	48	38	34	28	38.1	2.14
Narrow bridge	W5-2a	74	83	74	66	77.3	3.68
Divided highway *	W6-1	90	82	73	66	78.3	2.01
Divided highway ends *	W6-2	73	75	60	65	71.7	2.08
Two-way traffic	W6-3	91	91	86	84	89.2	1.49
Hill	W7-1	92	93	93	80	90.4	2.04
Pavement ends *	W8-3a	85	64	50	35	64.4	4.15
Slippery when wet	W8-5	41	46	40	47	44.6	1.60

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in Phase I, and another five were novel signs. Modified signs used the basic spatial layout of the MUTCD versions. Redesigned signs used a new spatial layout to convey the same message as their corresponding version in the manual. The signs selected for modification and redesign included four of the best, four of the intermediate, and four of the worst signs on the basis of the results of studies in Phase I on comprehension and legibility distance. Novel signs were newly designed signs that presented a message not in the MUTCD. The five novel signs—Reduced Visibility, Crosswinds, School Bus Stop Ahead, Horse-Drawn Vehicles, and Truck Entrance—were selected by FHWA. The modified, redesigned, and novel symbols are shown in Figures 1 to 3, respectively.

In the modification process the legibility of the signs was enhanced by an image-processing reiterative filter/redesign approach. Gray-scale images of each sign were digitized and stored in a computer. These images were filtered by using a sequence of low-pass order 2 (i.e., 12 dB/octave) Butterworth filters of progressively lower cutoffs. Signs were reiteratively filtered and revised until no further improvements in feature legibility could be discerned.

Several signs whose legibility distances and comprehension were relatively low were redesigned in a two-stage process. In the first stage a professional graphics design team was briefed by laboratory personnel on the specific limitations of signs tested in prior studies and on the spatial characteristics of signs that enhance their legibil-

TABLE 1 (continued)

AGE		18-39	40-59	60-69	70+	Total	Familiarity**
<u>Sign Name and MUTCD#</u>							
Bicycle crossing	W11-1	47	46	44	38	44.8	2.24
Pedestrian crossing	W11a-2	94	94	93	84	91.9	1.69
Deer crossing	W11-3	99	100	100	100	98.7	1.38
Cattle crossing	W11-4	100	100	100	100	99.8	2.32
Tractor	W11-5	98	95	99	91	95.2	3.28
Double arrow	W12-1	39	34	35	27	34.8	4.33
Low vertical clearance	W12-2	95	98	95	95	96.6	1.70
Playground	W15-1	96	97	98	92	96.6	3.07
Advance flagger *	W20-7a	73	75	59	58	69.5	1.71
Worker (construction)	W21-1a	84	84	84	78	83.1	2.75
Rest area	D5-5a	94	95	89	92	93.1	2.10
Phone	D9-1	100	99	100	100	99.8	1.35
Hospital *	D9-2	96	92	84	85	90.6	1.65
Camping *	D9-3	74	71	71	49	68.7	3.47
Recreational vehicle	D9-3	91	91	89	81	89.2	2.96
Handicapped *	D9-6	96	92	89	80	91.2	1.44
Gas	D9-7	100	100	100	99	99.6	1.68
Food	D9-8	96	97	98	94	96.4	1.96
Lodging	D9-9	86	81	79	70	80.6	2.82
Tourist information *	D9-10	62	53	48	30	52.6	3.50
Diesel	D9-11	99	98	95	96	97.7	2.95

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ity (i.e., large, simple contours and wide contour separations). Emphasis was placed on creating signs that could withstand blur by maximizing contour size, simplicity, and separation and by avoiding the interaction of adjacent contours; the use of examples of good and bad signs was enhanced by having the designer optimize the legibility of each feature when it was viewed through a strong blurring-positive sphere (5.5-D) lens. The resulting designs were reviewed by the laboratory staff, and suggestions for further improvement were offered through two iterations. In the second and final stage, black and white versions of the first-stage designs were digitized into the computer and were reiteratively filtered to increase their legibility by using the same procedure described for the modification process.

To maximize the comprehension level of each of the novel signs, the design team selected the most promising of the various concepts provided by the graphics designer. This initial concept was then refined by the designer over two successive design stages on the basis of input provided by the project team. The visibility of the resulting display was then optimized by the same image-processing approach described for modification and design.

Apparatus and Materials

The specific symbols evaluated are listed in Table 2.

The apparatus, facilities, and materials were similar to those in Phase I, except that the number of signs was 19 instead of 85.

TABLE 1 (continued)

AGE		18-39	40-59	60-69	70+	Total	Familiarity**
<u>Sign Name and MUTCD#</u>							
RV sanitary station	D9-12	65	73	69	62	68.7	2.93
Emergency medical services *	D9-13	80	79	73	56	74.8	3.72
Propane	D9-15	66	69	71	66	68.1	3.98
Hiking trail *	I-4	86	88	81	71	83.5	3.08
Airport*	I-5	95	94	86	72	89.4	2.01
Bus station	I-6	16	8	10	6	10.4	3.51
Train station *	I-7	97	97	90	86	94.2	3.78
Library *	I-8	62	60	48	38	55.0	4.49
Dock	I-9	58	52	58	43	53.5	4.31
Winter Recreation	I-100	19	9	9	0	11.0	4.47
Lighthouse	RG-120	92	91	89	76	89.6	4.27
Ranger Station *	RG-170	70	64	59	44	62.1	3.09
Rest rooms *	RM-140	96	92	69	86	91.2	2.24
Campfire *	RA-030	80	74	70	62	73.3	2.98
Shelter (sleeping)	RA-110	29	28	21	22	26.8	4.23
Showers *	RA-130	95	83	75	53	80.8	3.97
Amphitheater	RL-010	32	26	33	23	28.3	4.60
Canoeing	RW-020	93	90	90	80	87.5	3.44
Launch ramp	RW-080	89	86	88	87	87.3	2.27
Swimming *	RW-130	96	91	64	34	79.0	2.80
Ice skating *	RS-010	67	55	46	25	52.9	3.91
Sledding *	RS-060	79	79	73	58	75.2	4.04
Snowmobiling *	RS-070	79	71	68	59	71.5	3.27
School advance	S1-1	42	44	41	28	41.3	1.57
School crossing	S2-1	73	78	79	81	77.1	1.80
R.R. Advance warning	W10-1	99	97	95	94	97.0	1.56
R.R. Advance warning (parallel)*	W10-3	90	90	81	75	86.0	3.69

Age: Y = 18 - 39; M = 40 - 59; O = 60 - 69; E = 70+

*Indicates signs for which subjects 60 and older had lower comprehension than subjects under 60 years of age.

**Mean Familiarity rating (1=very familiar; 5=very unfamiliar).

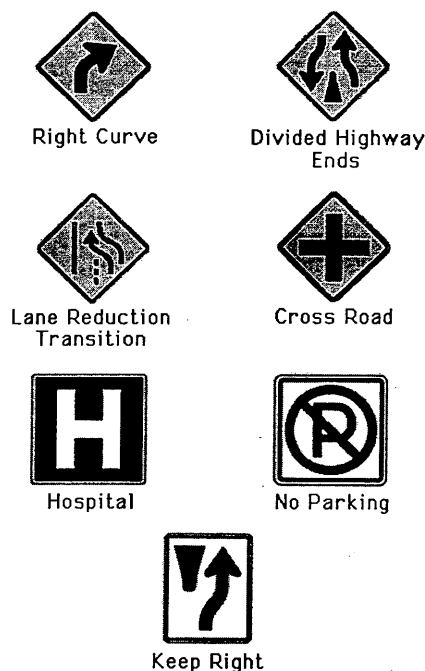


FIGURE 1 FHWA Modified signs.



FIGURE 2 FHWA Redesigned signs.

Procedure

To familiarize participants with the task, the No Pedestrians symbol (MUTCD R9-3a) was used as a practice sign at the beginning of each testing session.

The procedure was identical to that in Phase I except that the smaller number of signs tested made a midsession break unnecessary. Subjects viewed each sign and were asked to write the meaning of each sign in the appropriate place in the answer booklet and then to indicate on a five-point scale how familiar they were with it.

Results

The demographic data for annual distance driven, percentage of night driving, and driving environment revealed that the driving backgrounds of the participants were very similar to those of the participants in Phase I.

The scoring procedure was identical to that used in Phase I. To ensure reliability all data were scored by the same research assistant who did the scoring in Phase I.

The mean percent correct as a function of age for both the Phase I and Phase II data is given in Table 2. Table 3 shows the overall means for comprehension and familiarity ratings for both the new and standard signs. Phase I data are included for ease of comparison with the comprehension levels and familiarity for the standard designs.

It can be seen from the results in Table 2 that comprehension was poorer for drivers age 60 years and older than for the younger drivers on two modified, five redesigned, and three novel symbols. As in Phase I older drivers understood traffic sign symbols more poorly than did younger ones. With the exception of one sign (Right Curve) the mean level of understanding of drivers age 70 years and older was below those of drivers in all other age groups.

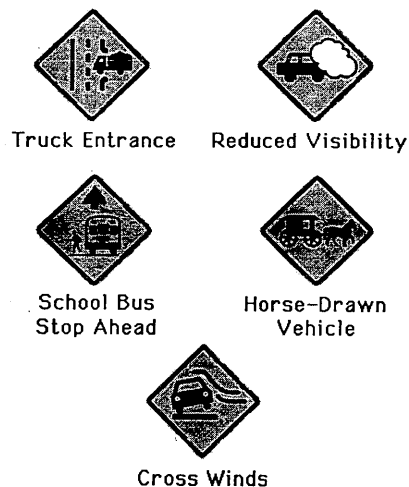


FIGURE 3 FHWA Novel signs.

Comprehension of the new designs is high for those messages that were well understood in Phase I (Right Curve, No Parking, Hospital, Cross Road) but remained relatively poor for those not previously well understood (Bicycle Crossing, Pavement Ends, Ranger Station, Lane Reduction Transition). Table 3 indicates that overall improvement resulted for two redesigned messages (Mandatory Seat Belts, Advanced Flagger) and one modified message (Lane Reduction Transition), whereas comprehension was worse for two modified messages (Divided Highway Ends, Cross Road) and two redesigned messages [Campfire, No Parking (pictograph)]. The decrement in comprehension of the Cross Road sign among drivers age 70 years and over probably affects sampling differences,

TABLE 2 Percentage of Correct Responses in Phases I and II as Function of Age

Sign	Age Group							
	<40		40-59		60-69		70+	
	I	II	I	II	I	II	I	II
<u>Modified Signs</u>								
Right curve	96.9	93.1	97.5	97.2	91.3	91.9	88.6	92.1
No parking (P)	97.5	100.0	97.5	95.8	93.4	89.2	88.6	81.6
Hospital	95.7	95.8	91.9	91.7	83.8	89.2	84.8	84.2
Cross road*	96.9	90.3	95.0	94.4	85.0	81.1	81.0	60.5
Keep right	88.8	88.9	88.8	90.3	81.3	89.2	74.7	60.5
Lane reduction transition*	47.8	79.2	36.9	55.6	33.8	51.4	25.3	28.9
Divided highway ends	73.9	69.4	75.0	55.6	60.0	62.2	64.6	47.4
Mean	85.2	88.1	83.2	82.9	75.5	79.2	72.5	65.1
<u>Redesigned Signs</u>								
Mandatory seat belts*	96.2	98.6	80.6	91.7	53.8	81.1	39.2	55.3
Advance flagger*	73.3	88.9	75.6	84.7	58.8	83.8	58.2	60.5
Ranger station*	69.6	90.3	65.0	65.3	58.8	51.4	44.3	42.1
Campfire*	80.1	73.6	73.8	79.2	70.0	32.4	62.0	31.6
Pavement ends *	85.1	63.9	65.0	66.7	50.0	43.2	35.4	36.8
Bicycle crossing	46.6	56.9	46.9	59.7	43.8	54.1	38.0	39.5
No parking (pictograph)	97.5	63.9	97.5	36.1	93.4	39.8	88.6	18.4
Mean	78.3	76.6	69.5	68.9	61.1	55.2	52.3	40.5
<u>Novel Signs</u>								
Truck entrance*		87.5		93.1		78.4		55.3
School bus stop ahead		73.6		88.9		78.4		68.5
Horse drawn vehicles*		87.5		86.1		64.9		52.8
Reduced visibility		79.2		82.0		77.0		63.2
Cross winds*		86.1		68.1		64.9		23.7
Mean		82.8		83.6		72.7		52.7

*indicates signs for which subjects 60 and older had lower comprehension than subjects under 60 years of age.

TABLE 3 Percentage of Correct Comprehension and Mean Familiarity Ratings for Standard and New Symbols

<u>Rank</u>	<u>Sign Names</u>		<u>Percent Correct</u> <u>Comprehension</u>		<u>Mean Familiarity</u> <u>Rating</u>	
<u>Modified Signs</u>						
			Standard	New	Standard	New
1	Right curve	c	94.9	94.1	1.62	1.35
2	No parking	c	95.4	93.6	1.38	1.37
3	Hospital	c	90.6	91.3	1.65	1.70
4	Cross road	a	92.9	84.9	2.98	2.41
5	Keep right	c	85.8	84.5	2.10	2.29
6	Divided highway ends	a	71.7	59.8	2.08	2.19
7	Lane reduction transition	ab	38.1	58.0	2.14	2.97
Mean			81.4	80.9	1.99	2.03
<u>Redesigned Signs</u>						
			Standard	New	Standard	New
1	Mandatory Seatbelts	ac	74.4	85.8	3.45	3.39
2	Advance flagger	a	69.5	81.7	1.71	1.98
3	Ranger station	b	62.1	67.1	3.09	4.09
4	Campfire	abc	73.3	61.2	2.98	3.53
5	Pavement ends		64.4	56.6	4.15	4.12
6	Bicycle crossing	b	44.8	54.3	2.24	3.55
7	No parking (pictograph)	a	95.4	41.1	1.38	3.30
Mean			79.8	74.2	2.71	3.39
<u>Novel Signs</u>						
1	Truck entrance		82.2		3.62	
2	School bus stop ahead		78.5		2.70	
3	Horse drawn vehicles	c	77.2		4.08	
4	Reduced visibility		76.3		4.59	
5	Cross winds		65.8		4.07	
Mean			76.0		3.85	

- a indicates significant differences ($p < .01$) in percent comprehension between Phases I and II.
- b indicates significant differences ($p < .01$) in familiarity ratings between Phases I and II.
- c indicates significant correlations ($p < .01$) between comprehension and familiarity in Phase II
- * Rank order in each sign category based on mean percent correct in Phase II.

because no changes would be expected on the basis of the minor modification made to this symbol.

A series of chi-square tests was used to make comparisons (separately for the four age groups as well as for the two older groups combined and for all subjects combined) between comprehension of the standard symbols in Phase I and that of the modified and redesigned versions in Phase II. Because of the large number of chi-square tests performed a probability of .01 or better was used. Comprehension levels improved for Lane Reduction Transition, Mandatory Seat Belts, and Advance Flagger, whereas they were lower for Crossroad, Divided Highway Ends, Campfire, and No Parking (pictograph). For engineering purposes of deciding which design to use, a less-stringent criterion (e.g., $p < .05$ or higher) might be more appropriate. Indeed, it could even be argued that no matter how small (statistically nonsignificant) a difference is between two versions of a sign, when there is no difference in cost the better one should be chosen when introducing a new symbol into the system or when replacing an existing symbol as signs deteriorate over time.

There appeared to be no systematic relationship between age and changes in symbol comprehension. That is, the number of signs for which there was any improvement in comprehension ranged from 6 to 8 (of 14) for all four age groups. However, improved performance was more prevalent among the young and middle-aged drivers for the redesigned symbols. The mean percent change in comprehension was greatest for the young group (+ 9.2) and least for the oldest group (- 8.3). However, these means were greatly influenced by one or two signs. It can be seen in Table 3 that the novel symbols, which had never been seen before, were understood nearly as well (76 percent correct) as the modified (80.9 percent) symbols were and were understood slightly better than the redesigned (74.2 percent) symbols were, supporting the design approach used in the present study.

These comparisons suggest that improvement in understanding can be accomplished through redesign and to a lesser degree through modification, especially for symbol designs that are poorly understood. Of those showing significant improvement, two were categorized as poor and one as intermediate on the basis of Phase I results. Those on which performance on the redesigned symbols was worse were good or intermediate signs in Phase I, suggesting that it is easier to improve on the understandability of those symbols that are understood less well initially by drivers.

Statistically significant correlations ($p < .01$) between comprehension and ratings of familiarity were found for 36 percent of the symbols (Table 3). This is just over half the 67 percent in Phase I. As before, more familiar symbols were better understood. The five novel symbols were rated as quite unfamiliar (1 = very familiar; 5 = very unfamiliar), with the exception of School Bus Stop Ahead (mean familiarity = 2.70). A high degree of familiarity with this sign may be due to location differences. In Alberta, where a similar School Bus Stop Ahead symbol is in use, it was rated as more familiar (Alberta = 2.17, Idaho = 3.19, Texas = 2.74).

As might be expected the level of familiarity was higher (lower score on the rating scale) for the modified (mean = 1.88) than for the redesigned (mean = 3.34) signs.

CONCLUSIONS

The present study confirms and extends to a larger number of symbols the results of previous work that showed that older drivers have a poorer understanding of traffic sign symbols used on U.S. highways. The changes made to 13 standard signs did not result in an overall improvement in comprehension, although three of them were better understood. Although there was no systematic age difference in the extent to which the new designs changed comprehension, the oldest group (70 + years), whose comprehension was poorest for most of the symbols, appeared to benefit least.

An effective way of enhancing driver understanding of poorly understood symbols is a campaign to educate drivers about the meanings of these messages. Although educational tabs are often used with new symbols, this is not sufficient to ensure adequate symbol comprehension.

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