Wrong-Way Driving: Off-Ramp Studies

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Drivers were observed and questioned and their responses were measured as they unexpectedly came upon "do not enter" signs while "driving" in the driving simulation laboratory.

Red-and-white signs elicited an earlier response than did the black-and-white signs, and more drivers responded correctly to the red-and-white signs. This finding was cross-validated by tests at another location.

A second set of signs was tested at the second location. Results at this writing are not conclusive regarding the relative "noticeability" of the four different messages.

Preliminary evaluation was made of the appearance of lane-line arrowheads painted on every fourth dashed line of an otherwise standard lane marking. The arrowheads were oriented in the direction of normal flow, so that a wrong-way driver would encounter a series of arrows with their points facing him. This particular type of lane-line arrow marking was judged not sufficiently noticeable to alert a wrong-way driver.

Observations were made of several styles of pavement marking arrows. When approaching them from the pointed end, as a wrong-way driver would in attempting to enter an off-ramp, the standard arrows (which originally were developed as directional guides) are not as detectable as two different styles.

•THIRTEEN fatal accidents killed 19 persons as a result of head-on collisions caused by wrong-way drivers on California freeways during 1961. In 1962, wrong-way drivers caused 23 fatal accidents killing 37 persons. This was 6 percent of all the fatalities on freeways in 1961 and 8 percent in 1962.

Recognizing this problem, a study of wrong-way driving movements was initiated as part of the highway safety research authorized by the California legislature. A portion of this study was conducted by the Institute of Transportation and Traffic Engineering at UCLA and is reported here.

The wrong-way ramp study is an attempt to predict the relative effectiveness of various types of signs in preventing drivers from entering freeways via off-ramps. The signs are viewed unexpectedly by drivers in the UCLA driving simulation laboratory, and driver reactions to the different signs are used as the bases for comparison.

The study was conducted in two phases with films made at two locations. Each phase will be described separately and in the chronological order in which they were conducted.

Definite conclusions have been reached regarding some of the signs and markings. These conclusions have been reported to the California State Traffic Engineer and are reflected in current remedial efforts to reduce the incidence of wrong-way driving. These California remedial efforts were reported in 1963 by F. E. Baxter (1) and in 1964 by George Hill (2).

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Two surveys have been made of wrong-way driving incidents in California. The first in 1963 was by C.V. Gay (3)—and the second in 1963 by D.J.Theobald (4). There is evidence from these surveys and from one special installation involving a hidden camera that older drivers and drunk drivers are many times more likely to be caught mistaking an off-ramp for an on-ramp, and that the ratio of reported to unreported incidents is probably much higher than previously thought. Over half of the reported incidents involved entering via an off-ramp.

PHASE I

Four different DO NOT ENTER signs were evaluated. Each sign (in turn) was correctly positioned on a freeway on-ramp which temporarily was made to appear an off-ramp. (Los Angeles police officers provided traffic control.) A 35-mm color motion picture film was taken of each sign from a moving vehicle and included a two-block-long approach to the ramp. The Dimension 150 optical system was used.

The signs filmed carried the message DO NOT ENTER in the following configurations:

1. California standard, white on black (Fig. 1a);
2. California standard, black on white (Fig. 1b);
3. California experimental sign, white on red (Fig. 1c); and
4. New York experimental sign, white letters and a horizontal white bar on a circular red background (Fig. 1d).

Some trial work was done to determine the visibility of lane-line arrowheads in alerting drivers that they are on the wrong side of the freeway. Concerning pavement arrows for ramps, the appearance of several shapes of pavement arrows is reported, as a result of trial work with paper cutouts viewed on a flat black-topped area.

Procedure

Initial testing consisted of recording reactions of 27 subjects to sign 1 (white on black), to determine the feasibility of using the simulation technique and to refine the experimental procedure. The test behavior of these subjects indicated that the drivers in the simulation laboratory would react in an apparently normal way and were not overly critical of the illusion that was created. The entire range of reactions encountered later was encountered in this initial testing.

During this trial work, an automatic event-indicating system (autopip) was designed, built, and installed to indicate events, landscape and sign cues for accurate measurement of reaction time. The autopip was utilized to indicate six location cues, both prior to and at the point of passing the signs.

The study consisted of testing 81 subjects on the four signs (each subject saw only one sign). Observation of the subjects and analysis of the recorded data were made and the results are reported below.

Subjects were recruited from undergraduate psychology classes on the UCLA campus. No requirements or limitations were set, including that of knowing how to drive. Past experience had shown that only a very small percentage of college students do not drive or have not had any driving experience, and this held true for the sample obtained for this study. Of 81 subjects recruited, only one subject had never driven before and only three others did not have licenses (they did have experience). No special attempt was made to recruit either males or females, and the 81 subjects consisted of 42 males and 39 females, ranging in age from 16 to 30 with an average age of 18.55 years.

The same experimental procedure was used for all subjects. They were told they were going to drive on two types of road: they would drive a two-lane mountain road, and then they would drive in a residential area. No mention was made of the freeway ramp they would encounter. The subjects were told to come to a full stop when the room lights came on, not to drive over 60-mph maximum, and to drive "as if they really were out on the road." The experimenter avoided answering questions until after the completion of the run, unless such questions pertained to the operation of the vehicle or to the driving task.

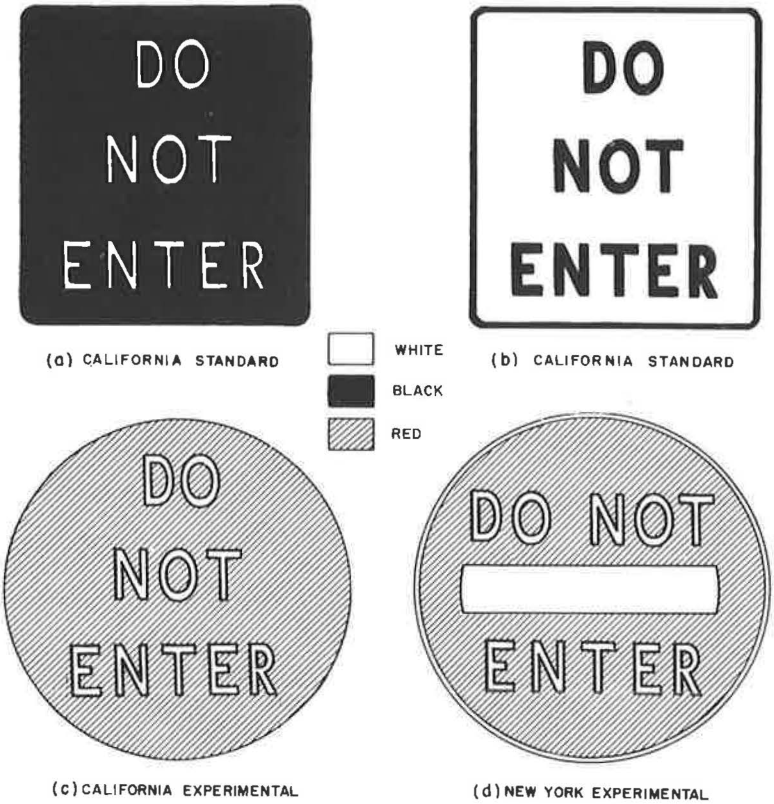


Figure 1. Test signs.

As a practice trial, all subjects first drove about one-third of a 30-min "drive" on a two-lane mountain road. The first subject each day saw the first third, the second subject the second third, the third subject the last third, the fourth subject a repeat of the first third, and so on throughout the day. Although each subject did not drive exactly the same stretch of practice road, they all drove the same type of road for the same length of time. Repetition of exactly the same film sequence for each subject was not deemed necessary since no analysis was to be made of this practice trial, and the entire road is quite similar in safe speed, frequency of curves, events, and landscapes.

At the end of approximately 10 minutes, the room lights were turned on, and the subject was requested to bring the car to a complete stop. This was necessary not only for the switchover to the second projector, but also because the second film begins from a near standstill (achieved by having the camera car start forward after the camera started running).

The second part of the test then began, in which the driver "drove" one of the wrong-way ramp test films. These films were preassigned in a random order set repeating each sign five times. At the end of a set, or each twenty runs, the random set was repeated. Thus the order was a randomly forced balance to assure an approximately equal number of exposures to each sign for each set of twenty subjects.

Each test drive is for two city blocks down a straight residential street, at the end of which is an on- and off-ramp to a freeway (Fig. 2). This intersection was changed for purposes of this experiment, and the film that each driver saw was of the intersection shown in Figure 3. Although there was no stop sign and no cross traffic, there was a road intersecting from the driver's left. The drivers reacted in several ways when coming upon this choice point. The test was terminated when the driver either reacted or when, after failing to react, he had traveled about three-quarters of the

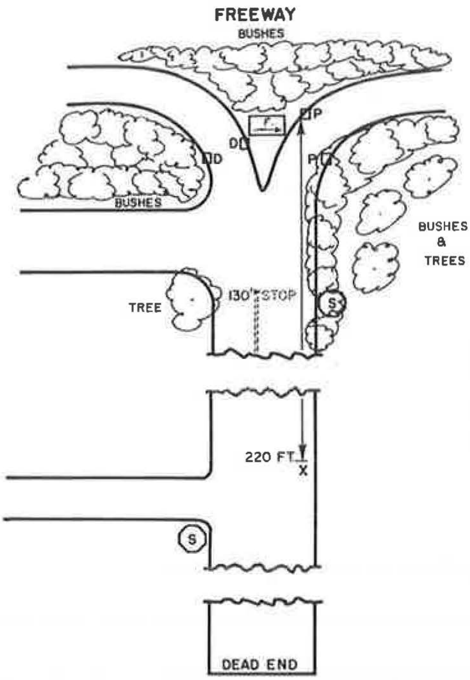


Figure 2. Actual intersection.

SIGNS

D - DO NOT ENTER
P - PEDESTRIANS, ETC., PROHIBITED
S - STOP
F. - FREEWAY

X - MAXIMUM DISTANCE CAN READ SIGNS ON SIMULATOR 220 FT.

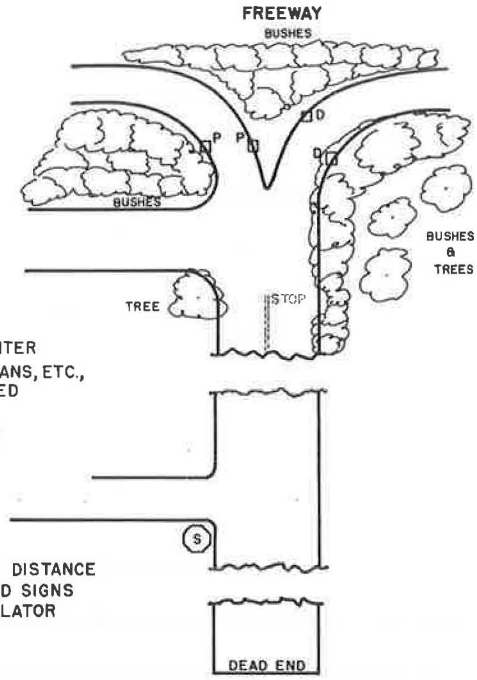


Figure 3. Experimental intersection.

distance up the ramp beyond the DO NOT ENTER signs. The wrong-way test drive consumed from 60 to 90 seconds of driving time, depending upon the speed the subject chose.

At the conclusion of the test, each driver completed a form requesting general information, such as number of years of driving experience and type of car usually driven. In addition, some interrogation was made of the driver's impression of his experience on the simulator. The experimenters carefully noted the obvious reactions of each subject and interrogated the subject after the test to determine his "observed reaction" to the sign. Subjects were never directly asked about a DO NOT ENTER sign, but if spontaneous verbalization or indirect questioning did not reveal that the subject saw the sign, he was asked if he "saw any signs" and, if so, "did he know what they were." At this time an attempt was also made to answer any questions the subject might have had concerning the laboratory and the study. Before he left, each subject was cautioned against discussion of the last (wrong-way) film with his classmates, although he was told that it was permissible to talk about the simulator. After the subject had left, his comments were written on the information sheet and his reactions logged into the study record.

Observations

After viewing all four DO NOT ENTER signs in the driving simulation laboratory, the experimenters concluded that the red-and-white signs can be seen from a much greater distance than the black-and-white signs when the viewer knows where to look. The latter tend to blend into the green foliage background more easily than the red signs. Landmarks noted in the film were measured at the actual location, and it was determined that the black-and-white signs could not be seen in the simulator except at an apparent distance of less than 500 ft, whereas the red-and-white signs were obvious at apparent distances in excess of 700 ft. While no such observations were made in the field, it is believed that these relative differences would have occurred there also. When the signs first become visible, the red-and-white signs can easily be

TABLE 1

	VERBALIZED STOP SIGN	DID NOT VERBALIZE STOP SIGN	TOTAL
BLACK & WHITE	1 (4.31)	34 (30.69)	35
RED & WHITE	7 (3.69)	23 (26.31)	30
TOTAL	8	57	65

Test for Independence Between Sign Color and Verbalizing it as a Stop Sign. (Theoretical frequencies in parentheses.) $x^2 = 6.27$ with 1 df significant at >0.02 level.

mistaken for stop signs (same color and same general shape). In all cases, the sign message cannot be read on the simulator until reaching an apparent distance of 220 ft or less (Fig. 2).

Comment is also necessary concerning the subjects who were lost to the study because they came to a stop at the intersection before reaching the ramp signs. All of these subjects commented that they saw "stop" written on the street, and in addition two of them said they "saw a stop sign." (The stop sign had been removed but a very worn STOP was faintly visible on the pavement.) Of those 40 subjects who encountered the black-and-white DO NOT ENTER signs, 10 percent (four) of them stopped because of the STOP on the street. Of those 41 subjects seeing the red-and-white signs, nearly 25 percent (ten) stopped at the STOP. In addition, 7 of the 30 subjects who completed the test on the red-and-white signs commented that they initially thought the sign was a stop sign, but then as they drove closer, they were able to read it. (A few never really read the sign but actually believed it to be a stop sign even though they had driven by it.) Only one of the 35 subjects completing the test on a black-and-white sign said he thought it was a stop sign.

Utilizing 2 x 2 chi square test for independence, the proportion of subjects reporting having perceived the DO NOT ENTER sign as a STOP sign is significantly better than chance for the red-and-white signs over the black-and-white signs (Table 1).

Results

The results of the data collected are presented in two categories: observed reactions and response measurements taken from the ink oscillograph record of speed, steering, brake, and accelerator pedal position.

Observed Reactions.—Most subjects could report having seen a DO NOT ENTER sign but many commented that the red-and-white signs looked like stop signs and two others believed the signs to be advertisements. On the basis of his answers, each subject was assigned a code signifying his "observed reaction" (before and independent of the examination of the oscillograph records). The codes used were divided into two sections as follows:

1. No reaction

   (a) Did not react, did not see sign.
   (b) Did not react, but reported seeing a sign.

2. Reacted

   (a) Slowed, saw sign, but continued up the ramp.
   (b) Stopped.
   (c) Turned left.
   (d) Pulled off road to right.
   (e) Attempted to enter on ramp.

Although the drivers who slowed, but continued up the ramp against the DO NOT ENTER sign did not react in a fully positive manner, many of them commented after the run that they saw the sign but that "the car was going that way," or that they tried to brake but the "car wouldn't stop." These drivers were included in the "reacted" column because it is believed that in the field they would not have continued up the ramp.

Seven subjects drove by the DO NOT ENTER signs and gave no indication that they would have stopped in the real-life situation. Four of these seven drove past sign 2 and one each of the other three drove past each of the remaining three signs.

Response Measurements.—In addition to the "subjective observations," computations were made of four scores: deceleration time and distance, braking time and distance. Deceleration time is the time in seconds between the first detectable reduction of speed and the reference point (pip) for that event, and braking time is the time in seconds between the onset of brake application and the reference point.

Deceleration and braking distances are defined as above, substituting feet for time. The formula for obtaining reaction distance directly from the ink oscillograph record data (which is in millimeters) was derived from the basic physics formulas for acceleration, $a = (V_t - V_o)/t$, and distance, $s = V_o t + \frac{1}{2} at^2$, combined with the conversion rates of the oscillograph (mm to common terms as mph time in sec, etc.).* The final working formula is

$$s = \frac{(V_o + V_t)\, t}{k}$$

where

s = distance in feet;
V_o = mm of vehicle speed at the reaction point (braking or deceleration);
V_t = mm of vehicle speed at a reference point;
t = mm between the above points; and
k = 9.0909 which is a conversion factor from ft/mi; sec/hr; mph/mm of vehicle speed; mm/sec of time (oscillograph paper transport rate) and the distortion factor of the simulator speedometer ($\frac{1}{2}$).

In all cases the computations are of either time in seconds or distance in feet relative to one of the landmark pips. This particular pip represents the location of the intersection stop sign (which had been removed). Of those pips which appeared on all records, this is the pip closest to the ramp. (The actual DO NOT ENTER signs were never reached by subjects who stopped or pulled off or slowed substantially.) The distance between this pip and the DO NOT ENTER signs is 130 feet.

Data for the individual signs are given in Tables 2 through 5. It can be concluded that the red-and-white signs were associated with earlier reactions in terms of mean

*The formula assumes a constant acceleration or deceleration. This is generally true for the short distances measured (8).

TABLE 2

WRONG-WAY RAMP STUDY

		N	Median	Mean	σ	Range	Sk
Deceleration Time (Seconds)	Sign 1	16	-8.60	-10.33	6.90	+2.70 /-23.80	+.75 *
	Sign 2	13	-10.05	-8.50	6.41	+5.80 /-16.80	-.73 *
	Sign 3	16	-14.30	-15.34	7.55	+1.20 /-25.40	+.41 *
	Sign 4	12	-13.00	-11.84	5.93	-4.20 /-23.40	-.59 *

TABLE 3

Deceleration Distance (Feet)	Sign 1	16	-165.11	-195.12	134.28	+73.92 /-512.33	+.67*
	Sign 2	13	-187.44	-160.96	131.49	+127.60 /-355.74	-.60*
	Sign 3	16	-281.74	-283.53	144.17	+25.74 /-481.97	+.04*
	Sign 4	12	-224.40	-241.02	124.26	-100.49 /-501.93	+.40*

*Difference between median and mean <u>not</u> significant at $P \leq 0.05$

TABLE 4

WRONG-WAY RAMP STUDY

		N	Median	Mean	σ	Range	Sk
Braking Time (Seconds)	Sign 1	16	-6.00	-5.35	3.85	+4.70 /-11.80	-.51*
	Sign 2	12	-5.40	-5.16	5.46	+5.80 /-14.80	-.13*
	Sign 3	16	-8.50	-7.88	6.21	+1.20 /-22.80	-.30*
	Sign 4	12	-11.50	-6.56	5.54	-3.80 /-14.90	-2.68***

TABLE 5

Braking Distance (Feet)	Sign 1	16	-109.95	-87.12	61.17	+138.20 /-182.49	-1.12**
	Sign 2	12	-77.39	-81.97	99.21	+150.04 /-227.92	+.14*
	Sign 3	16	-163.63	-140.24	111.53	+25.74 /-457.88	-.63*
	Sign 4	12	-143.28	-123.60	115.84	-117.98 /-430.24	-.51*

*Difference between median and mean <u>not</u> significant at $P = 0.05$

**Difference between median and mean significant at $P < 0.05$

***Difference between median and mean significant at $P < 0.01$

TABLE 6

WRONG-WAY RAMP STUDY—MEDIAN TESTS

	Red & Wht	Blk & Wht	
Above	15 (12.74)	12 (14.26)	27
Below	10 (12.26)	16 (13.74)	26
	25	28	53

Deceleration time (Number of cases) expected frequencies in parentheses. $x^2 = 1.548$ with 1 df not significant at $P = 0.05$.

	Red & Wht	Blk & Wht	
Above	19 (15.13)	13 (16.87)	32
Below	7 (10.87)	16 (12.13)	23
	26	29	55

Deceleration distance (Number of cases) expected frequencies in parentheses. $x^2 = 3.406$ with 1 df not significant at $P = 0.05$.

	Red & Wht	Blk & Wht	
Above	14 (11.00)	12 (15.00)	26
Below	8 (11.00)	18 (15.00)	26
	22	30	52

Braking time (Number of cases) expected frequencies in parentheses. $x^2 = 1.470$ (with Yate's correction) with 1 df not significant at $P \leq 0.05$.

	Red & Wht	Blk & Wht	
Above	17 (11.50)	9 (14.50)	26
Below	6 (11.50)	20 (14.50)	26
	23	29	52

Braking distance (Number of cases) expected frequencies in parentheses. $x^2 = 4.796$ (with 1 df significant at $P < 0.01$.

scores. In two cases (sign 4 braking time and sign 1 braking distance) the degree of skewness was significant at the 5 percent level or greater. Median scores (which are not sensitive to skewness) are given in Table 6. For these median scores, only braking distance was significant.

In comparing the signs one against the other (Table 7), the differences in mean time and distance for both deceleration and braking favor sign 3. Table 8 indicates a difference in deceleration distance in favor of the red-and-white vs the black-and-white signs.

There seems to be no question that the red signs (individually as well as combined) were effective both more often and earlier than the black-and-white signs.

Lane-Line Arrowheads

In an initial effort to evaluate the effectiveness of an often suggested remedial measure to alert a wrong-way driver to the fact that he is going the wrong way, a preliminary investigation was made of arrowheads painted on every fourth dashed line of one of the lane markings. These arrowheads were painted (by hand using a stencil) along a one-eighth-mile section of unopened freeway in the Los Angeles area. They were pointed in the direction of normal traffic movement and were placed only on the second (from the median) lane-marking dashed stripe.

TABLE 7

WRONG-WAY RAMP STUDY

Differences between means for deceleration time (dt), deceleration distance (dd), braking time (bt), and braking distance (bd) with longer sign number in parentheses. (Time in seconds and distance in feet.)

	Sign 1	Sign 2	Sign 3
Sign 2	dt(1) 1.83* dd(1)34.16 bt(1) .19* bd(1) 5.15*		
Sign 3	dt(3) 5.01* dd(3)88.41* bt(3) 2.53* bd(3)53.12*	dt(3) 6.84# dd(3)122.57# bt(3) 2.72* bd(3) 58.27*	
Sign 4	dt(4) 1.51* dd(4)45.90* bt(4) 1.21* bd(4)36.48*	dt(4) 3.34* dd(4) 80.06* bt(4) 1.40* bd(4) 41.63*	dt(3) 3.50* dd(3)42.51* bt(3) 1.32* bd(3)16.64*

TABLE 8

	Black & White
Red & White	dt(R) 3.78* dd(R) 88.61# bt(R) 2.40* bd(R) 53.12*

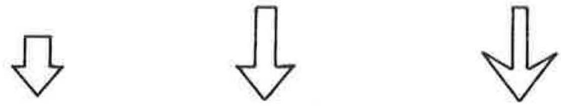
*Difference between means not significant at P = 0.05
#Difference between means significant at P < 0.05

Several wrong-way trips were made at speeds of 40, 50 and 60 mph in both the median and the second lane of this four-lane section of freeway. An 8-mm motion picture was made of a portion of this arrow-painted roadway.

Conclusions of those several persons who drove this road were that the arrowheads were very difficult to detect even when it was known when and where to look for them. This same conclusion has been reached by persons viewing the motion picture. Three other impressions are noteworthy:

1. The arrowheads were more noticeable when driving the correct direction than when driving the wrong way. Some drivers (going the correct way) reported the impression that the arrows indicated that those lanes (on either side of the arrowheaded line) were in some way "priority lanes."

Type A Type B Type C



Standard | Longer and narrower stem | Sweptback arrowhead + long narrow stem

2. The driving scene does not appear very unusual or at all disturbing when driving in the wrong direction.

3. The reverse side of some sign panels can be seen when going either in the correct direction or in the wrong direction. Therefore, this possible cue is not as effective as it was thought to be.

Pavement Arrows for Ramps

During the course of this study, a remedial measure was initiated by the California Division of Highways to help alert wrong-way drivers at off-ramps. It was decided to paint pavement marking arrows that would face a driver attempting to enter an off-ramp. Therefore, some consideration was made of the visual impression such arrows would present if the current design of arrow was used.

White paper arrows were cut out according to dimensions currently in use for pavement arrows. This "standard" arrow viewed on a flat black-topped area was rather difficult to discern as an arrow when one was looking toward the point (as a wrong-way driver would). Two modifications improved the "legibility" of the paper arrows: (a) extension and narrowing of the stem, and (b) creating a "sweptback" arrowhead.

Pavement arrows styled along lines similar to type C are therefore recommended when they are intended to be viewed from the pointed end.

PHASE II

Results of Phase I materially influenced the experiment plan for Wrong-Way Study Phase II in which drivers' responses were recorded as they unexpectedly encountered a variety of both "primary" and "secondary" signs at an off-ramp.

Eight films were produced utilizing an on-ramp which was converted to look like an off-ramp. The signs were photographed in 65-mm Eastman color negative using the patented Dimension 150 optical system, and 35-mm reduction prints were made for use in the UCLA driving simulation laboratory. Phase II includes two of the major primary signs from Phase I plus as additional primary not studied before, and five secondary signs with various messages.

The three primary signs each carry the message DO NOT ENTER in the following configurations:

- No. 2. Black letters on a white background, two lines, rectangular shape.
- No. 4. White letters on a red background with a horizontal white bar, circular shape.
- No. 6. Black letters on a white background with white on red DANGER mounted directly above and on the same post.

(Signs No. 2 and No. 4 were used in Phase I.)

The secondary signs (to be placed farther up the ramp) contain the following messages:

- A. WRONG WAY GO BACK—white letters on red background, rectangular shape.

B. STOP GO BACK—white letters on red background, rectangular shape.
C. GO BACK YOU ARE GOING WRONG WAY—white letters on red background, rectangular shape.
D. Sign B combined with DANGER directly above and on same post.
E. Sign A combined with DANGER directly above and on same post.

Considerations for Selecting Location of Ramp

The experience with Phase I plus subsequent trial work with various lens systems enabled certain considerations to be set forth for use in selection of the off-ramp for Phase II.

1. A clearly determinable point at which signs suddenly become visible; preferably at about 250- to 300-ft distance from foot of ramp.
2. After signs become visible the approach should be on a tangent section with the ramp curving to the right.
3. The foot of the ramp should be isolated from other traffic and intersections.
4. Ramp should be two-lane at the foot, narrowing to one lane.
5. Sunlight must fall on the face of the signs (both primary and secondary), requiring approach with the camera vehicle from a southerly direction.
6. The freeway and the direction of traffic on it should not be apparent in the films.
7. The approach street scene should be about ¼ to ½ mile in length without any stop signs or other reasons to stop; signalized intersections can appear if they can be kept green or encountered on green.

After selection of the ramp, eight different presentations of these signs were produced on film. Each of the three types of primary signs was combined with one type of the secondary signs to produce three films. Only the secondary signs appeared (without any primary signs) in the five other films.

The combinations of primary and secondary signs used were (1) 2-E; (2) 4-A; and (3) 6-C.

Procedure

A total of 243 drivers have been tested to date on Phase II from two major populations: students from Psychology 1A classes recruited by the circulation of sign-up sheets in the classrooms, and Air Force personnel who were recruited from the four local Air Bases through a joint agreement between the Air Force Office of Ground Safety and the University. None of these drivers can be considered as "volunteers." In addition, a few volunteer UCLA employees are included in the total figure.

For the primary signs, 110 drivers from UCLA were tested as follows: 2-E, 32 drivers; 4-A, 38 drivers; and 6-C, 40 drivers.

In all cases, the wrong-way ramp film was seen as a part of a series of films to which the individuals "drove." The series included two-lane mountain road, freeway or expressway (controlled-access, divided highway) and a "residential area." The latter was the wrong-way film which began in a residential type area, continued along the street for about three minutes, and then curved into the converted off-ramp. The same basic films were shown to all subjects, although the order was different for the Air Force and student groups. Both groups, however, had had the same amount of exposure time in the simulator (approximately 25 minutes of "driving") when the wrong-way film was presented, and each group had driven the mountain road and some controlled-access highway. Employees participating in this study were shown one or the other of the two series previously discussed.

Statistical Analyses

A Brush eight channel oscillograph, standard installation in the Driving Simulation Laboratory, recorded the reactions of the subject as he drove each film. Records obtained included: (a) the subject's driving speed (speedometer reading), (b) accelerator pedal patterns, (c) brake pedal patterns, (d) steering patterns, (e) respiration record, and (f) galvanic skin response (not all cases).

In addition, each driving record was automatically cued from the film for ten locations prior to and passing the wrong-way signs. It was thus possible to reduce the reaction distances for each subject. Reaction times, being dependent on the vehicle speed, cannot be accurately compared and thus were not calculated. Reaction distances, however, include the time modified by the speed.

All reaction distances are interpreted as being the number of feet the subject traveled along the course after passing a specific point and before he reacted to the sign. The specific point, the first of ten location cues, is the beginning of an underpass which precedes the wrong-way signs. At this point, the subject cannot yet see any signs and is not aware that he will be confronted by them. The first sign comes into view as the driver begins to emerge from the underpass and at a time when reactions to the underpass have already occurred. A very definite break point is observable on the oscillograph records since the subjects do not react to the signs until they have left the tunnel (cue 4), and in the majority of cases, the subjects do not react to the underpass except by slowing before entering it.

Deceleration distances (the distance between the first cue pip and the first point of slowing), and braking distances (the distance between the first cue pip and the first point of brake application), were measured by hand from the oscillograph records and these data were then keypunched for analysis by the UCLA computing facility's IBM 7094 computer.

For each of the reaction types (decelerations and braking) records were made in four parts, as follows:

Part I. 0 to 303 ft (303 ft is that point where the secondary signs first come into view—thus no reaction before that point can be attributed to a secondary sign where applicable).

Part II. 304 to 385 ft [385 ft is that point where the driver passes the last primary sign—thus within this category all four signs (right and left primary; right and left secondary) are in view where there is a combination of signs].

Part III. 386 to 555 ft (555 ft is that point where the driver passes the last secondary sign—thus any reaction after that point is not considered in the analyses).

Part IV. Totals (0 to 555 ft)

It seemed logical to categorize the reactions in this way as being:

Part I. To the primary sign only.
Part II. To the combination of primary and secondary signs.
Part III. To the secondary sign only.
Part IV. Total.

For these four parts, means and standard deviations were computed for each sign, and t-tests were made between signs. Tables 9 and 10 give sample sizes, means and sigmas for deceleration and braking distances and Tables 11 through 14 give the t-scores and significance levels for the difference between sign means. A test for skewness showed no evidence of skewed distributions.

It should be understood that the shorter the reaction distance, the sooner is the subject reacting to the sign. Thus it could be interpreted that the shorter the distance, the more effective the sign.

Primary Signs

Looking at the three primaries, it can be seen that in all parts sign 4 has a shorter deceleration and braking distance than sign 2, and that in Part I where the majority of

TABLE 9A

DECELERATION DISTANCE SAMPLE SIZES

	2 - E	4 - A	6 - C
Part I	11.0	18.0	21.0
Part II	12.0	6.0	8.0
Part III	3.0	2.0	1.0
Part IV	26.0	26.0	30.0

TABLE 10A

BRAKING DISTANCE SAMPLE SIZES

	2 - E	4 - A	6 - C
Part I	7.0	9.0	12.0
Part II	8.0	5.0	9.0
Part III	7.0	7.0	7.0
Part IV	22.0	21.0	28.0

TABLE 9B

DECELERATION DISTANCE MEANS

	2 - E	4 - A	6 - C
Part I	290.2	242.9	244.1
Part II	336.7	327.8	341.4
Part III	431.3	431.0	456.0
Part IV	327.9	277.0	277.1

TABLE 10B

BRAKING DISTANCE MEANS

	2 - E	4 - A	6 - C
Part I	288.9	273.9	263.9
Part II	347.9	344.4	346.7
Part III	443.0	439.0	425.0
Part IV	359.4	345.7	330.8

TABLE 9C

DECELERATION DISTANCE STANDARD DEVIATIONS

	2 - E	4 - A	6 - C
Part I	9.5	42.0	37.6
Part II	18.9	29.7	26.6
Part III	24.7	7.1	0.
Part IV	46.8	68.8	64.6

TABLE 10C

BRAKING DISTANCE STANDARD DEVIATIONS

	2 - E	4 - A	6 - C
Part I	8.4	23.5	12.8
Part II	23.2	26.4	24.9
Part III	53.6	50.4	29.6
Part IV	71.1	80.6	69.4

reactions lie, the deceleration difference is significant at a level of confidence greater than one percent. Sign 6 also has significantly shorter deceleration and braking distances (>0.001) than 2, in Part I. There is no significant difference between signs 4 and 6.

Secondary Signs

Additional testing is being conducted to determine if obtained measures are due to differences in the population from which the drivers were selected. There is some evidence that those signs not having the words wrong-way are confusing. Drivers slow but continue on, expecting to see a barricade or some other reason for the sign being there. They do not realize they are going the wrong direction. These results were obtained by questioning some drivers after completion of the testing session.

Interpretation

Experimentation of Phase II of this study substantiates Phase I's conclusion that the red primary sign 4 is either more visible or more meaningful than the white-and-black sign 2. It is believed that the important factor is the color red, and evidence of this is that the addition of the red DANGER sign significantly shortens the reaction time to the basically same black and white sign.

No evidence of difference was found between the European style symbol (sign 4) and the combination of the U. S. standard with a red DANGER sign on the same post. Because of the confusion of sign 4 with the U. S. red STOP sign, it is concluded that the results of this study favor the sign 6 configuration.

TABLE 11

DECELERATION AND BRAKING DIFFERENCES FOR CATEGORY I REACTIONS (PRIMARY SIGNS)

	2 - 4		2 - 6		4 - 6	
	DD	BD	DD	BD	DD	BD
t =	3.646	1.599	3.973	4.593	0.090	1.252
df =	27	14	29	17	37	19
sig. @	> 0.01	ns	> 0.001	> 0.001	ns	ns

TABLE 12

DECELERATION AND BRAKING DIFFERENCES FOR CATEGORY II REACTIONS (PRIMARY SIGNS)

	2 - 4		2 - 6		4 - 6	
	DD	BD	DD	BD	DD	BD
t =	0.774	0.250	0.464	0.103	0.897	0.160
df =	16	11	18	15	12	13
sig. @	ns	ns	ns	ns	ns	ns

TABLE 13

DECELERATION AND BRAKING DIFFERENCES FOR CATEGORY III REACTIONS (PRIMARY SIGNS)

	2 - 4		2 - 6		4 - 6	
	DD	BD	DD	BD	DD	BD
t =	0.018	0.144	0.866	0.778	2.887	0.633
df =	3	12	2	12	1	12
sig. @	ns	ns	ns	ns	ns	ns

TABLE 14

DECELERATION AND BRAKING DIFFERENCES FOR CATEGORY IV REACTIONS (PRIMARY SIGNS)

	2 - 4		2 - 6		4 - 6	
	DD	BD	DD	BD	DD	BD
t =	3.121	0.590	3.324	1.430	0.006	0.695
df =	50	41	54	48	54	47
sig. @	> 0.01	ns	> 0.01	ns	ns	ns

All of the secondary signs are red and white and therefore no color differentiation is possible. The message is the only difference since location and position of the sign were held constant. There is some indication of the need for having the message include the words "wrong-way" in order for the driver to realize why these large red signs have been erected. This finding agrees with results from interviews with six drivers who actually drove past some of these signs at an on-ramp in the Sacramento area. These six were part of thirteen drivers who were (experimentally) instructed to use an on-ramp where they unexpectedly encountered one of these large red signs located on the right-hand side of the ramp.

Obtained differences in deceleration distance and braking distance for the secondary signs are confounded with a difference in the population from which the drivers were selected. Subsequent testing will either confirm the differences obtained or will provide a basis for other conclusions regarding the relative "noticeability" of these signs.

Although several persons did "drive" by the primary and secondary combination of signs without reacting to them at all, there were no statistically significant differences among signs in this respect. The totals for these no measurable reactions were 2-E, 2 drivers; 4-A, 1 driver; and 6-C, 2 drivers.

This indicates that at least in this laboratory environment, these combinations of primary and secondary signs were not effective for all of the drivers tested. The degree to which this lack of complete effectiveness would extend to the actual highway situations is, of course, not known. However, it is reasonable to expect that some older drivers and drunken drivers might not be alerted by these signs. It is therefore recommended that additional remedial techniques be investigated.

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