WAYNE STATE UNIVERSITY

COLLEGE OF ENGINEERING

DETROIT, MICHIGAN 48202

Prepared in Cooperation with the

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and

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A LABORATORY INVESTIGATION OF DIAGRAMMATIC HIGHWAY GUIDE SIGN MESSAGES

Final Report

by

Myron M. Zajkowski, Ph.D.

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ABSTRACT

A Laboratory Investigation of Diagrammatic Highway Guide Sign Messages

by

Myron M. Zajkowski

The experiments summarized in this report were designed to establish a low cost reliable laboratory technique for the evaluation of highway guide signs and to resolve differences in previous laboratory studies with regard to diagrammatic guide signs. These two objectives were accomplished. However, validity is not implied in the results since the data were not unequivocably demonstrated to be related to actual driving performance.

The basic findings were replicated in each of the three experiments indicating a high reliability of the data. In addition it was found that the differences in the Gordon (1972) and Berger (1970) studies on diagrammatic signs could be resolved if one simply applied the same criteria for the scoring of the data to each of the studies. Consequently, it was concluded that the methodology established in the present investigation, which controlled for methodological differences in earlier studies, is a reliable means for assessing the impact of guide sign changes. The validity of the methodology is yet to be established.

Response times were consistently longer for diagrammatic signs than to conventional signs. This difference was probably due to an increase in information on diagrammatic signs. Subjects reported being more confident of and having a preference for conventional signs. The correctness of lane choices was slightly higher for conventional signs than for diagrammatic signs. However, this latter advantage diminished with practice.

An examination of the interrelationships among the dependent measures revealed inverse relationships between latency and both confidence of lane choices and correctness of lane choices. Positive relationships were found between preference for sign type and confidence in lane choices and between familiarity with the interchange and confidence in lane choice.

Post-experimental comments of the subjects suggest that diagrammatic signs might prove beneficial at locations containing unexpected manuevers or visual obstructions or when placed at the beginning of a signing sequence.

Finally, it was suggested that the utility of the methodology established in the present investigation can be established only by conducting a study of the predictive validity of the data using field driving performance as the criterion of success.

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INTRODUCTION

One purpose of the research described in this report was to establish a generalizable laboratorymethod for the evaluation of highway signing practices. An additional benefit of the present investigation is an assessment of the reliability of previous research findings concerning the use of graphic guide signs.

Several independent research needs dictated the specific research design used in the study. Historically, signing plans have frequently been made, approved, and signs erected without adequate opportunity to conduct research studies on the probable impact of such changes. The use of engineering judgment and field performance data isprobably ultimately effective, but usually quite costly. Inevitably, the high cost of such field research restricts the frequency with which it is employed which in turn results in an increasing reliance on judgment. Consequently, significant savings in time, money, and manpower would be possible if traffic response data could be obtained reliably and economically in the laboratory. Therefore, one of the major purposes of the present investigation was to assess the reliability and validity of laboratory methods of evaluating guide sign information.

As its primary purpose, the research attempts to focus on the problem of evaluation of innovations in guide signing--specifically the use of graphics. Recently, a great deal has been said and written about the use of graphics in highway signing. Symbology

for warning and regulatory signs has been used in Europe for many years, and has now been included in the 1971 edition of the Manual on Uniform Traffic Control Devices (U.S. Department of Transportation). However, few of the recommended uses are based upon sound empirical evidence. Several laboratory studies have been conducted to assess the effectiveness of diagrammatic guide signs (Berger, 1970; Gordon, 1972), but have produced contradictory conclusions and recommendations. On the other hand, field tests of diagrammatic signs (Michigan Department of Highways, 1963; Roberts, 1972; Kolsrud, 1972) have been well received but of somewhat limited use due to a lack of generalizability. Although limited recommendations have been made for the use of diagrammatics, there have been no vigorous efforts to synthesize the results of various findings. In the first experiment of the present investigation, an explicit attempt has been made to assess the differences in methodology and results obtained in the Gordon (1972) and Berger (1970) studies. The second study represents an attempt to replicate the results of Experiment I using new stimuli, i.e., locations to compare the results of this laboratory study with field data collected on the same sites. Our final experiment replicates the technique of the earlier studies using a third set of stimuli which contain some sites similar in geometrics to those used in Experiment I and some sites with geometrics which are uniquely different from those studied in Experiments I or II. All of the sites employed in Study III were located within the State of Michigan and thus the study provides data which are amenable to specific application.

The logic of proceeding in the described fashion follows from the need to evaluate previous laboratory methods, replicate the findings of

that evaluation with new stimuli, and to generate data which might find specific application in the State of Michigan. In subsequent sections, the rationale for each experiment is presented individually.

EXPERIMENT I

The two major laboratory investigations (Berger, 1970; Gordon, 1972), which preceded the present investigation, were characterized by significant differences in methodology as well as in results.

Differences in methodology occurred along a number of dimensions, including group versus individual testing, practice versus no practice, short stimulus presentation time versus indefinite stimulus presentation time, and questionnaire versus automated means of gathering response data. Similarly, the studies were not identical in terms of the response measures that were employed. The Gordon (1972) study employed lane choices, overall preferences and latency data. Berger (1970) employed lane choices and confidence of lane choices in the complete interchange signing study. It was also determined that there were significant differences in the criteria employed for assigning correctness of lane choice. It is obvious that such differences were sufficient to produce conflicting findings which in one case results in a recommendation for conventional signs and in the other a recommendation for diagrammatic signs.

Consequently, the present study was designed to assess the importance of both the methodological and criterial differences inherent in those studies. Initial efforts dealt with methodological and procedural problems. First, it was decided that a system with the capability for both telegraph key responses and for voice key responses would simulate

the essential differences between an automated data system and a questionnaire technique. This procedure permits the collection of latency data and lane choice data thus allowing a comparative analysis of methods which was not possible in earlier investigations. It was also decided that either an unlimited or extremely brief stimulus presentation time were not realistic representations of the amount of time that guide sign information is available to drivers. Therefore, an empirically determined estimate of this time interval was substituted for the external values used in the previous investigations. Third, rather than employ an overall preference for each interchange, a paired comparison technique was employed for each sign within an interchange. Fourth, several levels of practice were employed to simulate learning effects. Finally, stimuli identical to those employed by Gordon (1972) were used to insure the generalizability of our findings to the earlier studies.

Criterion differences between the two studies were examined in a direct fashion. To accomplish this analysis, the criteria employed by previous investigators were requested and obtained. The correctness of lane choice data were then analyzed twice, once using the Berger criteria and once using the Gordon criteria. Subsequently, three tests of significance were performed. In the first two of these tests, the current data were compared against both the Berger (1970) and Gordon (1972) data using their own criteria of correctness. In the third comparison, the current data were compared against itself employing those same criteria. Similar comparisons were made on the confidence and latency data. Each of these analyses is discussed in greater detail in the following sections of the report.

Method

Experimental design

The experiment followed a 2 (response method) x 2 (practice) x 2 (sign type) x 6 (intersection) factorial design with repeated measures on sign type and intersections. Dependent measures included correctness of lane choice, confidence of lane choice, preference of sign types, and latency of response to signs.

Stimulus materials

The basic stimuli utilized in this experiment were eight sets of 35 mm color slides (2 x 2 inch), each set consisting of 29 roadway scenes and 6 destination names. The slides, provided by the FHWA, were identical to those used in the study conducted by Donald Gordon (1972). Briefly, they depicted highway scenes along the Washington, D.C. beltway (I-495) at a distance of approximately 200 feet upstream from an appropriate guide sign and included number designations on each driving lane shown. These slides contained stimuli from six different types of freeway interchange: (1) lane drop (interchange #1 -- 6 slides); (2) multiple split ramp (interchange #4N -- 4 slides); (3) left ramp downstream from righthand ramp (interchange #4E -- 4 slides); (4) two rights in quick succession (interchange #16 -- 6 slides); (5) major fork (interchange #17 -- 3 slides); (6) cloverleaf (interchange #29 -- 6 slides). In addition, each interchange grouping was preceded by a destination name which served as the choice cue for the subjects. A more complete description of these intersections can be obtained in the Gordon (1972) report.

The roadway scenes depicted in each set of slides were identical except for the sign types utilized. Signs in four of the sets were of the "conventional" style (in conformity with the U.S. Manual on Uniform Traffic Control Devices), while signs in the remaining four sets were of

the "diagrammatic" type, duplicating the designs used in the Berger (1970) study.

Since all the interchange signs indicated a right, left, or through destination, several destinations were possible for each interchange. The availability of four sets each of the 29 conventional and the 29 diagrammatic type slides therefore made it possible to construct four different sequence combinations of destinations, creating, in effect, a counterbalancing of turn directions for the stimuli, which would control for any preference bias. Keeping the order of the six interchange types constant in conformity with the Berger and Gordon studies (i.e., : #1, #4N, #rE, #16, #17, #29), one set each of slides depicting conventional and diagrammatic signs included only all right-turn destinations, a second set each included only all left or through destinations, a third set each alternated with right-then-left or through destinations, and a fourth set each alternated with left or through then right-turn destinations.

A second set of stimuli were then prepared, converting a basic set of 29 conventional and 29 diagrammatic slides (3 x 5 inch) into color prints. Two scenes were subsequently eliminated from each set of prints (the first interchange picture for interchanges #4N and #17) since the conventional and diagrammatic signs utilized in the comparable scenes were identical for both, leaving a total of 54 prints. These 54 prints depicted 27 pairs of highway scenes, one print from each pair showing a conventional style sign, while the comparable print shown a diagrammatic type sign. The two prints in each pair were then mounted side by side (their positioning on the right or left being randomized) on separate pieces of poster board ($4\frac{1}{2}$" x $12\frac{1}{2}$"). Above each scene with a conventional

sign was printed a number one (1), and above each scene with a diagrammatic sign was printed a number two (2). This second set of stimuli, thus prepared, provided individual pair-wise comparisons of the two sign types within the twenty-seven roadway scenes.

Subjects

One hundred and twenty subjects were utilized for this experiment, constituting a random sample of licensed drivers with various driving experience from among the Wayne State University student body. Each subject was paid $2.00 for his/her participation.

Experimental procedure

The experimental procedure was basically the same for all subjects. Upon arriving at the laboratory, they were randomly assigned to one of four experimental conditions: (1) voice response with no practice before the testing session--30 subjects; (2) voice response with a practice session before the test session--30 subjects; (3) key response with no practice before the test session--30 subjects; (4) key response with a practice session before the test session--30 subjects. Subjects then sat at a table facing a rear projection screen (from a distance of 8 feet), and viewed slide sets of highway scenes from six freeway interchanges, half of which depicted conventional highway signs and the other half diagrammatic signs (as previously described in Stimulus materials). The presentation order of conventional or diagrammatic signs was counterbalanced, so that one half of the subjects (60) viewed conventional signs before viewing diagrammatic, while the other half (60 subjects) viewed graphic signs before the conventional ones. Furthermore, subjects within each of these sign type orders, were presented one of four turn-direction orders (as

described in Stimulus materials): 40 subjects received all left or through destinations; another 40 subjects received right-turn destinations. In the final group, 20 subjects received left or through then right-turn destinations, while the remaining 20 subjects received right then left or through destinations.

Before viewing the scenes from each interchange, a destination name was presented on the screen for the subject, which he announced aloud. Following this, he was presented the highway scenes for that particular interchange one at a time for a maximum period of five seconds, approximating the amount of time sign information is attended to by freeway drivers. Subjects were instructed to respond as quickly as possible (following the initial presentation of the slide) with the number corresponding to the lane in which they felt they should be in if traveling to the already designated destination. After responding with their lane choice, subjects then indicated their degree of confidence in the correctness of their lane choice. During the inter-trial (slide) interval of 10 seconds, the experimenter recorded the subject's lane choice, the latency of that response, and his confidence level, then reset the equipment and the next scene was displayed.

There were four variations on this basic procedure, corresponding to the four major experimental conditions. Subjects who received no practice session before testing, i.e., their first presentation was their test session, viewed one set each of the diagrammatic and conventional signs, to which they made the aforementioned responses. Practice condition subjects, on the other hand received two presentations each of the conventional and diagrammatic signs, making the appropriate responses. While the sign type order these latter subjects received was maintained in the

second session, the turn-direction order was reversed; i.e., subjects who viewed all right-turn destinations in practice, viewed all left or through destinations in the test session, etc. Thus, as in the Gordon study, while subjects became familiarized with the various sign designs, they did not do so with the actual problems asked in the test sessions.

The second variation in the basic procedure corresponded to the response type condition. Half the subjects within each of the practice and no practice conditions made their lane choices into a voice microphone, while the second half utilized a response key. In each case the subjects' response served to stop a latency timer. The response key condition corresponded to that utilized by Gordon while the voice key condition was included to approximate the questionnaire method used by Berger. A comparison of the latency obtained under these two conditions thus would permit an analysis of performance as a function of method.

A second phase of the experiment followed the slide presentations, and was identical for all subjects regardless of which experimental group they were in. In this session, subjects were presented 27 pairs of color prints (as described in Stimulus materials) depicting the highway scenes that had just been viewed in slide form. Subjects viewed each of these pairs one at a time, indicating which picture of the two presented sign information which they felt was easier to use, and therefore which they would prefer to see utilized in highway signing.

After indicating their 27 preferences, subjects were then asked to make any comment they wished concerning the two types of highway signs, indicating in particular what they may have liked or disliked about each. The experimenter recorded these comments, at the end of which the entire experimental session was completed.

Equipment

The equipment used in the investigation consisted of a Lafayette Instrument Company KT-800 Reaction Time Control and a 18010 Voice Activated Relay. The reaction time unit consists of three major components, a standard automatic projection tachistoscope; a response panel containing five response keys, a five-way connection block for additional response devices, and a 2800 Hertz Senalert Ready Signal; and a control panel containing a four bank timer, six response indicators, a 1/100 second digital stop clock, a manual override control for advancing slides and triggering the shutter, and a mode selection switch which determines whether a slide aborts upon a response. The unit is designed to automatically time an intertrial (ITI) interval, a ready signal period, a delay period, and the presentation time of the slide. The stop clock is automatically initiated upon slide presentation. Any response is recorded on the central control panel, automatically stops the clock, and will terminate the slide presentation. During the ITI period the experimenter must record the reaction time, reset the response indicators, and make any timing changes if desired. Otherwise, the unit is fully automatic and will continue to recycle until manually stopped. The voice activated relay is fully compatible with this unit and provides for the alternative of a vocal input. The advantages of a unit such as this are its standard manufacture, its relatively low cost, and its mobility. With a minimum of experience and modest instruction in the overall methodology, it is possible for various types of agencies to acquire the capability for the conduct of their own exploratory investigations.

Results

We shall first examine those data for which direct comparisons can be made between the results of the Gordon (1972), Berger (1970), and current study. The only data on which the three studies could be directly compared was the correctness of Lane Choices. The data are summarized by Interchange type in Tables 1-6. Three tests of significance were run on each interchange. First, the original Berger (1970) data were compared with the current data employing the Berger criteria. Two such tests were possible for each interchange, allowing for sign type (conventional or diagrammatic) and practice (practice or no practice). Only four of the 12 possible tests reached significance. This suggests that the data obtained in the current study are essentially of the same nature as that obtained in the Serendipity study. This finding clearly suggests that the data obtained in the Berger study are reliable. Our second set of significance tests compared the original Gordon (1970) data with the current data employing the FHWA criteria. Only two of twenty-four such comparisons were found to be significant. This finding suggests that the data obtained in the Gordon study are also reliable. However, the final set of significance tests provides the data for a rather important conclusion. In this final set of analyses the current data scored by the Berger criterion were compared with the same data scored by the FHWA criteria. Fifteen of 24 comparisons were found to be significant, i.e., the means were significantly different from each other. Since no essential significant differences were found when the earlier data were compared with current data employing the same criteria, only one conclusion is possible. It is suggested that data obtained in earlier laboratory studies is <u>reliable</u> but the

TABLE 1

COMPARATIVE DATA ON CORRECTNESS OF LANE CHOICE

Interchange #1

PRACTICE	SIGN TYPE	STUDY	CRITERIA OF CORRECTNESS	% CHOOSING PROPER LANE — SIGN WITHIN INTERCHANGE							SIGNIFICANCE TESTS BETWEEN MEANS*		
				1	2	3	4	5	6	$\bar{X}$	A	B	C
NO PRACTICE	CONV.	Serendipity	Serendipity	48	17	65	76	94	86	63.8	$<.01$	N.S.	N.S.
		FHWA	Gordon	unk	unk	unk	unk	unk	unk	91.1			
		Zajkowski	FHWA	95	41.7	83.3	94.2	96.7	98.3	84.9			
			Serendipity	75.8	48.4	83.9	95.2	98.4	100	83.6			
	DIAG.	Serendipity	Serendipity	96	46	94	56	98	84	78.3	N.S.	N.S.	N.S.
		FHWA	Gordon	unk	unk	unk	unk	unk	unk	87.5			
		Zajkowski	FHWA	90.8	48.3	60.8	79.2	93.3	98.3	78.4			
			Serendipity	79.0	40.3	61.3	83.9	96.8	98.4	76.6			

TABLE 1 (continued)

COMPARATIVE DATA ON CORRECTNESS OF LANE CHOICE

Interchange #1 (continued)

PRACTICE	SIGN TYPE	STUDY	CRITERIA OF CORRECTNESS	% CHOOSING PROPER LANE — SIGN WITHIN INTERCHANGE							SIGNIFICANCE TESTS BETWEEN MEANS*		
				1	2	3	4	5	6	$\bar{X}$	A	B	C
PRACTICE	CONV.	Serendipity	Serendipity	--	--	--	--	--	--	--	N.S.	N.S.	N.S.
		FHWA	Gordon	unk	unk	unk	unk	unk	unk	91.1			
		Zajkowski	FHWA	98.3	48.3	81.7	96.7	100	100	87.5			
			Serendipity	89.3	35.7	75.0	100	100	100	83.3			
	DIAG.	Serendipity	Serendipity	--	--	--	--	--	--	--	N.S.	N.S.	N.S.
		FHWA	Gordon	unk	unk	unk	unk	unk	unk	85.8			
		Zajkowski	FHWA	100	51.7	45.0	91.7	100	100	81.4			
			Serendipity	100	32.1	64.3	92.9	100	100	81.6			

*Significance Tests: A: Serendipity study vs. Zajkowski study by Serendipity criteria

B: FHWA study vs. Zajkowski study by Gordon crtieria

C: Zajkowski study -- Serendipity criteria vs. Gordon criteria

TABLE 2

COMPARATIVE DATA ON CORRECTNESS OF LANE CHOICE

Interchange #4 North

PRACTICE	SIGN TYPE	STUDY	CRITERIA OF CORRECTNESS	% CHOOSING PROPER LANE					SIGNIFICANCE TESTS BETWEEN MEANS*		
				SIGN WITHIN INTERCHANGE							
				1	2	3	4	$\bar{X}$	A	B	C
NO PRAC-TICE	CONV.	Serendipity	Serendipity	24	24	54	70	43.0	N.S.	N.S.	$<.001$
		FHWA	Gordon	unk	unk	unk	unk	94.2			
		Zajkowski	FHWA	100	92.5	65.8	95.8	88.5			
			Serendipity	12.1	36.2	91.4	94.8	58.6			
	DIAG.	Serendipity	Serendipity	25	86	92	82	71.3	$<.05$	$<.05$	N.S.
		FHWA	Gordon	unk	unk	unk	unk	94.2			
		Zajkowski	FHWA	100	91.7	35.8	93.3	80.2			
			Serendipity	91.4	86.2	91.4	67.2	84.1			

TABLE 2 (continued)

COMPARATIVE DATA ON CORRECTNESS OF LANE CHOICE (continued)

Interchange #4 North

PRACTICE	SIGN TYPE	STUDY	CRITERIA OF CORRECTNESS	% CHOOSING PROPER LANE SIGN WITHIN INTERCHANGE 1	2	3	4	$\bar{X}$	SIGNIFICANCE TESTS BETWEEN MEANS* A	B	C
PRACTICE	CONV.	Serendipity	Serendipity	--	--	--	--	--			
		FHWA	Gordon	unk	unk	unk	unk	94.6	N.S.	N.S.	< .001
		Zajkowski	FHWA	100	93.3	81.7	96.7	92.9			
			Serendipity	3.1	40.6	90.6	96.9	57.8			
	DIAG.	Serendipity	Serendipity	--	--	--	--	--			
		FHWA	Gordon	unk	unk	unk	unk	91.3	N.S.	N.S.	N.S.
		Zajkowski	FHWA	100	95.0	36.7	95.0	81.7			
			Serendipity	84.4	81.3	93.8	75.0	83.6			

*Significance Tests: A: Serendipity study vs. Zajkowski study by Serendipity criteria

B: FHWA study vs. Zajkowski study by Gordon criteria

C: Zajkowski study -- Serendipity criteria vs. Gordon criteria

TABLE 3

COMPARATIVE DATA ON CORRECTNESS OF LANE CHOICE

Interchange #4 East

PRACTICE	SIGN TYPE	STUDY	CRITERIA OF CORRECTNESS	% CHOOSING PROPER LANE					SIGNIFICANCE TESTS BETWEEN MEANS*		
				SIGN WITHIN INTERCHANGE							
				1	2	3	4	$\bar{X}$	A	B	C
NO PRACTICE	CONV.	Serendipity	Serendipity	15	36	69	76	49	N.S.	N.S.	N.S.
		FHWA	Gordon	unk	unk	unk	unk	87.1			
		Zajkowski	FHWA	99.2	36.7	85.0	98.3	79.3			
			Serendipity	28.8	91.5	3.4	94.9	54.7			
	DIAG	Serendipity	Serendipity	10	62	80	84	59	N.S.	N.S.	$< .001$
		FHWA	Gordon	unk	unk	unk	unk	86.7			
		Zajkowski	FHWA	93.3	64.2	74.2	81.7	78.4			
			Serendipity	25.4	91.5	18.6	98.3	58.5			

TABLE 3 (continued)

COMPARATIVE DATA ON CORRECTNESS OF LANE CHOICE (continued)

Interchange #4 East

PRACTICE	SIGN TYPE	STUDY	CRITERIA OF CORRECTNESS	% CHOOSING PROPER LANE — SIGN WITHIN INTERCHANGE 1	2	3	4	$\bar{X}$	SIGNIFICANCE TESTS BETWEEN MEANS* A	B	C
PRACTICE	CONV.	Serendipity	Serendipity	--	--	--	--	--	N.S.	N.S.	$<.001$
		FHWA	Gordon	unk	unk	unk	unk	82.1			
		Zajkowski	FHWA	100	46.7	86.7	100	83.4			
			Serendipity	18.8	87.5	0.0	93.8	50.0			
	DIAG.	Serendipity	Serendipity	--	--	--	--	--	N.S.	N.S.	$<.05$
		FHWA	Gordon	unk	unk	unk	unk	82.9			
		Zajkowski	FHWA	91.7	70.0	80.0	85.0	81.7			
			Serendipity	18.8	96.9	31.3	100	61.8			

*Significance Tests: A: Serendipity study vs. Zajkowski study by Serendipity criteria

B: FHWA study vs. Zajkowski study by Gordon criteria

C: Zajkowski study -- Serendipity criteria vs. Gordon criteria

TABLE 4

COMPARATIVE DATA ON CORRECTNESS OF LANE CHOICE

Interchange #16

PRACTICE	SIGN TYPE	STUDY	CRITERIA OF CORRECTNESS	% CHOOSING PROPER LANE							SIGNIFICANCE TESTS BETWEEN MEANS*		
				SIGN WITHIN INTERCHANGE									
				1	2	3	4	5	6	$\bar{X}$	A	B	C
NO PRACTICE	CONV.	Serendipity	Serendipity	14	14	28	54	86	96	48.7	N.S.	N.S.	<.001
		FHWA	Gordon	unk	unk	unk	unk	unk	unk	76.1			
		Zajkowski	FHWA	84.2	86.7	48.3	32.5	70.0	94.2	69.3			
			Serendipity	8.5	8.5	40.7	28.8	72.9	91.5	41.8			
	DIAG.	Serendipity	Serendipity	15	13	71	40	75	98	52.0	N.S.	N.S.	<.001
		FHWA	Gordon	unk	unk	unk	unk	unk	unk	80.6			
		Zajkowski	FHWA	93.3	94.2	33.3	45.8	61.7	90.8	69.9			
			Serendipity	8.5	10.2	37.3	49.2	59.3	86.4	41.8			

TABLE 4 (continued)

COMPARATIVE DATA ON CORRECTNESS OF LANE CHOICE

Interchange #16 (continued)

PRACTICE	SIGN TYPE	STUDY	CRITERIA OF CORRECTNESS	% CHOOSING PROPER LANE							SIGNIFICANCE TESTS BETWEEN MEANS*		
				SIGN WITHIN INTERCHANGE									
				1	2	3	4	5	6	$\bar{X}$	A	B	C
PRACTICE	CONV.	Serendipity	Serendipity	--	--	--	--	--	--	--	N.S.	$<.05$	$<.001$
		FHWA	Gordon	unk	unk	unk	unk	unk	unk	84.7			
		Zajkowski	FHWA	93.3	93.3	51.7	51.7	80.0	100	78.3			
			Serendipity	3.1	3.1	43.8	40.6	75.0	100	44.3			
	DIAG.	Serendipity	Serendipity	--	--	--	--	--	--	--	N.S.	N.S.	$<.001$
		FHWA	Gordon	unk	unk	unk	unk	unk	unk	85.0			
		Zajkowski	FHWA	96.3	96.3	46.7	53.3	66.7	93.3	75.4			
			Serendipity	3.1	3.1	37.5	53.1	68.8	93.8	43.2			

*Significance Tests: A: Serendipity study vs. Zajkowski study by Serendipity criteria

B: FHWA study vs. Zajkowski study by Gordon criteria

C: Zajkowski study -- Serendipity criteria vs. Gordon criteria

TABLE 5

COMPARATIVE DATA ON CORRECTNESS OF LANE CHOICE

Interchange #17

EXPERIENCE	SIGN TYPE	STUDY	CRITERIA OF CORRECTNESS	% CHOOSING PROPER LANE SIGN WITHIN INTERCHANGE 1	2	3	$\bar{X}$	SIGNIFICANCE TESTS BETWEEN MEANS* A	B	C
NO PRACTICE	CONV.	Serendipity	Serendipity	36	64	84	61.3	.05	N.S.	.001
		FHWA	Gordon	unk	unk	unk	97.8			
		Zajkowski	FHWA	100	93.3	94.2	95.8			
			Serendipity	45.8	93.3	94.2	77.8			
	DIAG.	Serendipity	Serendipity	28	80	92	66.7	N.S.	N.S.	.001
		FHWA	Gordon	unk	unk	unk	97.2			
		Zajkowski	FHWA	99.2	81.7	90.8	90.6			
			Serendipity	49.2	85.0	92.5	75.6			

TABLE 5

COMPARATIVE DATA ON CORRECTNESS OF LANE CHOICE

Interchange 17 (continued)

EXPERIENCE	SIGN TYPE	STUDY	CRITERIA OF CORRECTNESS	% CHOOSING PROPER LANE				SIGNIFICANCE TESTS BETWEEN MEANS*		
				SIGN WITHIN INTERCHANGE			$\bar{X}$			
				1	2	3		A	B	C
PRACTICE	CONV.	Serendipity	Serendipity	--	--	--	--	N.S.	N.S.	.01
		FHWA	Gordon	unk	unk	unk	98.9			
		Zajkowski	FHWA	100	96.7	96.7	97.8			
			Serendipity	58.3	98.3	95.0	83.9			
	DIAG.	Serendipity	Serendipity	--	--	--	--	N.S.	N.S.	N.S.
		FHWA	Gordon	unk	unk	unk	98.3			
		Zajkowski	FHWA	100	90.0	90.0	93.3			
			Serendipity	60.0	93.3	93.3	82.2			

*Significance Tests: A: Serendipity study vs. Zajkowski study by Serendipity criteria

B: FHWA study vs. Zajkowski study by Gordon criteria

C: Zajkowski study -- Serendipity criteria vs. Gordon criteria

TABLE 6

COMPARATIVE DATA ON CORRECTNESS OF LANE CHOICE

Interchange #29

PRACTICE	SIGN TYPE	STUDY	CRITERIA OF CORRECTNESS	% CHOOSING PROPER LANE — SIGN WITHIN INTERCHANGE							SIGNIFICANCE TESTS BETWEEN MEANS*		
				1	2	3	4	5	6	$\bar{X}$	A	B	C
NO PRACTICE	CONV.	Serendipity	Serendipity	38	57	36	50	98	98	62.8	N.S.	N.S.	$<.001$
		FHWA	Gordon	unk	unk	unk	unk	unk	unk	93.6			
		Zajkowski	FHWA	95.8	90.8	65.8	95.0	80.8	96.7	87.5			
			Serendipity	50.8	81.4	42.4	94.9	57.6	96.6	70.6			
	DIAG.	Serendipity	Serendipity	78	82	62	44	70	100	72.7	$<.01$	N.S.	$<.001$
		FHWA	Gordon	unk	unk	unk	unk	unk	unk	87.8			
		Zajkowski	FHWA	96.7	64.2	82.5	69.2	57.5	95.0	77.5			
			Serendipity	55.9	61.0	13.6	57.6	13.6	94.9	49.4			

TABLE 6 (continued)

COMPARATIVE DATA ON CORRECTNESS OF LANE CHOICE

Interchange #29 (continued)

PRACTICE	SIGN TYPE	STUDY	CRITERIA OF CORRECTNESS	% CHOOSING PROPER LANE SIGN WITHIN INTERCHANGE							SIGNIFICANCE TESTS BETWEEN MEANS*		
				1	2	3	4	5	6	$\bar{X}$	A	B	C
PRACTICE	CONV.	Serendipity	Serendipity	--	--	--	--	--	--	--	N.S.	N.S.	$\leq .05$
		FHWA	Gordon	unk	unk	unk	unk	unk	unk	94.4			
		Zajkowski	FHWA	96.7	96.7	70.0	98.3	86.7	100	91.4			
			Serendipity	56.3	87.5	53.1	96.9	75.0	100	78.1			
	DIAG.	Serendipity	Serendipity	--	--	--	--	--	--	--	N.S.	N.S.	$\leq .01$
		FHWA	Gordon	unk	unk	unk	unk	unk	unk	88.1			
		Zajkowski	FHWA	93.3	68.3	75.0	76.7	60.0	96.7	78.3			
			Serendipity	53.1	59.4	25.0	75.0	21.9	96.9	55.2			

*Significance Tests: A: Serendipity study vs. Zajkowski study by Serendipity criteria

B: FHWA study vs. Zajkowski study by Gordon criteria

C: Zajkowski study -- Serendipity criteria vs. Gordon criteria

criteria employed in those studies were not. A summary of correctness by FHWA criteria at exit point broken down by interchange, sign, and practice is given in Table 7. The mean proportion correct for conventional signs was .96 and for diagrammatic was .91. An analysis of variance of correctness of lane choice across all interchanges revealed no significant differences in correctness due to sign type (conventional versus diagrammatic) $F_{(1,112)} = 2.8188$, or experience (practice versus no practice) $F_{(1,112)} = 1.0757$, when analyzed by F.H.W.A. criteria. Similar results were obtained in an analysis of variance using the Berger criteria. A complete summary of these analyses is given in Table 34 of Appendix A. Generally, the results tend to support Gordon's findings that the proportion of correct lane choice is higher for conventional signs than diagrammatic, although in the present investigation this difference was not statistically significant. A result such as this is not unanticipated since most drivers are familiar with conventional signs and consequently diagrammatic signs produce a novelty effect which initially may cause some slight deteriorations in performance. However as data obtained in later studies will show, diagrammatic signs can have some utility when employed in unusual driving situations and when designed properly for the circumstances in which they are employed.

Table 8 summarizes the comparative analyses on confidence of lane choices. Only comparisons with the Berger data were possible since Gordon did not collect confidence data. In the six possible comparisons (across interchanges) of the Berger data and the current data on conventional signs, only in a single instance were the means statistically different from one another. In the case of diagrammatic signs none of the

TABLE 7

CORRECTNESS OF LANE CHOICE AT EXIT POINT

Experiment 1

Interchange		Conventional # Correct	Conventional # Incorrect	Conventional Correct	Diagrammatic # Correct	Diagrammatic # Incorrect	Diagrammatic Correct	Sig. Diff. in proportion correct
1	No Prac	118	2	.983	115	5	.958	N.S.
	Prac	60	0	1.000	60	0	1.000	N.S.
4N	No Prac	113	7	.942	113	7	.942	N.S.
	Prac	60	0	1.000	60	0	1.000	N.S.
4E	No Prac	114	6	.950	96	24	.800	*
	Prac	56	4	.933	54	6	.900	N.S.
16	No Prac	113	7	.942	109	11	.908	N.S.
	Prac	60	0	1.000	56	4	.933	*
17	No Prac	113	7	.942	109	11	.908	N.S.
	Prac	58	2	.967	55	5	.917	N.S.
29	No Prac	115	5	.958	107	13	.892	N.S.
	Prac	60	0	1.000	51	9	.850	*
TOTAL	No Prac	686	34	.953	649	71	.901	
	Prac	354	6	.983	336	24	.933	
MEAN PROPORTION CORRECT				.96			.91	

*.05 significance level

six mean differences were statistically different from one another. As in the case of correctness of lane choices, this finding is interpreted to mean that the data obtained in the earlier investigation is reliable. When the mean of the conventional confidences (3.43 on scale ranging from 1 to 4) were compared with the mean of the diagrammatic confidences (3.13) for the current data, it was found that the difference between means was significant both for practice ($t_{(5df)} = 4.098$, $p \simeq .005$) and for no practice conditions ($t_{(5df)} = 3.88$, $p < .01$). Berger obtained results which were not in agreement with the above findings, i.e., the mean confidence for conventional signs was 3.09 and for diagrammatic, 3.02. It is believed that the findings of the present investigation are intuitively more interpretable in that individuals should be more confident of stimuli which are familiar to them and less confident of stimuli which are novel or unique. Of course, diagrammatic signs fall into this latter category. The Chi Square tests in part A of Table 9 also indicate that there is a significant relationship between confidence of lane choice and correctness of lane choice. That is, the more confident an individual is of his lane choices, the more apt he is to be correct. Moreover, as part C of Table 9 shows, <u>if</u> an individual prefers diagrammatic signs, he is also confident of his responses to them and this is independent of practice condition. However, this relationship does not appear to hold for conventional signs.

The subjects also clearly preferred conventional signs over diagrammatic signs ($t_{26df} = 47.91$, $p < .0005$). The mean percentage of preferences for each interchange is given in Table 10. Reference to

TABLE 8

MEAN COMPARATIVE DATA ON CONFIDENCE OF RESPONSE

Interchange #1

PRACTICE	SIGN TYPE	STUDY	FOR EACH SIGN WITHIN INTERCHANGE						OVER ALL MEAN	SIGNIFICANCE OF MEAN DIFFERENCES*		
			1	2	3	4	5	6		A	B	C
NO PRACTICE	Conv.	Serendipity	2.52	2.11	3.20	3.35	3.90	2.73	2.97	N.S.	N.S.	$<.025$
		Zajkowski	3.41	3.17	3.50	3.73	3.81	3.40	3.50			
	Diag.	Serendipity	3.60	2.13	3.11	3.25	3.90	2.57	3.09			
		Zajkowski	3.13	3.00	2.78	3.13	3.73	3.31	3.18			
PRACTICE	Conv.	Serendipity	--	--	--	--	--	--	--	---	---	$<.05$
		Zajkowski	3.62	3.18	3.45	3.68	3.85	3.55	3.56			
	Diag.	Serendipity	--	--	--	--	--	--	--			
		Zajkowski	3.28	3.08	2.55	2.85	3.67	3.55	3.16			

Interchange #16

NO PRACTICE	Conv.	Serendipity	1.86	2.00	2.86	3.52	3.58	3.77	2.93	N.S.	N.S.	$<.05$
		Zajkowski	3.08	3.06	3.41	3.38	3.37	3.91	3.37			
	Diag.	Serendipity	2.25	1.86	3.49	2.71	3.67	3.82	2.97			
		Zajkowski	2.99	2.98	3.33	2.59	3.10	3.76	3.13			
PRACTICE	Conv.	Serendipity	--	--	--	--	--	--	--	---	---	$<.05$
		Zajkowski	3.23	3.17	3.47	3.25	3.30	3.95	3.40			
	Diag.	Serendipity	--	--	--	--	--	--	--			
		Zajkowski	3.03	3.10	3.40	2.42	2.97	3.83	3.13			

*A: Seren. Conv. vs. Zajk. Conv.; B: Seren. Diag. vs. Zajk. Diag.; C: Zajk. Conv. vs. Zajk. Diag.

TABLE 8 (continued)

MEAN COMPARATIVE DATA ON CONFIDENCE OF RESPONSE

Interchange #4 North

PRACTICE	SIGN TYPE	STUDY	FOR EACH SIGN WITHIN INTERCHANGE 1	2	3	4	OVER ALL MEAN	SIGNIFICANCE OF MEAN DIFFERENCES* A	B	C
NO PRACTICE	Conv.	Serendipity	2.25	3.33	3.63	3.54	3.19	N.S.	N.S.	N.S.
		Zajkowski	3.60	3.14	3.68	3.19	3.40			
	Diag.	Serendipity	2.15	3.44	3.17	3.42	3.05			
		Zajkowski	3.58	3.09	3.42	2.82	3.23			
PRACTICE	Conv.	Serendipity	--	--	--	--	--	---	---	< .005
		Zajkowski	3.65	3.27	3.62	3.30	3.46			
	Diag.	Serendipity	--	--	--	--	--			
		Zajkowski	3.30	3.05	3.35	2.83	3.13			

Interchange #4 East

NO PRACTICE	Conv.	Serendipity	2.44	3.15	3.47	3.59	3.16	N.S.	N.S.	<.05
		Zajkowski	3.09	3.59	3.41	3.78	3.47			
	Diag.	Serendipity	3.40	2.52	3.38	3.31	3.15			
		Zajkowski	3.10	3.46	2.68	3.45	3.17			
PRACTICE	Conv.	Serendipity	--	--	--	--	--	---	---	<.05
		Zajkowski	3.25	3.57	3.43	3.73	3.15			
	Diag.	Serendipity	--	--	--	--	--			
		Zajkowski	3.25	3.35	2.52	3.27	3.10			

*A: Seren. Conv. vs. Zajk. Conv.; B: Seren. Diag. vs. Zajk. Diag.; C: Zajk. Conv. vs. Zajk. Diag.

TABLE 8 (continued)

MEAN COMPARATIVE DATA ON CONFIDENCE OF RESPONSE

Interchange #29

PRACTICE	SIGN TYPE	STUDY	FOR EACH SIGN WITHIN INTERCHANGE 1	2	3	4	5	6	OVER ALL MEAN	SIGNIFICANCE OF MEAN DIFFERENCES* A	B	C
NO PRACTICE	Conv.	Serendipity	3.25	3.33	2.68	3.50	3.88	3.86	3.42	N.S.	N.S.	∠.005
		Zajkowski	3.47	3.67	3.53	3.87	3.20	3.38	3.52			
	Diag.	Serendipity	2.72	2.85	2.48	2.86	3.17	3.76	2.97			
		Zajkowski	2.84	2.88	3.24	2.74	2.35	3.24	2.88			
PRACTICE	Conv.	Serendipity	--	--	--	--	--	--	--	---	---	∠.01
		Zajkowski	3.50	3.63	3.45	3.83	3.20	3.37	3.50			
	Diag.	Serendipity	--	--	--	--	--	--	--			
		Zajkowski	2.62	2.70	3.25	2.48	2.37	3.22	2.77			

Interchange #17

NO PRACTICE	Conv.	Serendipity	2.44	2.84	3.07				2.78	∠ .05	N.S.	N.S.
		Zajkowski	3.03	3.43	3.44				3.30			
	Diag.	Serendipity	2.60	3.00	3.29				2.96			
		Zajkowski	3.14	3.15	3.31				3.20			
PRACTICE	Conv.	Serendipity	--	--	--				--	---	---	∠.05
		Zajkowski	3.27	3.55	3.45				3.42			
	Diag.	Serendipity	--	--	--				--			
		Zajkowski	3.23	3.07	3.25				3.18			

*A: Seren. Conv. vs. Zajk. Conv.; B: Seren. Diag. vs. Zajk. Diag.; C: Zajk. Conv. vs. Zajk. Diag.

TABLE 9

CHI SQUARE TESTS OF VARIABLE INTERRELATIONSHIPS

Experiment I

A. Correctness of lane choice to conventional and diagrammatic signs by degree of confidence in lane choice

		X^2	df	p	C	N
No Practice	Conventional	67.68	3	.001	.6004	120
	Diagrammatic	127.10	3	.001	.7130	120
Practice	Conventional	38.807	3	.001	.6266	60
	Diagrammatic	75.97	2	.001	.7434	60

*B. Correctness of lane choice to conventional and diagrammatic signs by preference for conventional or diagrammatic signs

		X^2	df	p	C	N
No Practice	Conventional	11.024	1	.001	.2685	120
	Diagrammatic	159.86	1	.001	.7557	120
Practice	Conventional	2.002	1	.250(ns)	.1794	60
	Diagrammatic	11.777	1	.001	.4049	60

*C. Preference for conventional or diagrammatic signs by degree of confidence in lane choice

		X^2	df	p	C	N
No Practice	Conventional	4.86	3	.250(ns)	.1972	120
	Diagrammatic	53.10	3	.001	.5538	120
Practice	Conventional	.739	3	.500(ns)	.1100	60
	Diagrammatic	36.897	3	.001	.6170	60

*Preference for slide #1 for both interchanges #4N and 17 not included.

TABLE 10

MEAN PERCENTAGE OF PREFERENCES

TO CONVENTIONAL AND DIAGRAMMATIC SIGNS

Interchange	Sign Type		
	Conventional		Diagrammatic
	Mean	SD	Mean
1	69.17	22.97	30.83
4E	67.07	19.92	32.93
4N	76.40	17.35	23.60
16	78.48	13.01	21.51
17	62.90	5.40	37.10
29	84.05	17.98	15.95
EXIT POINT ONLY	75.15	11.11	24.85

Table 9, part B, indicates that the subjects were more often correct for signs that they preferred. These results tend to corroborate the preference findings of Gordon (1972).

Comparisons of Latency data were possible only for the Gordon (1972) and current data. The comparisons are summarized for overall interchanges in Table 11 and for the exit point within each interchange in Table 12. It can be observed from Table 11 that in two out of four comparisons with the Gordon (1972) data the mean latencies obtained in the two studies were significantly different from one another. The effects were restricted to the practice condition and, in general, mean latencies were higher in the present investigation than in the Gordon study.

Although the studies differed significantly in magnitude of mean latencies, the pattern of means is quite similar. That is, response latencies to conventional signs are lower than those to diagrammatic signs. Thus, latency data of the present investigation tend to support the earlier findings of Gordon. This sort of interpretation is supported by an examination of Table 12 where a similar pattern of results were obtained for latency at the exit point. We conclude from these comparisons that the results obtained in the present study are essentially of the same nature as those obtained in the Gordon (1972) study. A breakdown of latencies by sign within interchanges is provided in Table 35 of Appendix A.

In an overall analysis of variance of latency data, it was found that the main effects of sign type, $F_{(1,116)} = 80.41$, $p < .001$, and interchange type, $F_{(5,580)} = 8.89$, $p < .001$, were significant.

TABLE 11

COMPARATIVE DATA ON MEAN LATENCY OF RESPONSE (SECS.)

Experiment I

EXPERIENCE	SIGN TYPE	STUDY	N	INTERCHANGE						AVE	SIGNIFI-CANCE TEST
				1	4E	4N	16	17	29		
NO PRACTICE	Conv	Gordon	60	3.18	3.19	3.04	3.22	3.15	2.91	3.12	N.S.
		Zajkowski	60	3.14	2.89	3.01	3.14	3.39	2.74	3.05	
	Diag	Gordon	60	3.80	3.33	3.46	3.59	3.32	3.51	3.50	N.S.
		Zajkowski	60	3.54	3.21	3.18	3.55	3.64	3.50	3.44	
PRACTICE	Conv	Gordon	60	2.60	2.68	2.56	2.70	2.66	2.48	2.61	$<.005$
		Zajkowski	60	2.78	2.98	3.10	3.24	3.25	2.89	3.04	
	Diag	Gordon	60	2.92	2.81	2.83	2.90	2.83	3.16	2.91	$<.005$
		Zajkowski	60	3.20	3.50	3.36	3.61	3.59	3.78	3.51	

TABLE 12

COMPARATIVE DATA ON MEAN LATENCY AT EXIT POINT

PRACTICE	SIGN TYPE	STUDY	INTERCHANGE 1 MEAN	4E MEAN	4N MEAN	16 MEAN	17 MEAN	29 MEAN	$\bar{X}$	SIGNIFICANCE TEST BETWEEN MEANS*
NO PRAC	Conv	Gordon	1.94	2.57	2.47	1.86	3.20	1.81	2.31	N.S.
		Zajkow (key)	2.14	2.27	2.65	1.95	3.32	2.07	2.40	
	Diag	Gordon	2.37	2.96	3.05	2.12	2.24	2.57	2.55	$< .05$
		Zajkow (key)	2.18	2.62	2.98	2.28	3.63	2.99	2.78	
PRAC	Conv	Gordon	1.64	2.32	2.19	1.67	2.78	1.57	2.03	$< .005$
		Zajkow (key)	1.92	2.69	2.67	1.88	3.64	2.03	2.47	
		Gordon	1.87	2.69	2.43	1.88	2.83	2.29	2.33	$< .0005$
		Zajkow (key)	1.95	3.35	3.30	2.48	3.78	3.54	3.07	

*one-tailed test of significance

The former effect is based on the fact that the mean latency of response to conventional signs (2.8125) was significantly faster than the mean latency to diagrammatic signs (3.2075). The latter effect is due of course to the fact that latencies differed significantly as a function of the type of interchange being employed. Surprisingly the interchange which produced the longest overall mean latency (3.115) was the major fork. Although this finding seems to be consistent with other studies, it is nevertheless puzzling since this type of interchange is neither the most geometrically complex nor one which requires an extreme amount of explanatory information on guide signs. Intuitively, it would also appear to be the most easily understood of the diagrammatic signs. This point would seem to be verified by the fact that the overall mean percentage of correct lane choices for this interchange was the highest (94.37 by F.H.W.A. criteria) of all those obtained in this study. One significant difference between this interchange and all others employed in the study was that the major fork requires a driver to make a judgment or a direction change at highway speeds while all the others require an exit judgment which would involve slowing the vehicle.

Several other significant latency effects were found in this overall analysis. Verbal responses were found to be significantly faster than key pressing responses, $F_{(1,116)} = 14.63$, $p < .001$. The magnitude of this difference was approximately .50 second. It was also found that practice ($F_{(5,580)} = 8.55$, $p < .001$), response type ($F_{(5,580)} = 4.52$, $p < .001$), and sign

type ($F_{5,58} = 13.71$, $p < .001$) interact significantly with interchange type. The basis for the interaction with practice was that in several instances mean latencies increased when practice was given while in others it decreased. It is suggested that this effect is both uninterpretable and of little practical significance. This latter point is verified by the value of w^2 in Table 36, which indicates that less than one percent of the total variance is accounted for by this effect. A similar analysis can be made for the interaction of response type with interchange type. The sign type by interchange interaction is due primarily to two interchanges, one in which the mean latencies for conventional and diagrammatic signs tend to converge toward one another and a second in which they tend to diverge. As the w^2 statistic in Table 36 for the effect indicates, it is of little practical significance, accounting for only one percent of the total variance. A similar analysis of variance was done on the latencies at the exit point only. The results of this analysis were essentially the same as the analysis on overall latencies. The results of the analysis are given in Table 37 of Appendix A.

Analyses of variance were also performed on the latencies to individual intersections. The major portion of the analyses duplicate the findings of the overall analyses with respect to practice, sign type, and response type. However, it was also found that latencies differed significantly as a function of their position in the entire sequence of signs. Generally, the initial

latency is relatively low. Latencies in the middle of the sequence have a tendency to be greater than the initial sign latency and are followed by a general decline in latencies near the end of the sequence. This pattern seems to reflect the information processing behavior of the driver who is extracting information from highway guide signs. It would seem logical to assume that the initial sign in sequence is simply an announcement of subsequent information tasks that will be demanded and consequently requires little processing. This would be reflected in relatively low latencies. The signs in the middle of a sequence are those which communicate information relevant to the driving task and thus require somewhat longer responses due to the information processing which is required. The final sign in the sequence is simple announcement which emphasizes more the detection of a point of action for which a decision has previously been made than any additional information processing.

The final set of analyses dealing with latencies demonstrates the relationship between latency and the two dependent measures of correctness of lane choice and confidence of lane choice. The average correlation between confidence and latency was $-.79$, $p < .001$, which suggests that the more confident one is of his judgment the more quickly he will respond. The average correlation between correctness of lane choices and latencies of response was $-.43$, $p < .02$, which suggests that individuals respond more quickly to stimuli on which they have made a correct judgment. Clearly, these findings demonstrate the sensitivity of measures of latency to other variables which play an important role in the analysis of sign reading behavior.

In an analysis of the absolute number of lane changes (position change between lanes) across interchanges, it was found that there was no significant difference ($t_{5df} = .77$) between conventional ($\bar{X} = 195.17$) and diagrammatic ($\bar{X} = 189.17$) signs but that such changes decreased as a function of practice. Generally, the total number of lane changes was lower for practice conditions (124.83) than for no practice conditions (259.50).

Finally, at the end of the experimental session, each subject was invited to make whatever evaluative statement he desired with respect to the advantages or disadvantages of conventional or diagrammatic signs. These comments are summarized in Table 13. It should be noted that categories are non-independent, i.e., one person may be included in a number of categories. The experimenter collapsed comments into categories with essentially synonomous meaning. This classification is arbitrary, but an examination of the comments should give the researcher some insight into the user's view of guide sign problems. Freely translated, it seems that users require a logical sequence of information, which is presented with the minimum of complexity and which is specifically relevant to the particular type of decision required for that choice point.

Discussion

As stated in the introduction, the purpose of this experiment was to assess the differences in methodology and results obtained in the Berger (1970) and Gordon (1972) studies of diagrammatic signs. The specific goal in mind was the development of a reliable laboratory method for the evluation of highway guide signs. It is believed that this experiment has accomplished these goals. In the analysis of correctness of lane choices it was demonstrated that the results of the current

TABLE 13

POST EXPERIMENTAL INTERVIEW COMMENTS

Experiment I

frequency of comment	comment
61	Diagrammatic sign too confusing, too long, or difficult to understand.
30	Too much information or too many directions on diagrammatic signs.
28	Prefer conventional signs with small arrow pointing to exit lane.
9	With practice diagrammatic signs as clear as conventional signs.
5	Prefer long curved arrows at exit point as long as they are not too complicated.
3	Sign preceding exit should only include distance to the exit and sign at exit should indicate where to go.
2	Sign preceding exit should be diagrammatic while sign near the exit should be conventional.
1	With multiple arrows on signs information is needed to indicate which lane goes with each arrow

investigation could be made to match the results of the other two studies, depending upon the criteria employed. When the effects of employing the different cirteria are analyzed, the conflicting results of the earlier studies are also obtained. Obviously, the conclusion to be reached from this observation is that either of the two laboratory methods can produce reliable data, but validity requires an independent field check since the data analyses did differ significantly.

It should be pointed out that the present investigator prefers the methodology employed by Gordon, with our equipment modification, because of its relative simplicity and ease of obtaining data, and because of its mobility. With a minimum of equipment expense and a small amount of training in the procedural aspects of the research, any agency can carry out an evaluative guide-signing project before significant economic committments are made. This would seem to be a reasonable alternative to current practices in guide sign decision making.

To reiterate the results briefly, no overall differences were found in correctness of lane choices to conventional or diagrammatic guide signs. Conventional guide signs were preferred over diagrammatic guide signs. Subjects also seemed to be more confident of their responses to conventional guide signs and on the whole responded more quickly to them. Thus it would appear that for the particular interchanges employed in this investigation diagrammatic guides would produce no significant benefits over conventional guide signs. However, in the opinion of the present investigator the stimuli employed in this study which were identical to those employed in earlier invetigations, were not of a particularly high quality. This is to be expected in

pioneering research due to a lack of guidelines. It is anticipated that with de-bugged methodology, and with a selection of sites which have unexpected visual and/or geometric components, diagrammatic signs may prove to be beneficial.

EXPERIMENT II

Introduction

The specific purpose of this study was to replicate the methodology of Experiment I and to compare the results with those of a field study of the same highway sites. A complete report of the field investigation and of the sites employed can be found in Kolsrud (1972). The procedure in this investigation differed slightly from that used in the first study since the stimuli consisted of before-after photographs rather than simulations of the after phases of signing changes. Dr. Wallace Berger provided criteria for the correctness of lane choice data similar to those employed in the original Serendipity data. The investigators generated a set of criteria based on the original F.H.W.A. guidelines. These two sets of criteria thus provided the basis for a comparative analysis of correctness of lane choices similar to that of Experiment I. Additional analyses directly comparable to those of Experiment I also were performed. Thus the outcome of this phase of the research may be used for several purposes. First, the data will permit an assessment of the reliability of the data with regard to the relative efficacy of diagrammatic guide signs. Second, the data also permit the initial assessment of the reliability of the laboratory method developed for the research. Finally, the comparison of the laboratory data and the field data represents an initial attempt to examine the validity of laboratory research methods. It must be pointed out that this latter comparison is of an extremely tenuous nature because of the lack of directly comparable dependent measures, differences in data analyses, and differences in data collection methods which resulted in non-comparable

data points. Nevertheless, the results of this comparison may provide the impetus for further research of this type.

Method

Experimental Design

The basic design of the experiment was a 2 (practice) x 2 (response type) x 2 (sign type) x 6 (Interchange type) factorial with repeated measures on sign type and interchange type. This design fully replicated the design employed in Experiment I.

Stimuli

The stimuli utilized in this experiment were four sets of 35 mm color slides (2 x 2 inch), each set consisting of 20 roadway scenes and six destination names. The slides, provided by F.H.W.A., consisted of before-after photographs of highway scenes along the Washington, D.C. beltway (I-495) at a distance of approximately 200 feet upstream from an appropriate guide sign and included number designations on each driving lane shown. These slides contained stimuli from six different types of freeway interchanges:

> (1) right hand ramp (interchange 15 North - 1 slide); (2) tangential off ramp leading to collector-distributor (interchange 16 north - 4 slides); (3) two right exits to a collector distributor with a lane drop (interchange 16 south - 5 slides); (4) major fork (interchange 17 north - 3 slides); (5) diamond interchange (interchange 18 east - 3 slides); (6) partial cloverleaf (Democracy Boulevard - 4 slides).

Each interchange grouping was preceded by a destination name which served as the choice cue for the subjects.

The roadway scenes were identical in each set of slides except for the sign types utilized. Signs in two of the sets were of the conventional style (in conformity with the U.S. Manual on Uniform Traffic Control Devices), while signs in the remaining two sets were of the "diagrammatic" type. These latter signs were designed specifically

for use in the Kolsrud (1972) study. With the exception of the 15 North interchange, two different destinations were possible for each interchange. The availability of 2 sets each of the 20 conventional and 20 diagrammatic type slides allowed a counterbalancing by destination. The order of the interchanges within a set was randomized and the presentation order of sets of slides was counterbalanced.

As in Experiment 1, a second set of stimuli were then prepared converting a basic set of 20 conventional and 20 diagrammatic slides into 3 x 5 inch color prints. These 40 prints depicted 20 pairs of highway scenes, one print from each pair showing a conventional style sign, while the comparable print showed a diagrammatic type sign. The two prints were then mounted in pairs. Above each scene containing a conventional sign was printed a number one (1), and above each scene with a diagrammatic sign was printed a number two (2). This set of stimuli provided 20 individual pair-wise comparisons of the two sign types for use in the analysis of preference data.

Subjects

Forty-eight subjects were utilized for this experiment, constituting a random sample of licensed drivers with various driving experiences from among the Wayne State University study body. Each subject was paid $2.00 for his/her participation.

Experimental Procedure and equipment

The experimental procedure and equipment were basically identical to those employed in Experiment 1. The major exception to this generalization was the number of subjects in each of the four major experimental conditions. Subjects were randomly assigned to one of the four conditions:

(1) voice response with no practice -- 12 subjects; (2) voice response with practice -- 12 subjects; (3) key response with no practice -- 12 subjects; (4) key response with practice -- 12 subjects. Order of sign type presentation was counterbalanced.

Results

The results of the comparative analyses on correctness of lane choice are given by interchange in Tables 14 to 19. For each interchange, the data are analyzed separately by the Berger criteria and the criteria based on FHWA guidelines. The results of these analyses are summarized as a function of sign type and practice conditions and significance tests were run on each level of comparison. An examination of the tables reveals that only 5 out of 24 such comparisons revealed a statistically significant difference. This finding supports the conclusion made in Experiment I that the original discrepancies between the results of the Gordon (1972) and Berger studies were due primarily to criterial problems and not inherent differences due to sign types. Analyses of variance of the overall correctness data by F.H.W.A. criteria and by the Berger criteria revealed that in the former instance, the subjects responded more accurately to conventional signs (91.04% correct) than diagrammatic (83.53% correct), $F_{(1,\ 76\ df)} = 5.6896$, $p < .025$, while the effect was not significant in the latter analysis. Practice and the interaction of practice and sign type were found to be nonsignificant in both analyses. Again, these results were consistent with those of Experiment I, with the exception of the lack of a significant effect due to sign type in the analysis by Berger criteria. This latter result may be due to a number of extraneous sources of error, of which the

TABLE 14

COMPARATIVE DATA ON CORRECTNESS OF LANE CHOICE

Interchange 15

Experiment II

EXPER-IENCE	SIGN TYPE	STUDY	$\bar{X}$	% CHOOSING PROPER LANE BY SIGN WITHIN INTERCHANGE	SIGNIFICANCE TESTS FOR DIFFERENCE BETWEEN MEANS
				1	
NO PRACTICE	Conv	Berger	79.2	79.2	N.S.
		Zajkowski	79.2	79.2	
	Diag	Berger	37.5	37.5	N.S.
		Zajkowski	37.5	37.5	
PRACTICE	Conv	Berger	100.0	100.0	N.S.
		Zajkowski	100.0	100.0	
	Diag	Berger	58.3	58.3	N.S.
		Zajkowski	54.2	54.2	

TABLE 15

COMPARATIVE DATA ON CORRECTNESS OF LANE CHOICE

Interchange #16 North (Washington-Potomac)

Experiment II

EXPERIENCE	SIGN TYPE	STUDY	$\bar{X}$	% CHOOSING PROPER LANE BY SIGN WITHIN INTERCHANGE				SIGNIFICANCE TESTS FOR DIFFERENCE BETWEEN MEANS
				1	2	3	4	
NO PRACTICE	Conv	Berger	90.6	83.3	91.7	95.8	91.7	$p < .05$
		Zajkowski	94.8	100.0	91.7	95.8	91.7	
	Diag	Berger	89.6	83.3	83.3	95.8	95.8	N.S.
		Zajkowski	89.6	83.3	83.3	95.8	95.8	
PRACTICE	Conv	Berger	96.9	100.0	100.0	100.0	87.5	N.S.
		Zajkowski	96.9	100.0	100.0	100.0	87.5	
	Diag	Berger	87.5	79.2	91.7	95.8	83.3	N.S.
		Zajkowski	91.7	83.3	95.8	100.0	87.5	

TABLE 16

COMPARATIVE DATA ON CORRECTNESS OF LANE CHOICE

Interchange 16 South (Washington-Glenecho)

Experiment II

EXPERIENCE	SIGN TYPE	STUDY	$\bar{X}$	% CHOOSING PROPER LANE BY SIGN WITHIN INTERCHANGE					SIGNIFICANCE TESTS FOR DIFFERENCE BETWEEN MEANS
				1	2	3	4	5	
NO PRACTICE	Conv	Berger	73.3	37.5	54.2	83.3	100.0	91.7	$p < .02$
		Zajkowski	90.0	87.5	87.5	83.3	91.7	100.0	
	Diag	Berger	77.5	66.7	58.3	79.2	100.0	83.3	N.S.
		Zajkowski	75.8	66.7	66.7	79.2	83.3	83.3	
PRACTICE	Conv	Berger	76.7	50.0	54.2	79.2	100.0	100.0	$p < .01$
		Zajkowski	94.2	95.8	95.8	79.2	100.0	100.0	
	Diag	Berger	71.7	54.2	58.3	70.8	91.7	83.3	N.S.
		Zajkowski	66.6	58.3	83.3	75.0	33.3	83.3	

TABLE 17

COMPARATIVE DATA ON CORRECTNESS OF LANE CHOICE

Interchange 17 North (Rockville-Bethesda)

Experiment II

EXPERIENCE	SIGN TYPE	STUDY	$\bar{X}$	% CHOOSING PROPER LANE BY SIGN WITHIN INTERCHANGE			SIGNIFICANCE TESTS FOR DIFFERENCE BETWEEN MEANS
				1	2	3	
NO PRACTICE	Conv	Berger	81.9	54.2	95.8	95.8	N.S.
		Zajkowski	97.2	100.0	95.8	95.8	
	Diag	Berger	83.3	62.5	91.7	95.8	N.S.
		Zajkowski	95.8	100.0	91.7	95.8	
PRACTICE	Conv	Berger	83.3	50.0	100.0	100.0	N.S.
		Zajkowski	100.0	100.0	100.0	100.0	
	Diag	Berger	87.5	75.0	95.8	91.7	$p < .05$
		Zajkowski	100.0	100.0	100.0	100.0	

TABLE 18

COMPARATIVE DATA ON CORRECTNESS OF LANE CHOICE

Interchange 18 East (Bethesda-Rockville)

Experiment II

EXPER-IENCE	SIGN TYPE	STUDY	$\bar{X}$	% CHOOSING PROPER LANE BY SIGN WITHIN INTERCHANGE			SIGNIFICANCE TESTS FOR DIFFERENCE BETWEEN MEANS
				1	2	3	
NO PRACTICE	Conv	Berger	68.1	79.2	66.7	58.3	N.S.
		Zajkowski	70.8	83.3	66.7	62.5	
	Diag	Berger	79.2	66.7	87.5	83.3	N.S.
		Zajkowski	79.2	66.7	87.5	83.3	
PRACTICE	Conv	Berger	70.8	95.8	66.7	70.8	N.S.
		Zajkowski	70.8	87.5	66.7	70.8	
	Diag	Berger	93.1	91.7	91.7	95.8	$p < .05$
		Zajkowski	88.9	87.5	87.5	91.7	

TABLE 19

COMPARATIVE DATA ON CORRECTNESS OF LANE CHOICE

Interchange - Democracy Blvd.

Experiment II

EXPERIENCE	SIGN TYPE	STUDY	$\bar{X}$	% CHOOSING PROPER LANE BY SIGN WITHIN INTERCHANGE				SIGNIFICANCE TESTS FOR DIFFERENCE BETWEEN MEANS
				1	2	3	4	
NO PRACTICE	Conv	Berger	88.6	100.0	100.0	54.2	100.0	N.S.
		Zajkowski	87.5	95.8	100.0	54.2	100.0	
	Diag	Berger	88.5	95.8	87.5	75.0	95.8	N.S.
		Zajkowski	86.4	87.5	87.5	75.0	95.8	
PRACTICE	Conv	Berger	97.9	100.0	100.0	91.7	100.0	N.S.
		Zajkowski	96.9	95.8	100.0	91.7	100.0	
	Diag	Berger	86.4	95.8	83.3	75.0	91.7	N.S.
		Zajkowski	89.6	95.8	87.5	79.2	95.8	

most likely would seem to be a shift in the criteria applied by Berger. Since his original criteria were never formally stated, the possibility of error in their regeneration is quite likely. However, the results thus far do suggest the conclusion that for a majority of interchange types, conventional signs produce a higher proportion of correct responses than diagrammatic signs. An examination of the correctness of lane choices at exit point in Table 20 reveals that as in Experiment I, the mean correctness of lane choice for conventional signs (89.027) was higher than that for diagrammatic signs (81.925). The fact that these data once again tend to support the Gordon (1972) results adds additional credence to the idea that these laboratory methods provide a reliable means for evaluating highway guide signs. It should also be noted that the major fork once again produced the highest proportion of correct responses. The interchange having the lowest overall percentage of correct responses was the right hand ramp which had only a single slide presentation and therefore its reliability is suspect. Generally, it would seem safe to conclude that the more complex the interchange , the lower the overall proportion of correct responses obtained.

Table 21 summarizes the data on confidence of lane choices. No comparative analyses were possible for this set of analyses. It was found that on the average subjects were more confident of their responses to conventional signs than to diagrammatic signs. This difference proved to be significant both for practice conditions ($t_{5df} = 2.301$, $p < .025$) and no practice conditions ($t_{5df} = 3.529$, $p < .005$). This finding tends to replicate the findings of Experiment I. The Chi Square tests in Part A of Table 22 indicate that there is a significant relationship

TABLE 20

CORRECTNESS OF LANE CHOICE AT EXIT POINT

Experiment II

INTERCHANGE		Conventional			Diagrammatic		
		# Correct	# Incorrect	% Correct	# Correct	# Incorrect	% Correct
15	No Prac	19	5	79.2	9	15	37.5
	Prac	24	0	100.0	14	10	58.3
16N	No Prac	23	1	95.8	23	1	95.8
	Prac	24	0	100.0	24	0	100.0
16S	No Prac	22	2	91.7	21	3	87.5
	Prac	24	0	100.0	14	10	58.3
17N	No Prac	23	1	95.8	23	1	95.8
	Prac	24	0	100.0	24	0	100.0
18E	No Prac	15	9	62.5	20	4	83.3
	Prac	17	7	70.8	23	1	95.8
Demo.	No Prac	21	3	87.5	20	4	83.3
	Prac	24	0	100.0	21	3	87.5
TOTAL	No Prac	123	21	85.92	116	28	80.56
	Prac	137	7	95.13	120	24	83.33
MEAN PROPORTION CORRECT				89.027			81.925

TABLE 21

MEAN CONFIDENCE OF RESPONSE BY INTERCHANGE TYPE

Experiment II

		INTERCHANGE						$\bar{X}$	SIGNIFICANCE OF DIFFERENCE BETWEEN MEANS
		15	16N	16S	17N	18E	Demo		
NO PRACTICE	Conv.	3.92	3.15	3.74	3.71	3.86	3.69	3.68	$< .005_a$
	Diag.	3.29	3.64	3.46	3.53	3.67	3.41	3.50	
PRACTICE	Conv.	3.71	2.86	3.54	3.63	3.71	3.64	3.51	$< .025_b$
	Diag.	3.25	3.32	3.32	3.38	3.54	3.45	3.38	
	$\bar{X}$	3.54	3.24	3.52	3.56	3.70	3.56		

$^a t = 3.529$

$^b t = 2.301$

TABLE 22

CHI SQUARE TESTS OF VARIABLE INTERRELATIONSHIPS

Experiment II

A. Correctness of lane choice to conventional and diagrammatic signs by degree of confidence in lane choice

		X^2	df	p	C	N
NO PRACTICE	Conventional	16.27	3	.005	.19	456
	Diagrammatic	6.76	3	.10	.12	456
PRACTICE	Conventional	1.60	3	N.S.	.06	456
	Diagrammatic	35.22	3	.005	.27	456

B. Correctness of lane choice to conventional and diagrammatic signs by preference for conventional or diagrammatic signs

		X^2	df	p	C	N
NO PRACTICE	Conventional	.52	1	N.S.	.03	432
	Diagrammatic	.15	1	N.S.	.01	432
PRACTICE	Conventional	3.75	1	.10	.09	432
	Diagrammatic	2.54	1	N.S.	.07	432

C. Preference for conventional or diagrammatic signs by degree of confidence in lane choice

		X^2	df	p	C	N
NO PRACTICE	Conventional	8.67	3	.05	.14	432
	Diagrammatic	5.36	3	N.S.	.11	432
PRACTICE	Conventional	11.89	3	.01	.16	432
	Diagrammatic	3.22	3	N.S.	.09	432

between confidence and correctness of lane choice. However as the contingency cofficients indicate, this relationship is not particularly strong and perhaps of little practical significance. However tenuous, it would still seem proper to conclude that the more confident an individual is, the more likely he is to be correct. The strength of this relationship will be examined further in Experiment III. Moreover, as Part C of Table 22 shows, if an individual prefers conventional signs he also is more confident of his response to them. Unfortunately, this relationship does not hold for diagrammatic signs.

The subjects also indicated a preference for conventional signs just as they did in Experiment I ($t_{5df} = 6.621$, $p < .005$). The mean percentage of preference for each interchange is given in Table 23. However, an examination of Table 22, Part B reveals that there was no significant relationship between correctness and preferences for sign type. This finding generally tends to corroborate Gordon (1972). A further examination of this relationship will take place in Experiment III in order to assess the true empirical nature of this relationship.

Latency data were analyzed for both the overall interchanges for latency at the exit point only. The mean latencies are summarized in Table 24 for the overall interchanges and in Table 25 for the exit point latencies. A complete summary of latencies within interchanges is given in Table 39 of Appendix A. An analysis of variance of the overall latencies revealed that the mean response time was higher for the key response (2.95 secs.) than for the voice response condition (2.25 secs.), $F_{1,44} = 23.50$, $p < .001$. This is in accord with our earlier findings. Latencies were also higher for no practice (2.74 secs.)

TABLE 23

MEAN PERCENTAGE OF PREFERENCES TO

CONVENTIONAL AND DIAGRAMMATIC SIGNS

Experiment II

INTERCHANGE	SIGN TYPE	
	Conventional	Diagrammatic
15	56.2%	43.8%
16N	70.3%	29.7%
16S	61.7%	38.3%
17N	43.8%	56.2%
18E	54.9%	45.1%
Democracy	54.2%	45.8%
$\bar{X}$	56.85	43.15
S.D.	8.021	8.021

TABLE 24

MEAN LATENCY OF RESPONSE BY INTERSECTION

Experiment II

PRACTICE	RESPONSE	SIGN TYPE	INTER 15	16N	16S	17N	18E	DEMOCRACY	$\bar{X}$
NO PRACTICE	Voice	Conv	2.32	2.30	2.17	2.26	2.17	2.56	2.30
		Diag	2.61	2.37	2.35	2.34	2.55	2.84	2.51
	Key	Conv	2.68	3.06	3.18	3.00	2.55	2.91	2.90
		Diag	3.23	3.13	3.10	3.36	3.43	3.16	3.24
PRACTICE	Voice	Conv	1.73	2.16	1.77	2.04	1.81	2.05	1.93
		Diag	2.15	2.26	2.07	2.22	2.30	2.33	2.22
	Key	Conv	2.40	2.70	2.47	2.73	2.38	2.84	2.59
		Diag	2.96	2.79	2.93	3.22	3.35	3.00	3.04
	OVERALL MEANS		2.51	2.60	2.51	2.65	2.57	2.72	

TABLE 25

MEAN LATENCY OF RESPONSE AT EXIT POINT BY INTER

Experiment II

PRACTICE	SIGN TYPE	INTER						
		15	16N	16S	17N	18E	DEMO	$\bar{X}$
NO PRACTICE	Conventional	2.40	2.32	2.42	2.64	2.51	2.56	2.48
	Diagrammatic	2.99	2.23	2.98	2.62	2.51	2.79	2.69
PRACTICE	Conventional	2.09	1.87	2.25	2.41	2.01	2.11	2.12
	Diagrammatic	2.83	2.04	2.82	2.03	2.18	2.48	2.40
	OVERALL $\bar{X}$	2.58	2.12	2.62	2.42	2.30	2.48	

than for the practice conditions (2.44 secs), $F_{1,44} = 4.44$, $p < .05$. As in both Gordon (1972) and Experiment I, response times were longer to diagrammatic signs (2.75 secs) than to conventional signs (2.44 secs.), $F_{1,44} = 23.22$, $p < .001$. Interchange type also proved to be a significant main effect in the analysis, $F_{5,220} = 3.48$, $p < .005$. It is interesting to note that in rank order of mean response time, the partial cloverleaf interchange produced the longest latencies (2.72 secs.), followed by the major fork (2.65 secs.) and the interchange having two right exits to a collector distributor with a lane drop (2.60 secs.). Although the major fork did not elicit the highest latencies it again was among the highest, supporting the supposition made in Experiment I with regard to the driving behavior required by this type interchange. In addition this interchange was once again among the highest in overall percent correct lane choice (91.13), exceeded only by the interchange depicting a tangential offramp leading to a collector distributor (92.2). The sign type by interchange type interaction effect ($F_{5,220} = 6.60$, $p < .001$) was restricted to two interchanges—the tangential off ramp and the right hand ramp. In both instances the mean for diagrammatic signs increased while the means to conventional signs decreased. In all other interchanges the means for diagrammatic signs were higher than, but parallel to, the conventional signs. A complete summary of this analysis of variance is given in Table 40 of Appendix A. An analysis of variance of latencies at the exit point duplicated the results of the overall analysis and is given in Table 41 of Appendix A. An examination of Table 25 verifies this analysis. In both of these analyses response type accounted for a significant amount

of variance--18% for the overall analysis and 16% for the choice point analysis, as estimated by the w^2 statistic. Sign type accounted for only 4% of the total variance in the overall analysis. While an effect may produce a statistically significant result as in this study, one should be extremely cautious in estimating the practical significance of the finding. Analyses of variance were also performed on the latencies for each interchange separately, with essentially the same results. The only other finding of significance was that generally latencies were higher in the middle of a sign sequence than at the beginning or end, supporting an earlier information processing analyses of this effect. The relationship between latency of response and confidence of response was essentially identical to that obtained in Experiment I ($r_{ave} = -.677$, $p < .01$) suggesting once again that confidence is inversely related to latencies. The average correlation between correctness and latency was -.201, which was nonsignificant. However in the practice condition this relationship for diagrammatic signs was significant. Generally, the order of magnitude obtained in the analysis is less than that in Experiment I but somewhat similar in that it demonstrates the lack of a strong relationship. Perhaps it will be possible to resolve the discrepancies between Experiment I and II in our third investigation.

It was also determined that there were no significant differences in total number of lane changes as a function of sign type ($t = .228$). The comments made by subjects did however bear a striking similarity to those obtained in Experiment I. The comments are summarized in Table 26. Each of the categories represents an arbitrary classification of similar

TABLE 26

POST EXPERIMENTAL INTERVIEW COMMENTS

Experiment II

Frequency of Comment	Comment
31	Diagrammatic signs too confusing, contain too much information
16	conventional signs are more informational
11	Diagrammatic signs are easier to comprehend
9	Preferred diagrammatic signs because they show the direction of roads
8	Prefer verbal rather than symbolic conventional signs
7	Prefer simple diagrammatic signs
1	Prefer diagrammatic at beginning of sequence, conventional at exit
1	Liked dotted lines indicating number of lanes
1	diagrammatic better at exit point

statements and are not independent, i.e., the same individual may be included in a number of categories. The comments seem to justify our earlier conclusion that drivers require specific information, with minimum complexity in a logical sequence.

Finally, an attempt was made to compare the dependent measures used in the present investigation and one conducted in the field on the same sites by Kolsrud (1972). Extreme caution should be used in the interpretation of these comparisons, since they are not directly comparable in the number of observations in each data point, the scale on which the measure is based, or in the exact meaning of scales. The comparisons are given in Figures 1-6. The upper half of each figure represents a summary of the dependent measures employed by Kolsrud (1972), abstracted from their final report. The lower half of each figure represents a summary of the dependent measures employed in the present investigation. Thus the figures serve two purposes. First it is possible to visually compare the dependent measures of the present investigation which have already been summarized statistically. Second, one can compare the Biotechnology and present dependent measures. An examination of the latter type revealed a rather interesting result. In each instance where the comparison was possible, it was found that the pattern of latencies in the present investigation tended to correspond to the pattern of total lane maneuvers in the Biotechnology study, generally decreasing as the subject proceded through the interchange. Obviously, this is a tenuous and superficial conclusion. Nevertheless, it suggests the possibility of a valid

FIGURE 1
BIOTECHNOLOGY VERSUS ZAJKOWSKI:
A COMPARISON OF DEPENDENT MEASURES BETWEEN A FIELD AND A LABORATORY INVESTIGATION

Interchange: 15 North
(At Gore Point)

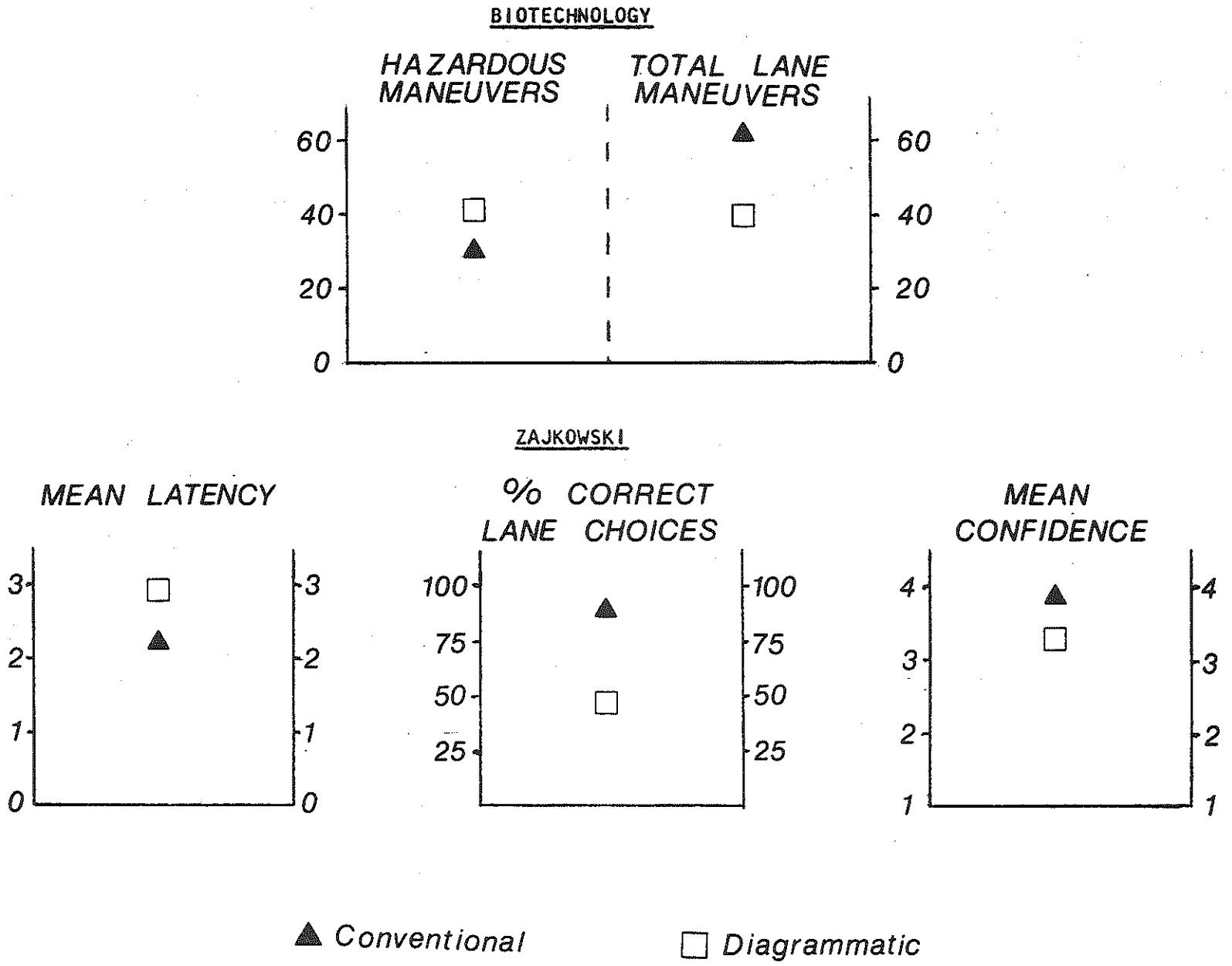


FIGURE 2
BIOTECHNOLOGY VERSUS ZAJKOWSKI:
A COMPARISON OF DEPENDENT MEASURES BETWEEN A FIELD AND A LABORATORY INVESTIGATION

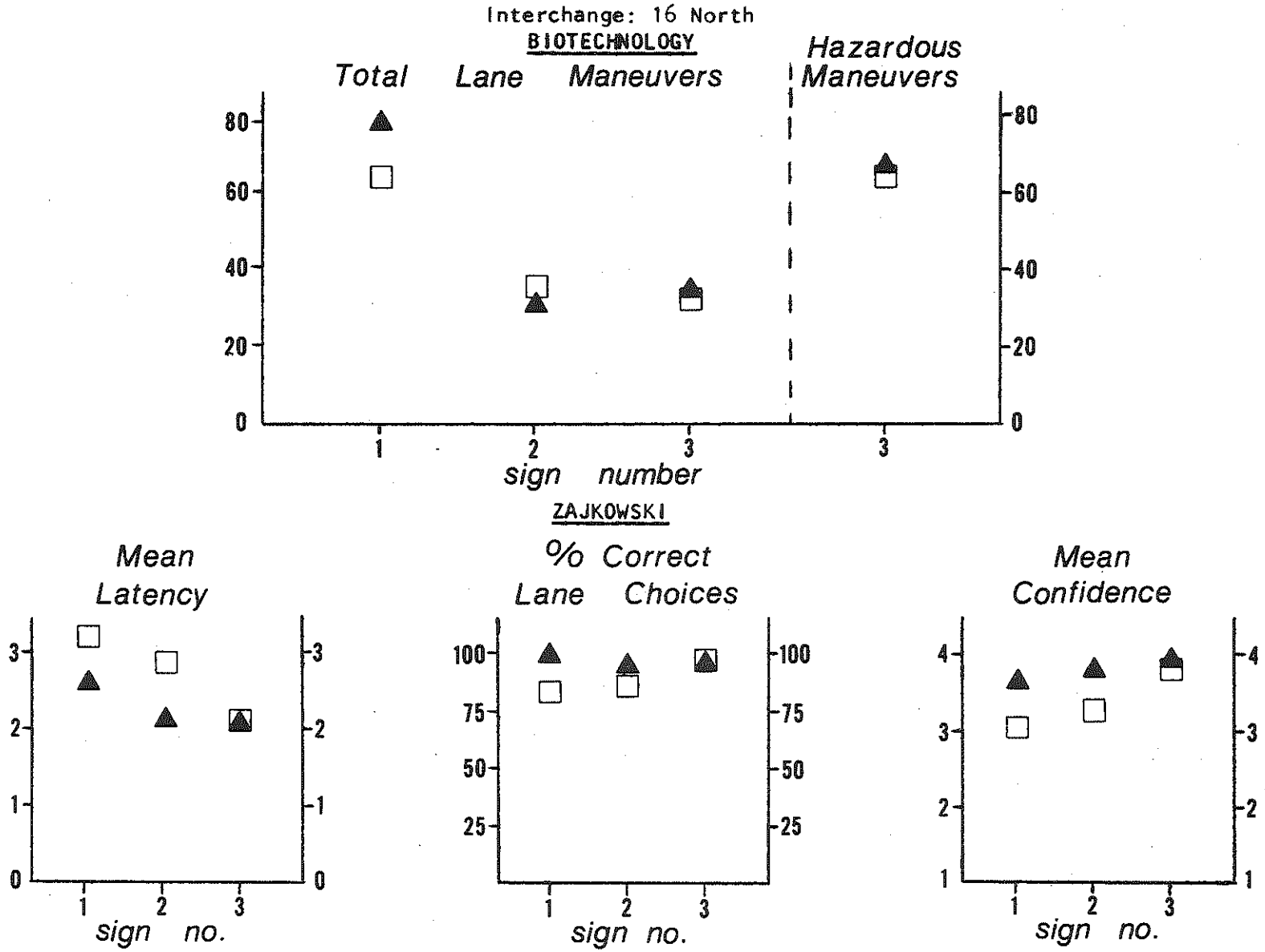


FIGURE 3
BIOTECHNOLOGY VERSUS ZAJKOWSKI:
A COMPARISON OF DEPENDENT MEASURES BETWEEN A FIELD AND A LABORATORY INVESTIGATION

Interchange: 16 South

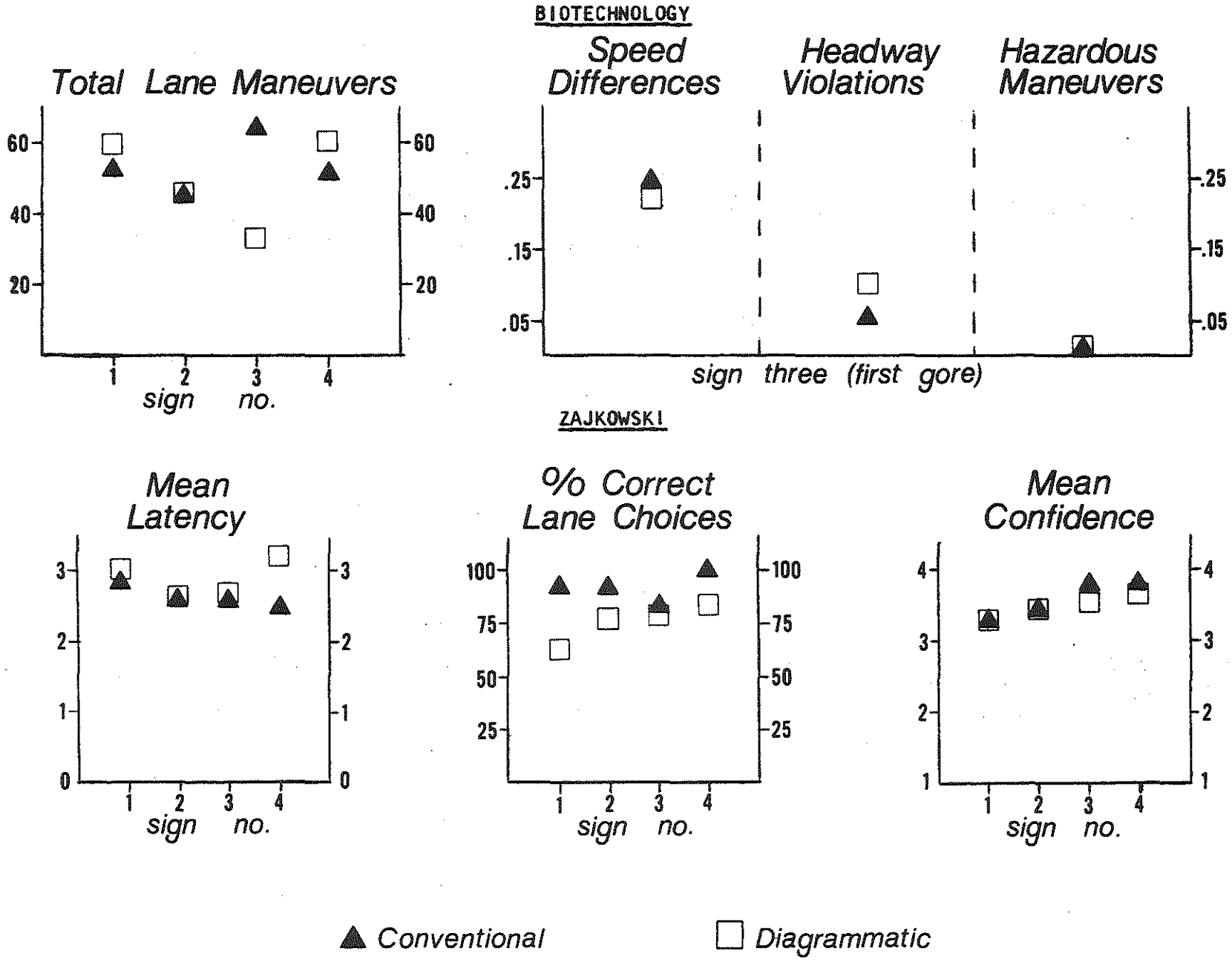
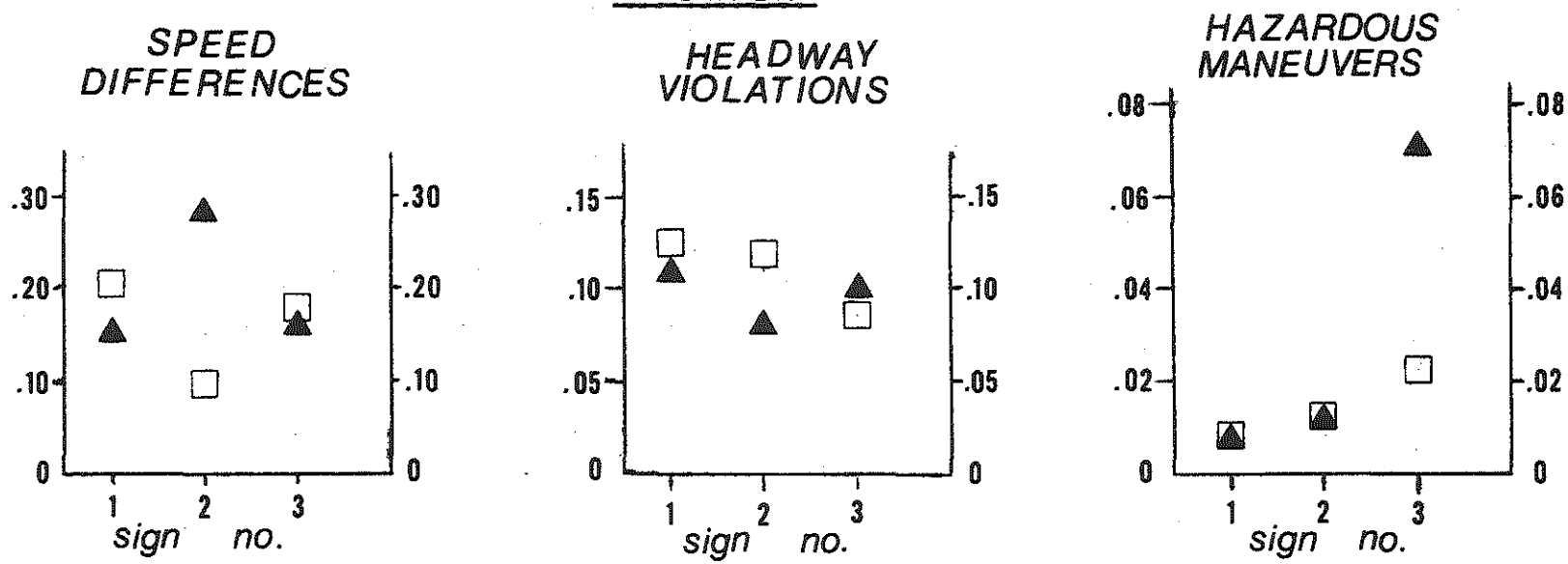


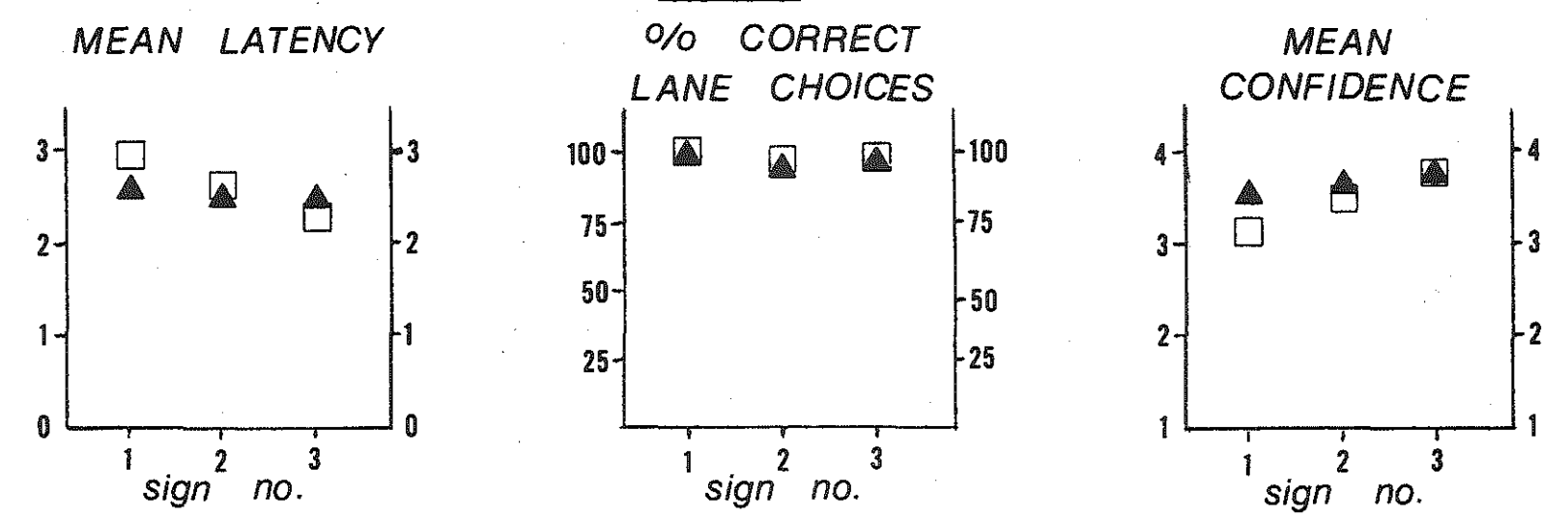
FIGURE 4
BIOTECHNOLOGY VERSUS ZAJKOWSKI:
A COMPARISON OF DEPENDENT MEASURES BETWEEN A FIELD AND A LABORATORY INVESTIGATION

Interchange: 17 North

BIOTECHNOLOGY



ZAJKOWSKI

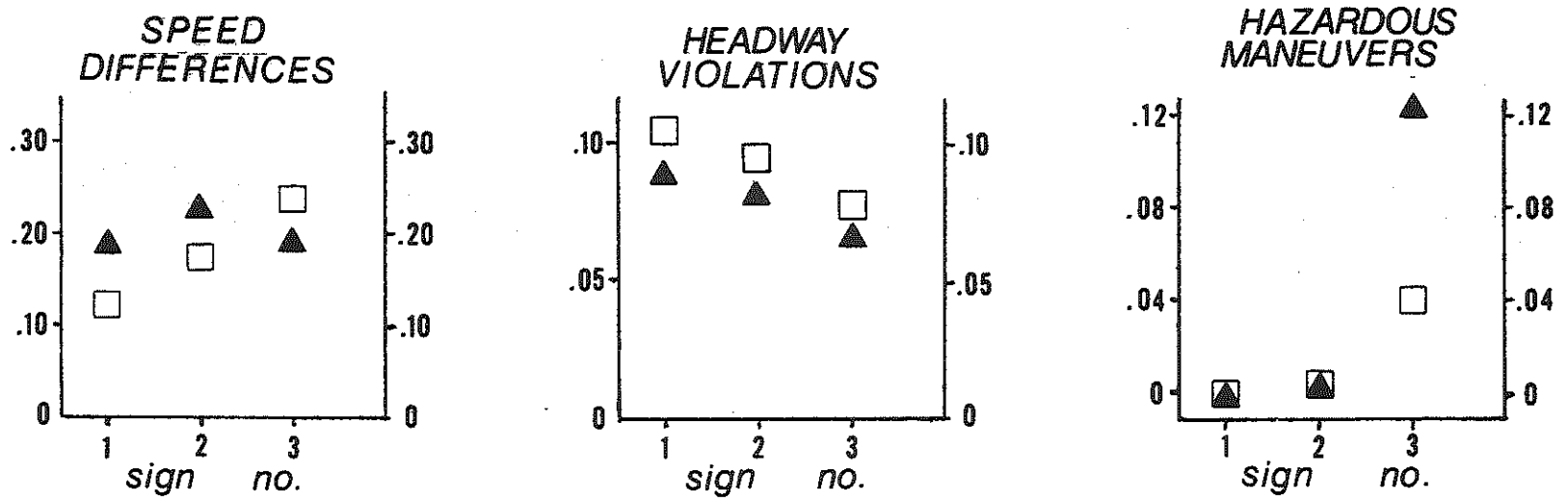


▲ Conventional □ Diagrammatic

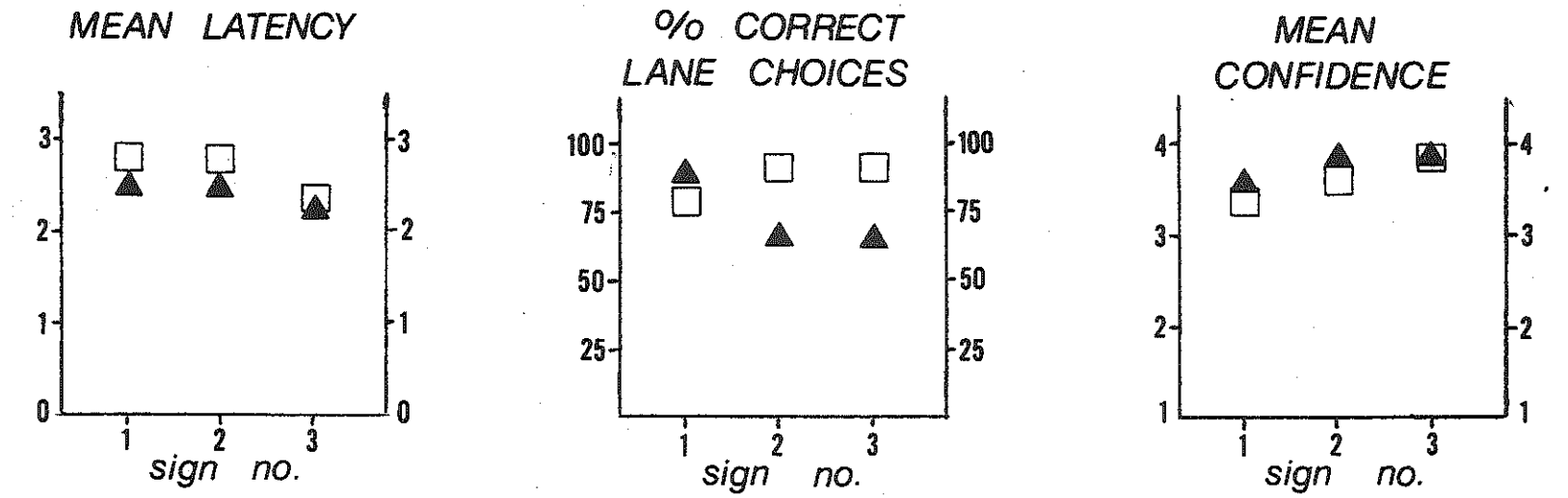
FIGURE 5
BIOTECHNOLOGY VERSUS ZAJKOWSKI:
A COMPARISON OF DEPENDENT MEASURES BETWEEN A FIELD AND A LABORATORY INVESTIGATION

Interchange: 18 East

BIOTECHNOLOGY



ZAJKOWSKI

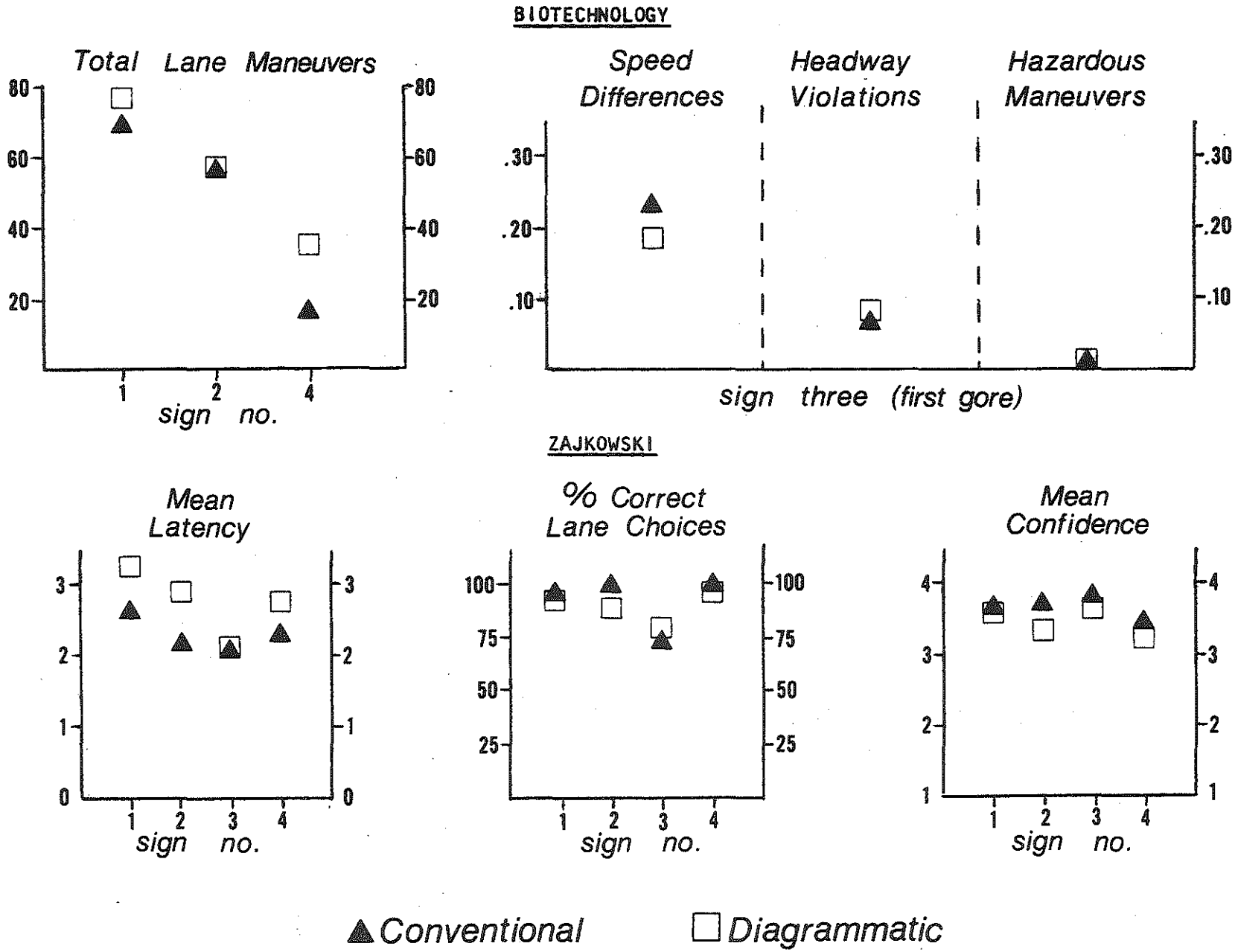


▲ Conventional □ Diagrammatic

FIGURE 6

BIOTECHNOLOGY VERSUS ZAJKOWSKI:
A COMPARISON OF DEPENDENT MEASURES BETWEEN A FIELD AND A LABORATORY INVESTIGATION

Interchange: Democracy Boulevard



predictive relationship between laboratory and field studies. It shall remain for future studies to conduct tightly controlled laboratory-field investigations. It is imperative that such studies be conducted to establish the utility of the laboratory research whose reliability has been established in the current research.

Discussion

The specific purpose of this study was to replicate the findings of Experiment I. This goal has been accomplished. It was found that as in the first experiment the percentage of correct lane choices is higher to conventional signs than to diagrammatic, that drivers prefer diagrammatic signs to conventional signs, that drivers respond more quickly to conventional signs, and that drivers are more confident of their responses to conventional signs.

However, it must be pointed out that in both of these studies, the stimuli were not of the highest photographic quality. In addition, the earlier investigations had no guidelines on which to fall back in their design of diagrammatic signs. In Experiment III special attention has been given to the preparation of the stimuli. We shall also examine the impact of driver familiarity on the overall utility of various types of guide signs. The experiment shall also use highway sites which have never been used before in the hope that a third independent assessment can be made of the reliability of our methodology and data. The evidence accumulated thus far, clearly suggests a limited application of diagrammatic signs. It would seem that diagrammatic signs are best used at sites involving unexpected maneuvers or

situations involving limited visibility and then only after a careful examination of the relative advantages and disadvantages of each type of sign has been made.

EXPERIMENT III

The final experiment in this series represents another attempt to replicate the results of previous research. However, in this study we have elected to utilize highway sites which would serve several additional purposes. First, a number of sites were selected which were geometrically similar to several of those used in Experiment I. This permits an analysis of the reliability and generalizability of previous data collected on such sites. A second set of relatively complex sites were included because they were identified by members of the Michigan Department of State Highways and Transportation as being somewhat problematic. It was felt that a laboratory evaluation of these sites might provide design guidelines for future guide signs at those intersections. For both sets of sites, special diagrammatic signs were designed following the guidelines established for diagrammatic signs by Berger (1972) and Mast and Kolsrud (1972). In some instances the guidelines did not provide sufficient information relevant to guide sign designs for geometrics of a unique nature. On these occasions, the experimenter exercised his judgment on the relative appropriateness of design modifications. The final set of interchanges which were included in the experiment represented sites at which diagrammatic signs had already been installed. The purpose for the inclusion of these sites was to provide an evaluation of these diagrammatics. This analysis also permits a comparison of performance on diagrammatics designed according to existing standards and those designed according to the newly recommended standards. All of the locations used in this study are

situated in the State of Michigan. Thus, the results of this experiment permit an assessment of the reliability, generalizability, and general utility of both the laboratory technique and the data obtained using this technique.

Method

Experiment Design

The experiment followed a 2 (sign type) x 11 (interchange) within subjects design. Response type and practice were excluded as independent variables because an evaluation of their overall effect in the earlier experiments indicated a constant as opposed to a differential impact. Once the magnitude of a constant effect is known it is of little interest as an independent variable. Dependent measures included correctness of lane choice, confidence of lane choice, preference of sign type, latency of response to signs, and familiarity of the intersections being utilized.

Stimulus materials

The stimuli used in this experiment were four sets of 35 mm color slides (2 x 2 inches), each set consisting of either 50 (conventional) or 57 (diagrammatic) roadway scenes and eleven destination names. Approximately half the slides were on the interstate highway system and the remainder on other freeways in Michigan. Each slide depicted highway scenes at a distance of approximately two hundred feet from the guide sign and included number designations on each driving lane shown. These slides contained stimuli from eleven different types of freeway interchanges:

1. double lane drop (U.S. 10 westbound at U.S. 24--8 scenes);
2. major fork with split ramp (I-75 Northbound at I-375-16 scenes);

3. left-hand ramp downstream from a right-hand ramp (U.S. 10 northbound at Davison Fwy -- 6 scenes);

4. simultaneous right and left exit ramps (I-94 eastbound at U.S. 10 -- 6 scenes);

5. left hand exit (Michigan 39 northbound at U.S. 10 -- 4 scenes);

6. tangential right hand exit ramp (I-96 eastbound at I-296 southbound -- 3 slides);

7. cloverleaf (I-75 northbound at U.S. 10 westbound -- 8 scenes);

8. sharp right with restricted visibility (U.S. 10 eastbound at I-75 southbound -- 6 scenes);

9. curve with right hand exit ramp (U.S. 23 northbound at Michigan 14 eastbound -- 3 scenes)

10. tangential right hand exit ramp (U.S. 23, southbound at Michigan 14 westbound -- 6 scenes); and

11. fork (I-75 northbound at Michigan 85 -- 3 scenes).

Each of the interchange groupings was preceded by a destination name which served as the choice cue for the subjects. Wherever possible, two destinations were used for each interchange. The availability of 2 sets each of the conventional and diagrammatic sequences made it possible to counterbalance travel directions for the stimuli. In addition, 2 random orders of interchanges for both the conventional and diagrammatic sequences allowed a counterbalancing for order of interchanges. Two different kinds of stimuli were included in the diagrammatic sequences. For intersections 1 through 6, the experimenters designed diagrammatic signs for points approaching interchange where such signs might be beneficial. It should be noted that this is a departure from the original studies where diagrammatic signs were used at each sign location. These designs were then fabricated to scale in art board by the Michigan Department of State Highways and Transportation. Appropriate slides of

highway scenes were then converted into 8 x 10 inch color prints. The letters on the signs in those prints were measured to determine the visual angle subtended. Then the appropriate simulation of a diagrammatic sign was photographed in such a manner so as to subtend the same visual angle as its corresponding conventional sign. Color prints were made of these latter photographs. The diagrammatic signs were then cutout of these prints and superimposed on the original 8 x 10 print of the scene, along with numbers on each of the visible driving lanes. This collage was then photographed and converted into 35 mm slides which constituted the basic stimuli of the experiment. For interchanges 7 through 11, the stimuli consisted of 35 mm slides of the actual highway scenes, with lane numbers added, because for each of these interchanges diagrammatic signs had already been installed. In most instances these diagrammatic signs were installed in addition to the normal conventional sequence of signs. Thus, for the purposes of the experiment, these signs were simply eliminated from the conventional sequences. In those cases where both conventional and diagrammatic signs were included in the sequence, the diagrammatic signs were simply blacked out. A second set of stimuli were then prepared for the preference tests, converting a basic set of 22 diagrammatic and 15 conventional slides into color prints. The difference in number of slides in the two conditions is due to the fact that in some circumstances there was no sign in the conventional sequence which directly corresponded to the diagrammatic sign. These prints were combined into 22 pairs, one print showing the diagrammatic sign and the other the appropriate conventional or lack of conventional

sign. Above each scene with a conventional sign was printed the number one (1) and above the diagrammatic sign was printed the number two (2). This second set of stimuli, thus provided individual pair-wise comparisons of the two sign types for the eleven interchanges Black and white photographs of the points at which diagrammatic signs were used are given by interchange in Figures 7-17 in Appendix B.

Subjects

Thirty-two subjects, 16 males and 16 females, were used in this experiment, constituting a random sample of licensed drivers with various driving experience from among the Wayne State student body. Each subject was paid $3.00 for his/her participation.

Procedure

The experimental procedure and equipment were essentially identical to that employed in Experiments I and II with several minor modifications. Subjects viewed all combinations of sign and interchange Responses were restricted to the response key since it had been determined that the voice key produced a constant depressing effect on latency and no effect whatsoever on the other dependent measures. Each slide was presented for a single trial, which is equivalent to the no practice condition of our earlier studies. This decision was based on the finding that practice appears to have a constant but non-interactive effect on the dependent measures. The presentation order of conventional and diagrammatic signs was counterbalanced, so that one half of the subjects (16) viewed conventional signs before viewing diagrammatic while the other half (16) viewed graphic signs before the conventional. Destinations were also counterbalanced. In addition to the dependent measures employed in the previous studies, an assessment

was made of each subject's familiarity with the intersection involved. Familiarity was measured on a five point scale with the following steps:

1. never
2. seldom - a few times a year
3. often - several times a month
4. frequently - once or twice a week
5. very frequently - almost daily or even more frequently

The inclusion of this measure was deemed necessary because of our conviction that a driver's familiarity with highway geometrics interacts significantly with his/her utilization of guide sign information. In this study there was a high probability that drivers were familiar with the interchanges since both the subjects and the interchanges were drawn from Michigan populations. Preference data were collected for each interchange only for those scenes on which corresponding conventional and diagrammatic guides were utilized.

Results

The analyses on per cent correct lane choices revealed results which correspond quite closely to those of Experiments I and II. That is, in the analysis of overall correct lane choices, response to conventional (95.37) was significantly greater than that to diagrammatic signs (91.05), $F_{1,85} = 8.073$, $p < .01$. However, part of this effect is due to the fact that in several instances the percentage of correct responses to diagrammatic signs was significantly less than to the corresponding conventional signs even though the sign was identical in both sequences. See the summary data for interchanges in Table 27. Perhaps such an anomalous result can be best explained by use of the concept of contrast comparison. Specifically, it is possible that identical information is interpreted differently depending on the context in which

TABLE 27

PER CENT CORRECT LANE CHOICES

Experiment III

INTER-CHANGE	SIGN TYPE	SIGN WITHIN INTERCHANGE 1	2	3	4	5	6	7	8	$\bar{X}$
1	Conv	100	87.5	84.4	96.9					92.2
	Diag	75.0*	68.8	90.6	87.5					80.5
2	Conv	100	96.9	100	87.5	96.9	93.8	96.9	93.8	95.7
	Diag	100	87.4*	81.3	96.9*	93.8*	90.6	84.4*	96.9	91.0
3	Conv	100	100	100	68.8	87.5	96.9			92.2
	Diag	100	81.3*	56.3	87.5*	96.9*	100			87.0
4	Conv	96.9	--	93.8	84.4	100	100	--	--	95.0
	Diag	96.9	78.1*	43.8	87.5*	96.9*	100	--	--	83.9
5	Conv	84.4	87.5	96.9	100	--	--	--	--	92.2
	Diag	84.4	93.8*	100*	96.9	--	--	--	--	93.8
6	Conv	96.9	100	100	--	--	--	--	--	99.0
	Diag	93.8*	84.4*	96.9	--	--	--	--	--	91.7
7	Conv	100	100	100	100	93.8	--	96.9	100	98.7
	Diag	100	100	100	100	96.9	93.8*	96.9	93.8	97.7

TABLE 27 (continued)

PER CENT CORRECT LANE CHOICES

Experiment III

INTER-CHANGE	SIGN TYPE	SIGN WITHIN INTERCHANGE 1	2	3	4	5	6	7	8	$\bar{X}$
8	Conv	100	90.6	96.9	71.9	96.9	--	--	--	91.2
	Diag	100	78.1	93.8	84.4	100	87.5*	--	--	90.6
9	Conv	100	--	100	--	--	--	--	--	100
	Diag	100	87.5*	96.9	--	--	--	--	--	94.8
10	Conv	100	87.5	--	--	93.8	96.9	--	--	94.5
	Diag	100	87.5	90.6*	96.9*	93.8	100	--	--	94.8
11	Conv	96.9	--	100	--	--	--	--	--	98.4
	Diag	100	87.5*	100	--	--	--	--	--	95.8

*represents points at which diagrammatic signs were included. The remaining signs in the diagrammatic sequence were identical to those in the conventional sequence.

it occurs. Nevertheless this result tends to verify the results of both our earlier experiments and those of Gordon (1972). Interchange type proved to be a nonsignificant factor, $F_{10,85} = 2.6095$. The interaction of sign type and interchange was significant, $F_{10,85} = 6.852$, $p < .01$. This effect seemed to be restricted to a divergence of mean correctness by sign at intersection 1, 4, and 6 and a reversal of means on interchange 5. The complete analysis of overall correctness is given in Table 42 of Appendix A. A direct comparison of the mean correctness of interchanges 1, 2, 3, 4, 5, and 6 of the present study and interchanges 1, 4N, 4E, 16, 17 and 29 of Experiment I reveals a highly similar pattern of results. Note that corresponding interchanges in the two studies have highly similar geometrics. A similar comparison of interchanges 7-11 and those employed in Experiment II reveals a similar result. An examination of mean per cent correct responses at <u>exit point</u> revealed no significant differences between conventional and diagrammatic signs, $t_{10df} = 1.495$. A summary of means at exit point is given in Table 28. An analysis of the percentage of variance accounted for by sign type ($w^2_{overall} = .037$) indicates that although statistical significance was achieved, the difference obtained has little practical implication. One may choose to interpret this as evidence that at least diagrammatic signs will produce no meaningful deficit in performance and in certain circumstances might prove to be beneficial.

Table 29 summarizes the data on the mean confidence of lane choice responses. It was found that the mean confidence for conventional signs (3.54) was significantly greater than that for diagrammatic signs (3.38), $t_{10df} = 3.219$, $p < .005$. However, extreme care should

TABLE 28

PER CENT CORRECT LANE CHOICE AT EXIT POINT

Experiment III

INTERCHANGE	SIGN TYPE	
	Conventional % Correct	Diagrammatic % Correct
1	93.8	84.4
2	93.8	96.9
3	93.8	100.0
4	100.0	100.0
5	100.0	96.9
6	99.0	91.7
7	100.0	93.8
8	96.9	87.5
9	100.0	96.9
10	96.9	100.0
11	100.0	100.0
MEAN PERCENT CORRECT	97.7	95.3

TABLE 29

MEAN CONFIDENCE OF RESPONSE

Experiment III

SIGN TYPE	INTERCHANGE 1	2	3	4	5	6	7	8	9	10	11	$\bar{X}$
Conv	3.31	3.31	3.48	3.63	3.38	3.28	3.15	3.42	3.50	3.39	3.94	3.54
Diag	3.23	3.30	3.58	3.58	3.57	3.42	3.02	3.27	2.17	3.37	3.65	3.38

be used in interpreting this difference. Essentially, confidence was high for both types of signs in this experiment. However, in our earlier experiments this difference was of a greater magnitude and therefore more meaningful. We choose to interpret this result as meaning that for all practical purposes our subjects essentially were equally confident of both sign types. The Chi Square tests in Part A of Table 9 also indicate that there is a significant relationship between confidence and correctness. That is, the more confident an individual is, the more likely he is to be correct. Moreover as parts C and D of Table 30 indicate, subjects are more confident of responses to sign types they prefer and are more confident of responses to familiar stimuli.

The subjects clearly preferred diagrammatic signs (68.9%) over conventional signs (31.1%). The mean percent of preferences is given by intersection in Table 31. However as Part B of Table 30 indicates there was no signficant relationship between preference for sign type and correctness of lane choice. Part D of Table 30 indicates that familiarity with the intersections did not affect preferences for sign type. The fact that subjects in this experiment preferred diagrammatic signs is at odds with the results of our earlier experiment and those of other investigators. We suggest that this difference is partially due to the fact that we were able to draw upon the experience of earlier investigators and the guidelines which have been established for the design of diagrammatic signs. Combined with a more efficient means of generating the stimuli, we believe that the diagrammatic stimuli were more realistic and meaningful and hence more preferred by the subjects when they are used at selected locations.

TABLE 30

CHI SQUARE TESTS OF VARIABLE INTERRELATIONSHIPS

Experiment III

A. Correctness of lane choice to conventional and diagrammatic signs by degree of confidence in lane choice

	X^2	df	p	C	N
Conventional	15.30	3	.005	.097	1600
Diagrammatic	56.31	3	.001	.173	1824

B. Correctness of lane choice to conventional and diagrammatic signs by preference for conventional and diagrammatic signs

	X^2	df	p	C	N
Conventional	3.55	1	N.S.	.085	480
Diagrammatic	1.93	1	N.S.	.052	704

C. Preference for conventional or diagrammatic signs by degree of confidence in lane choice

	X^2	df	p	C	N
Conventional	14.90	3	.005	.1734	480
Diagrammatic	4.50	3	N.S.	.079	704

D. Familiarity by preference for conventional or diagrammatic signs

X^2	df	p	C	N
1.1853	4	N.S.	.049	480

E. Familiarity by correctness of lane choices for conventional and diagrammatic signs

	X^2	df	p	C	N
Conventional	9.21	4	N.S.	.075	1600
Diagrammatic	3.89	4	N.S.	.046	1824

TABLE 30 (continued)

CHI SQUARE TESTS OF VARIABLE INTERRELATIONSHIPS

Experiment III

F. Familarity by confidence for conventional and diagrammatic signs

	X^2	df	p	C	N
Conventional	25.15	12	.02	.124	1600
Diagrammatic	33.36	12	.001	.1337	1824

TABLE 31

MEAN PERCENT PREFERENCES

Experiment III

INTERCHANGE	CONVENTIONAL	DIAGRAMMATIC
1	37.5	62.5
2	31.2	68.8
3	31.2	68.8
4	18.8	81.2
5	28.1	71.9
6	40.6	59.4
7	51.6	48.4
8	26.0	74.0
9	31.2	68.8
10	26.6	73.4
11	25.0	75.0
$\bar{X}$	31.1	68.9

The mean latencies for overall intersections and for latencies at exit point are summarized in Table 32. An analysis of variance revealed that only the main effect of interchange type proved to be significant, $F_{10,300} = 43.58$, $p < .001$. An examination of the means revealed no particular pattern to the means. However, it should be noted that the longest latency occurred for the complex double lane diagrammatic of interchange I and the lowest latency occurred for the fork in interchange II. It is also interesting that once again the major fork produced a relatively high latency (second only to interchange I), a finding which is consistent with previous research. A significant interaction between sign type and interchange type seemed to be due to several reversals of latencies as a function of sign type within various interchanges. Again no specific pattern for this effect could be determined. The complete analysis of variance for overall latencies is given in Table 43 of Appendix A. An analysis of latencies at exit point were essentially a duplicate of the overall analysis. This analysis is summarized in Table 44 of Appendix A. A complete summary of the latencies within interchanges is given in Table 45 of Appendix A.

In our last set of analyses dealing with latency it was found that latency correlated significantly with familiarity only for the diagrammatic signs (-.014 conventional and +.058 diagrammatic). In addition, latency correlated significantly with correctness of lane choice (-.540 diagrammatic) and confidence (-.760 conventional and -.634 diagrammatic). Thus, latency is inversely related to both lane choices and confidence. However, it would appear that when subjects

TABLE 32

MEAN LATENCY OF RESPONSE FOR OVERALL LATENCIES

Experiment III

SIGN TYPE	INTERCHANGE 1	2	3	4	5	6	7	8	9	10	11	$\bar{X}$
Conv	3.39	3.38	2.92	3.02	2.72	3.15	2.98	2.96	2.86	3.19	2.08	2.96
Diag	3.74	3.40	3.00	3.16	2.70	3.08	3.04	3.00	3.19	3.01	2.34	3.06

MEAN LATENCY OF RESPONSE AT EXIT POINT

SIGN TYPE	INTERCHANGE 1	2	3	4	5	6	7	8	9	10	11	$\bar{X}$
Conv	3.29	2.89	2.40	2.57	2.22	2.74	2.61	2.56	2.90	3.15	1.86	2.65
Diag	3.23	2.78	2.56	2.64	2.31	2.77	2.74	3.26	2.71	2.84	1.78	2.69

Note: [a] = first drop of a double lane drop used as destination;
[b] = second drop of a double lane drop used as destination.

are highly familiar with an interchange , the addition of a diagrammatic guide sign may increase latencies. These results are consistent with the findings of Experiments I and II.

In an examination of the degree of familiarity of subjects with the intersections it was found that mean familiarity was 2.293 on a five point scale, which indicates only a moderate degree of familiarity with the interchanges. An examination of Part F in Table 30 indicates that familiarity interacts significantly only with confidence, i.e., the more familiar a subject is of the interchange,, the more confident he is of the response to it.

Finally, as Table 33 indicates, the post interview comments of our subjects were highly similar to those obtained in Experiments I and II. Essentially subjects indicate that diagrammatic signs contain too much information and are complex and difficult to comprehend. They do suggest that such signs would be most useful at the beginning of a signing sequence and where the interchange is particularly complex or contains unexpected maneuvers.

Discussion

The results of Experiment III make it patently obvious that the results obtained in Experiments I and II are not stimuli specific. It would seem relatively safe to conclude that diagrammatic signs will usually but not necessarily lead to longer response times, suggesting that their use should be restricted to advance sign positions. The data also indicate that while diagrammatic signs might not provide an advantage in terms of correct lane choices or confidence of response, they nevertheless may prove useful by allowing drivers to anticipate

TABLE 33

POST EXPERIMENTAL INTERVIEW COMMENTS

Experiment III

Frequency of Comment	Comment
12	Diagrammatic signs contain too much information, are too complex, or too confusing
8	Diagrammatics are preferable because they present an accurate representation of the choice points
6	Prefer signs with downward oriented arrows pointed to appropriate lanes
3	Diagrammatic signs are preferred when the situation is complex
3	Diagrammatic signs are very confusing on multilane highways (greater than 2 or three lanes)
2	Diagrammatic signs are novel and require a period of adjustment
1	When signs are already in use, prefer conventionals but prefer diagrammatic signs at new unsigned locations

future maneuvers at complex or difficult choice points. Further, it is believed that the reliability of the laboratory method employed in all three experiments has been more than adequately demonstrated. However, a reliable laboratory method does not, and should not, imply validity. The validity of the research method employed in this experiment as well as the results of all three experiments remains to be tested in unobtrusive field studies.

SUMMARY

The research studies summarized in this report were designed to serve several purposes. One of these purposes was the establishment of a reliable, relatively low-cost laboratory technique for the evaluation of highway guide signs. However, the primary purpose was to resolve the differences in conclusions reached by earlier laboratory investigations of diagrammatic signs. Generally, it is believed that these two purposes have been accomplished. However, the validity of the data were not clearly established.

The fact that each of the experiments produced data which were essentially identical speaks to the reliability of the methodology. The additional fact that the data agree with those of earlier investigations further attests to its reliability. Furthermore, it was possible to demonstrate that the differences in results obtained by Gordon (1972) and Berger (1970) were due primarily to criterion differences and not substantive differences in their data. The methodology established in these experiments makes it possible for any agency to develop the capability for conducting its own laboratory guide sign evaluation studies. The cost for such a capability would be minimal and restricted primarily to the equipment described in the

report. The only other cost associated with such a program would be the development of a training program or training manual whose cost would also be quite minimal.

The results clearly suggest that response time is consistently longer for diagrammatic signs than conventional signs. This is to be expected since diagrammatic signs generally contain more information than conventional signs. Subjects also are more confident of and prefer conventional signs. The exception to this general rule is in Experiment III where subjects preferred diagrammatic signs. We attribute this latter finding to the fact that the graphic designs were both visually aesthetic and based on guidelines established in earlier research. Preference for the conventional signs may be attributable to the fact that drivers are more familiar with conventional signs and therefore are reacting less favorably toward diagrammatic signs because of their novelty. This supposition is borne out by the decreasing advantage of conventional signs when practice is given. The relatively small advantage of conventional signs is further borne out by the fact that only small differences were obtained in the correctness of lane choice obtained in the various signing conditions. In Experiment I there was no significant difference between conventional and diagrammatic. In Experiment II the significant difference between the two means was 7.51 percentage points. In Experiment III the difference was 4.32 percentage points. The amount of difference hardly establishes the overwhelming superiority of conventional signs.

An examination of the relationships between dependent measures revealed inverse relationships between latency and both confidence of lane choices and correctness of lane choices. Positive relationships

were found for the correlations of preference for sign type with confidence and familiarity of interchange with confidence in response.

The postexperimental comments of subjects and the experimental results suggest several guidelines for the use of diagrammatic signs. First, diagrammatic signs might be particularly beneficial at interchanges and intersections containing unexpected maneuvers or visual obstructions. Diagrammatic signs also may be useful when placed at the beginning of a signing sequence. This practice would provide both an overview of the interchange and the time to absorb the information on the sign. Diagrammatics will probably be most effective when they are kept as simple as possible and are efficiently combined with existing conventional information.

Finally, it is clear that while the experiments discussed in this report indicate that laboratory techniques are a reliable means of gathering various types of data on highway guide signs, they do not establish the validity of those data. Validity can be established only by a direct comparison of laboratory data with field data collected under non-experimental conditions. Hopefully such comparisons will be made in the near future.

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APPENDIX A

SUMMARIES OF STATISTICAL ANALYSES IN

Experiments I, II, and III

TABLE 34

ANOVA OF CORRECTNESS OF LANE CHOICES

BY FHWA AND BERGER CRITERIA

Experiment I

FHWA CRITERIA

SOURCE	SS	df	MS	F	
A (sign type)	1040.582	1	1040.582	2.8188	N.S.
B (practice)	397.120	1	397.120	1.0757	N.S.
AB	8.594	1	8.594	.0232	N.S.
Error	41,344.406	112	369.146		

BERGER CRITERIA

SOURCE	SS	df	MS	F	
A (sign type)	39.862	1	39.862	.038	N.S.
B (practice)	217.392	1	217.392	.206	N.S.
AB	21.208	1	21.208	.020	N.S.
Error	118,315.536	112	1056.389		

TABLE 35

MEAN LATENCIES WITHIN INTERCHANGES

Experiment I

INTER-CHANGE	PRACTICE	RESPONSE TYPE	SIGN TYPE	1	2	3	4	5	6	$\bar{X}$
1	NO PRAC	Voice	Conv	3.39	2.86	3.18	2.69	2.22	2.38	2.79
			Diag	3.17	3.38	3.66	3.49	2.44	2.58	3.12
		Key	Conv	3.51	3.57	3.71	2.69	2.35	2.98	3.14
			Diag	3.98	3.93	4.51	3.81	2.49	2.53	3.54
	PRAC	Voice	Conv	2.26	2.50	2.90	2.61	2.04	2.24	2.42
			Diag	2.32	2.54	3.86	2.89	2.43	2.26	2.72
		Key	Conv	2.70	2.88	3.52	2.79	2.37	2.42	2.78
			Diag	3.25	3.12	4.34	3.79	2.43	2.30	3.20
4E	PRAC	Voice	Conv	2.78	2.50	2.61	2.30	--	--	2.55
			Diag	2.76	2.76	3.84	2.52	--	--	2.97
		Key	Conv	3.08	3.12	3.08	2.27	--	--	2.89
			Diag	3.30	3.05	3.88	2.62	--	--	3.21
	NO PRAC	Voice	Conv	2.45	2.58	2.85	2.05	--	--	2.48
			Diag	2.18	2.52	3.65	2.59	--	--	2.74
		Key	Conv	2.75	2.98	3.51	2.69	--	--	2.98
			Diag	2.63	3.56	4.40	3.41	--	--	3.50
4N	PRAC	Voice	Conv	2.33	2.66	2.47	2.87	--	--	2.58
			Diag	2.26	2.59	2.52	3.27	--	--	2.66
		Key	Conv	2.71	2.88	3.04	3.41	--	--	3.01
			Diag	2.85	2.87	3.25	3.73	--	--	3.18
	NO PRAC	Voice	Conv	2.10	2.45	2.36	2.95	--	--	2.46
			Diag	2.41	2.58	2.85	3.48	--	--	2.83
		Key	Conv	2.88	2.93	3.12	3.46	--	--	3.10
			Diag	3.27	2.83	3.35	4.01	--	--	3.36

TABLE 35 (continued)

MEAN LATENCIES WITHIN INTERCHANGES

Experiment I

INTER-CHANGE	PRACTICE	RESPONSE TYPE	SIGN TYPE	1	2	3	4	5	6	$\bar{X}$
16	NO PRAC	Voice	Conv	3.14	3.00	2.68	3.04	2.65	2.17	2.78
			Diag	3.06	3.21	2.69	4.00	2.98	2.12	3.01
		Key	Conv	3.41	3.50	3.38	3.31	3.31	1.95	3.14
			Diag	3.76	3.76	3.61	4.45	3.40	2.32	3.55
	PRAC	Voice	Conv	2.62	2.46	2.74	3.19	2.60	1.50	2.52
			Diag	3.03	2.71	3.16	3.85	3.23	2.00	3.00
		Key	Conv	3.21	3.40	3.37	3.96	3.60	1.88	3.24
			Diag	3.57	3.37	3.41	4.84	4.00	2.48	3.61
17	NO PRAC	Voice	Conv	2.72	2.75	2.73	--	--	--	2.73
			Diag	2.81	3.14	3.10	--	--	--	3.02
		Key	Conv	3.44	3.38	3.34	--	--	--	3.39
			Diag	3.29	3.99	3.63	--	--	--	3.64
	PRAC	Voice	Conv	2.41	2.72	2.69	--	--	--	2.61
			Diag	2.13	3.10	2.83	--	--	--	2.69
		Key	Conv	2.93	3.17	3.64	--	--	--	3.25
			Diag	2.74	4.24	3.78	--	--	--	3.59
29	NO PRAC	Voice	Conv	2.44	2.32	2.51	2.25	2.92	2.83	2.54
			Diag	3.22	3.25	3.15	3.14	3.91	2.78	3.24
		Key	Conv	2.99	2.86	2.80	2.23	3.01	2.55	2.74
			Diag	3.76	3.40	3.02	3.85	4.02	2.92	3.50
	PRAC	Voice	Conv	2.71	2.18	2.72	2.06	3.20	2.22	2.52
			Diag	3.44	3.10	2.95	3.70	3.77	2.70	3.28
		Key	Conv	2.94	2.80	2.88	2.32	3.67	2.75	2.89
			Diag	3.89	3.69	3.11	4.42	4.41	3.17	3.78

TABLE 36

ANALYSIS OF VARIANCE FOR OVERALL MEAN LATENCIES

Experiment I

SOURCE	df	MS	F	P	w^2
TOTAL	1439				
Between subjects	119				
A (practice)	1	1.45	.25	n.s.	--
B (response type)	1	84.65	14.65	.001	.0662
A X B	1	2.93	.51	n.s.	--
subj. w. groups	116	5.78	--	--	--
Within subjects	1320				
C (sign type)	1	53.56	80.41	.001	.0446
A X C	1	.36	.54	n.s.	--
B X C	1	.45	.68	n.s.	--
A X B X C	1	.03	.04	n.s.	--
C X subj. w. groups	116	.67	--	--	--
D (interchange type)	5	2.20	8.89	.001	.0082
A X D	5	2.12	8.55	.001	.0079
B X D	5	1.12	4.52	.001	.0037
A X B X D	5	.17	.69	n.s.	--
D X subj. w. groups	580	.25	--	--	--
C X D	5	2.57	13.71	.001	.0100
A X C X D	5	.08	.41	n.s.	--
B X C X D	5	.10	.54	n.s.	--
A X B X C X D	5	.24	1.27	n.s.	--
C X D X subj. w. groups	580	.19	--	--	--

TABLE 37

ANALYSIS OF VARIANCE SUMMARY: Latency at Exit Point

(Regardless of Destination)

Experiment I

SOURCE	df	MS	F	P	w^2
Total	1439	--	--	--	--
Between subjects	119	--	--	--	--
A (response type)	1	41.97	8.23	.005	.019
B (practice)	1	.73	.14	n.s.	--
A x B	1	6.56	1.29	n.s.	--
Subj. w. groups	116	5.10	--	--	--
Within subjects	1320	--	--	--	--
C (sign type)	1	66.07	74.08	.001	.034
A X C	1	1.21	1.35	n.s.	--
B X C	1	5.00	5.60	.025	.002
A X B X C	1	.04	.04	n.s.	--
C X subj. w. groups	116	.89	--	--	--
D (interchange type)	5	47.22	62.83	.001	.121
A X D	5	3.46	4.61	.001	.007
B X D	5	1.97	2.62	.025	.003
A X B X D	5	1.62	2.16	n.s.	--
D X sub. w. groups	580	.75	--	--	--
C X D	5	4.46	7.09	.001	.010
A X C X D	5	1.18	1.88	n.s.	--
B X D X D	5	0.71	1.13	n.s.	--
A X B X D X D	5	0.38	0.61	n.s.	--
C X D X subj. w. groups	580	0.63	--	--	--

TABLE 38

ANALYSES OF VARIANCE OF CORRECTNESS OF LANE CHOICES

Experiment II

F.H.W.A. CRITERIA

SOURCE	SS	df	MS	F	p	w^2
Sign Type (A)	1127.251	1	1127.251	5.6896	.025	.055
Practice (B)	346.525	1	346.525	1.749	N.S.	
AB	55.615	1	55.615	.2807	N.S.	
Error	15057.284	76	198.122			

BERGER CRITERIA

SOURCE	SS	df	MS	F	p	w^2
Sign Type (A)	96.58	1	96.58	.334	N.S.	
Practice (B)	237.02	1	237.02	.8197	N.S.	
AB	157.641	1	157.641	.5451	N.S.	
Error	21,975.059	76	289.145			

TABLE 39

MEAN LATENCIES WITHIN INTERCHANGES

Experiment II

INTER-CHANGE	PRACTICE	RESPONSE TYPE	SIGN TYPE	1	2	3	4	5	$\bar{X}$
16S	NO PRAC	Voice	Conv	2.56	2.42	2.17	2.16	1.97	2.26
			Diag	2.72	2.27	2.08	2.60	2.03	2.34
		Key	Conv	3.47	3.32	3.23	2.49	2.50	3.00
			Diag	3.54	3.21	3.13	3.65	3.25	3.36
	PRAC	Voice	Conv	2.33	2.07	2.11	1.93	1.75	2.04
			Diag	2.45	1.97	2.21	2.31	2.18	2.22
		Key	Conv	2.91	2.61	2.82	3.02	2.29	2.73
			Diag	3.26	2.99	3.17	3.92	2.75	3.22
15	NO PRAC	Voice	Conv	2.17					2.17
			Diag	2.55					2.55
		Key	Conv	2.55					2.55
			Diag	3.43					3.43
	PRAC	Voice	Conv	1.81					1.81
			Diag	2.30					2.30
		Key	Conv	2.38					2.38
			Diag	3.35					3.35
DEMO	NO PRAC	Voice	Conv	2.59	2.44	2.80	2.42		2.56
			Diag	2.44	3.66	2.64	2.61		2.84
		Key	Conv	3.07	2.76	3.27	2.66	2.94	
			Diag	2.72	3.51	2.89	3.53	3.16	
	PRAC	Voice	Conv	1.92	1.94	1.92	2.44		2.05
			Diag	2.08	2.47	2.04	2.72		2.33
		Key	Conv	2.71	2.82	2.91	2.90		2.84
			Diag	2.69	3.20	2.85	3.25		3.00

TABLE 39

MEAN LATENCIES WITHIN INTERCHANGES

Experiment II

INTER-CHANGE	PRACTICE	RESPONSE TYPE	SIGN TYPE	1	2	3	4	5	$\bar{X}$
16N	NO PRAC	Voice	Conv	2.74	2.35	2.11	2.07		2.32
			Diag	3.35	2.81	1.89	2.41		2.61
		Key	Conv	3.04	2.49	2.43	2.78		2.68
			Diag	3.76	3.35	2.44	3.36		3.23
	PRAC	Voice	Conv	1.96	1.69	1.58	1.70		1.73
			Diag	2.51	2.21	1.61	2.25		2.15
		Key	Conv	2.68	2.14	2.16	2.62		2.40
			Diag	3.28	3.12	2.47	2.95		2.96
17N	NO PRAC	Voice	Conv	2.50	2.33	2.06			2.30
			Diag	2.56	2.26	2.28			2.37
		Key	Conv	3.15	2.96	3.09			3.06
			Diag	3.53	3.01	2.84			3.13
	PRAC	Voice	Conv	2.19	2.06	2.24			2.16
			Diag	2.80	2.42	1.56			2.26
		Key	Conv	2.73	2.76	2.60			2.70
			Diag	2.04	2.83	2.50			2.79
18E	NO PRAC	Voice	Conv	2.23	2.24	2.05			2.17
			Diag	2.51	2.46	2.08			2.35
		Key	Conv	3.20	3.42	2.91			3.18
			Diag	3.26	3.20	2.83			3.10
	PRAC	Voice	Conv	1.91	1.64	1.74			1.77
			Diag	2.24	2.09	1.87			2.07
		Key	Conv	2.58	2.55	2.28			2.47
			Diag	3.05	3.25	2.50			2.93

TABLE 40

OVERALL LATENCY

Experiment II

SOURCE	df	MS	F	P	w^2
TOTAL	575				
Between Subjects	47				
A (practice)	1	13.36	4.44	.05	.029
B (response type)	1	70.72	23.50	.001	.188
A X B	1	.12	.04	NS	--
subj. w. groups	44	3.01	--	--	--
Within subjects	528				
C (sign type)	1	14.32	23.22	.001	.038
A X C	1	.46	.75	NS	--
B X C	1	.54	.88	NS	--
A X B X C	1	.06	.10	NS	--
C X subj. w. groups	44	.62	--	--	--
D (interchange type)	5	.73	3.48	.005	.007
A X D	5	.17	.81	NS	--
B X D	5	.36	1.72	NS	--
A X B X D	5	.30	1.45	NS	--
D X subj. w. groups	220	.21	--	--	--
C X D	5	1.11	6.60	.001	.013
A X C X D	5	.10	.57	NS	--
B X C X D	5	.27	1.58	NS	--
A X B X C X D	5	.06	.34	NS	--
C X D X subj. w. groups	220	.17	--	--	--

TABLE 41

EXIT POINT LATENCY

Experiment II

SOURCE	df	MS	F	P	w^2
TOTAL	575				
Between Subjects	47				
A (practice)	1	14.73	5.46	.025	.0266
B (response type)	1	77.03	28.55	.001	.1648
A X B	1	.15	.06	NS	--
subj. w. groups	44	2.70	--	--	--
Within subjects	528				
C (sign type)	1	8.49	12.82	.001	.0174
A X C	1	.15	.22	NS	--
B X C	1	1.91	2.89	NS	--
A X B X C	1	.13	.20	NS	--
C X subj. w. groups	44	.66	--	--	--
D (interchange type)	5	3.34	8.24	.001	.0327
A X D	5	.25	.61	NS	--
B X D	5	.40	.98	NS	--
A X B X D	5	.24	.60	NS	--
D X subj. w. groups	220	.41	--	--	--
C X D	5	2.57	8.07	.001	.0251
A X C X D	5	.29	.91	NS	--
B X C X D	5	.17	.52	NS	--
A X B X C X D	5	.37	1.17	NS	--
C X D X subj. w. groups	220	.32	--	--	--

TABLE 42

ANALYSES OF VARIANCE OF CORRECTNESS OF LANE CHOICES

Experiment III

SOURCE	df	MS	F	p	w^2
Total (within)	106				
A (sign type)	1	412.45	8.073	.01	.037
B Interchange	10	133.315	2.6095	N.S.	
A x B	10	350.053	6.852	.01	.31
Error	85	51.087	--	--	--

TABLE 43

ANALYSIS OF VARIANCE OF OVERALL LATENCY

Experiment III

SOURCE	df	MS	F	Sig(p)	w^2
Between Subjects					
A (Destination)	1	21.10	2.56	N.S.	--
Subj. w. group	30	8.25	--	--	--
Within Subjects					
B (Sign Type)	1	1.14	1.47	N.S.	--
A x B	1	0.03	0.04	N.S.	--
B x subj. w. groups	30	0.78	--	--	--
C (Interchange)	10	7.82	43.58	.001	.156
A x C	10	1.33	7.40	.001	.023
C x subj. w. group	300	0.18	--	--	--
B x C	10	0.50	3.54	.001	.007
A x B x C	10	0.35	2.51	.005	.004
B x C x subj. w. groups	300	0.14	--	--	--

TABLE 44

ANALYSIS OF VARIANCE OF LATENCY AT EXIT POINT

Experiment III

SOURCE	SS	df	MS	F	Sig	w^2
TOTAL	731.683					
Between Subjects						
A (Destination)	7.092	1	7.092	0.815	N.S.	--
A X Subjects with	260.961	30	8.699	--	--	--
Within Subjects						
B (Sign Type)	0.260	1	0.260	0.292	N.S.	--
AB	1.890	1	1.890	2.120	N.S.	--
B x Subj. within	26.751	30	0.892	--	--	--
C (Interchange type)	95.275	10	9.528	18.980	.001	.123
AC	65.600	10	6.560	13.068	.001	.083
C x Subj. within	150.593	300	0.502	--	--	--
BC	10.982	10	1.098	3.071	.001	.010
ABC	4.992	10	0.499	1.396	N.S.	--
BC x Subj. with	107.287	300	0.358	--	--	--

TABLE 45

MEAN LATENCY OF RESPONSE

Experiment III

INTER-CHANGE	SIGN TYPE	1	2	3	4	5	6	7	8	$\bar{X}$
1	Conv	3.20	3.63	3.53	3.21	--	--	--	--	3.39
	Diag	4.22*	4.10*	3.31	3.33	--	--	--	--	3.74
2	Conv	3.21	3.51	3.55	3.71	3.34	3.17	3.69	2.89	3.38
	Diag	2.81	3.94*	3.60	3.87*	3.35*	3.36	3.49*	2.76	3.40
3	Conv	2.98	3.21	3.19	2.83	2.69	2.62	--	--	2.92
	Diag	2.90	3.72*	3.37	2.68*	269*	2.65	--	--	3.00
4	Conv	3.24	--	3.49	3.25	2.55	2.52	--	--	3.02
	Diag	3.32	3.70*	3.53	3.03*	2.74*	2.64	--	--	3.16
5	Conv	3.06	3.00	2.58	2.22	--	--	--	--	2.72
	Diag	2.93	2.92*	2.65*	2.31	--	--	--	--	2.70
6	Conv	3.68	3.03	2.74	--	--	--	--	--	3.15
	Diag	3.43*	3.05*	2.77	--	--	--	--	--	3.08
7	Conv	2.91	3.33	3.49	3.13	2.79	--	2.60	2.61	2.89
	Diag	3.03	3.15	3.36	3.01	2.81	3.39*	2.81	2.74	3.04
8	Conv	3.09	3.00	2.86	3.28	2.56	--	--	--	2.96
	Diag	3.04	2.97	2.81	3.28	2.62	3.26*	--	--	3.00
9	Conv	2.82	--	2.90	--	--	--	--	--	2.86
	Diag	2.66	4.19*	2.71	--	--	--	--	--	3.19
10	Conv	3.53	2.94	--	--	3.14	3.15	--	--	3.19
	Diag	3.22	3.00	2.98*	2.83*	3.18	2.84	--	--	3.01
11	Conv	2.30	--	1.86	--	--	--	--	--	2.08
	Diag	2.06	3.16*	1.78	--	--	--	--	--	2.34

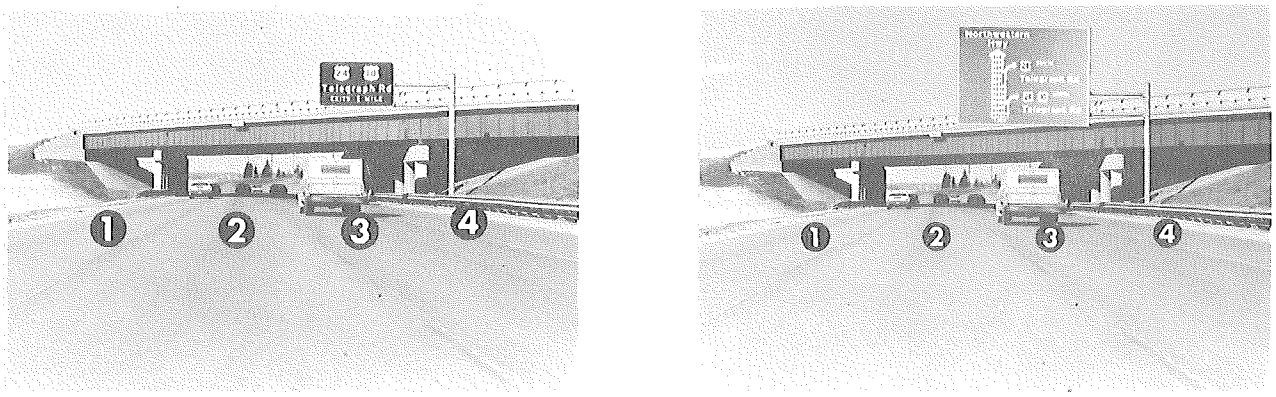
*represents points at which diagrammatic signs were included. The remaining signs in the diagrammatic sequence were identical to those in the conventional sequence.

APPENDIX B

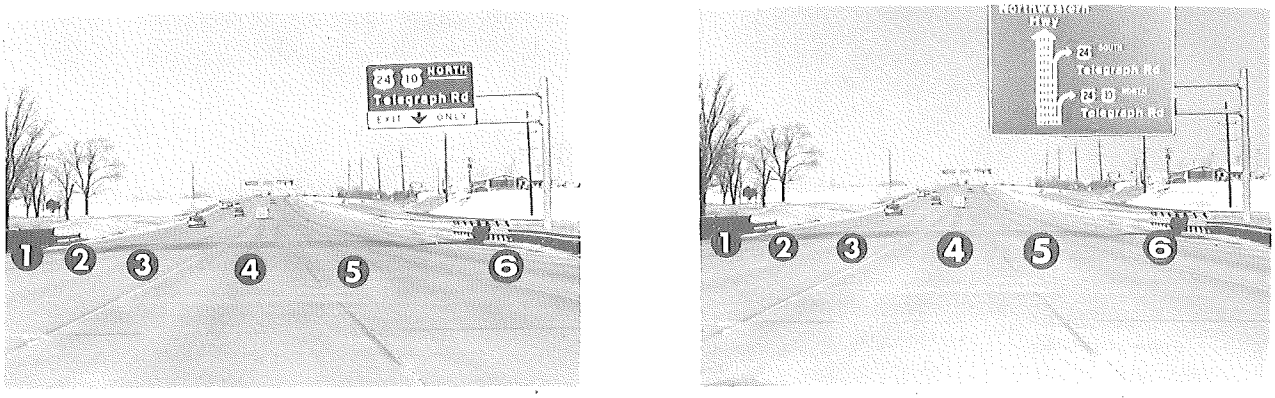
BEFORE/AFTER PHOTOGRAPHS OF DIAGRAMMATIC SIGNS USED IN EXPERIMENT III

BEFORE

AFTER



ADVANCE SIGN 1

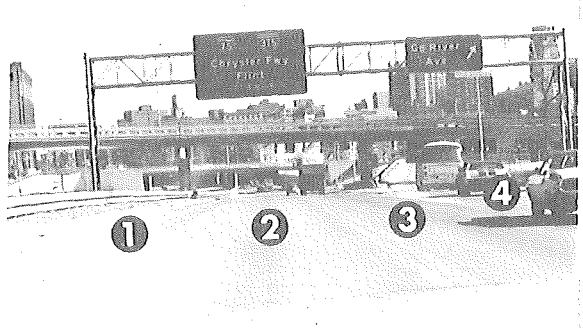


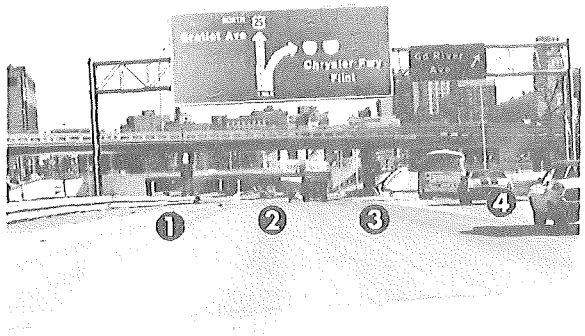
ADVANCE SIGN 2

FIG. 7 Before/After Signs for Interchange 1 of Experiment III.

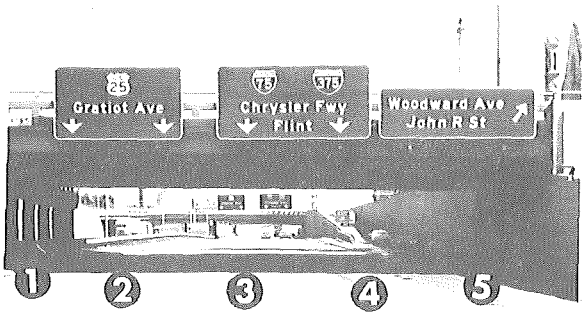
BEFORE

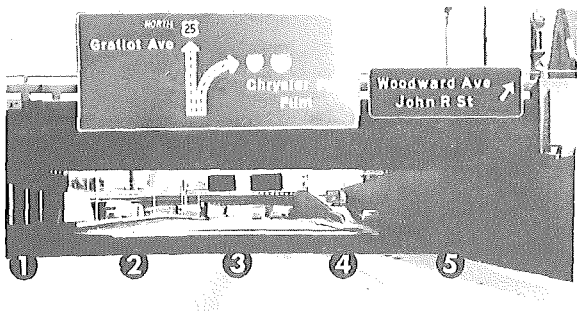
AFTER



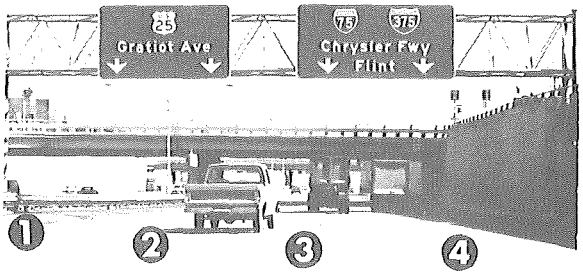


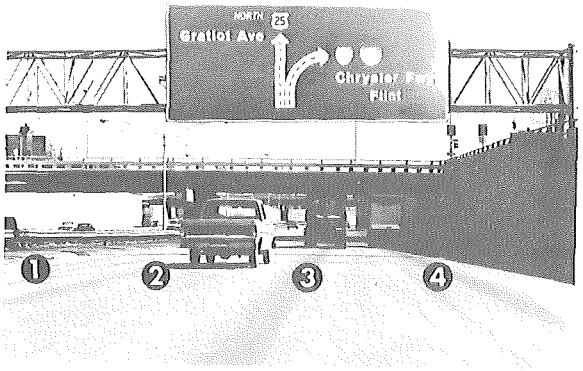
ADVANCE SIGN 2





ADVANCE SIGN 4





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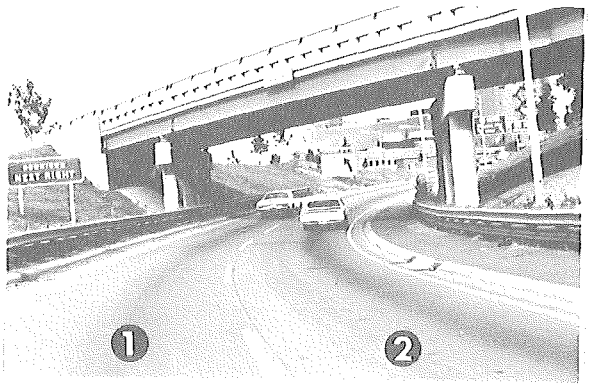
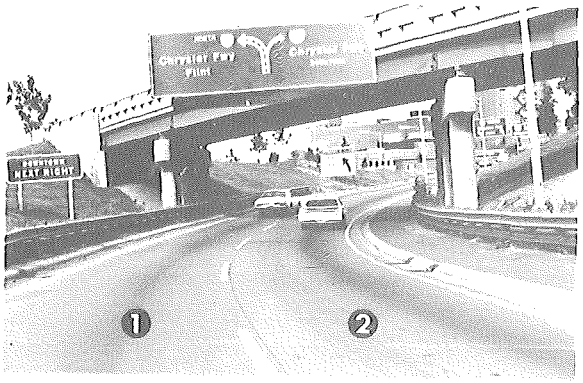




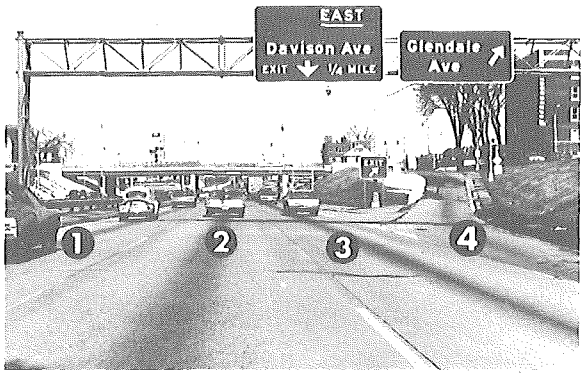
ADVANCE SIGN 7

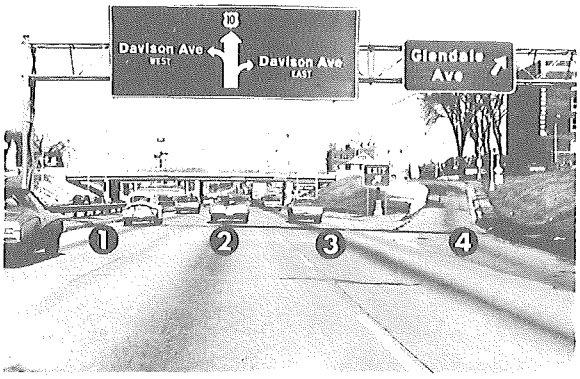
FIG. 8 Before/After Signs for Interchange 2 of Experiment III.

BEFORE

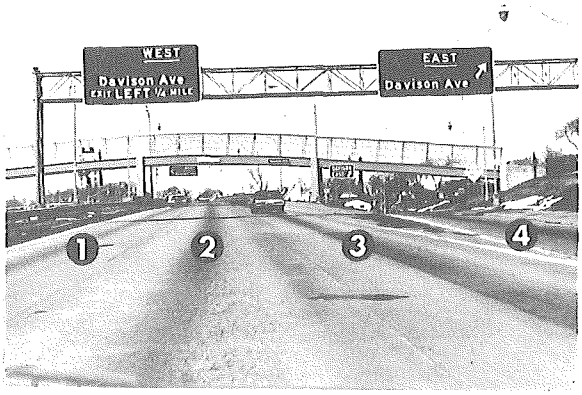
AFTER

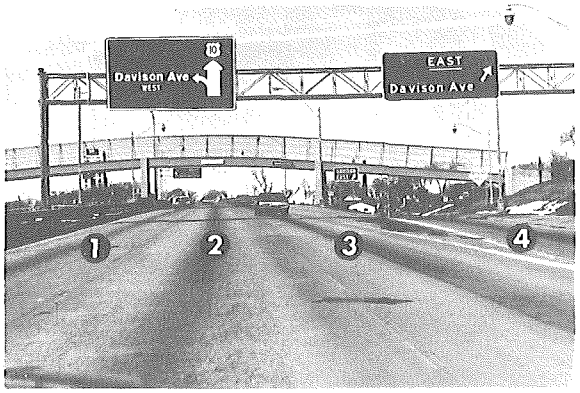
ADVANCE SIGN 2





ADVANCE SIGN 4



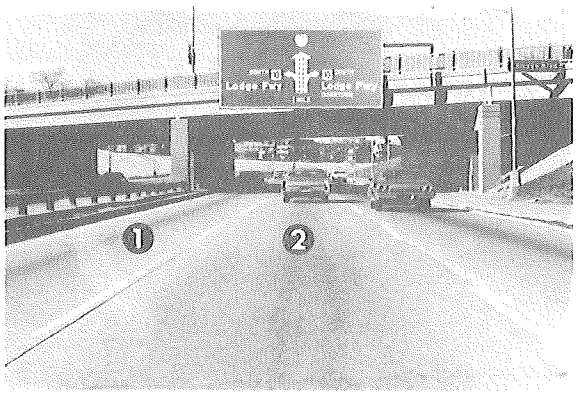


ADVANCE SIGN 5

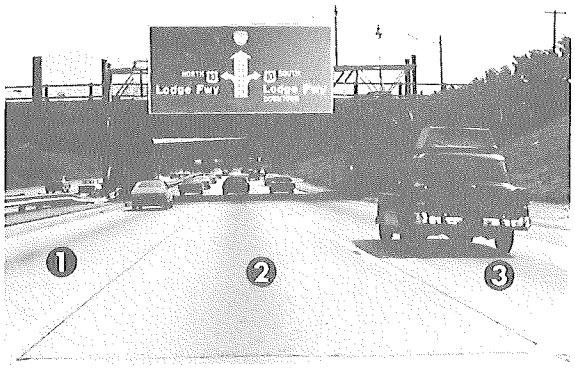
FIG. 9 Before/After Signs for Interchange 3 of Experiment III.

BEFORE

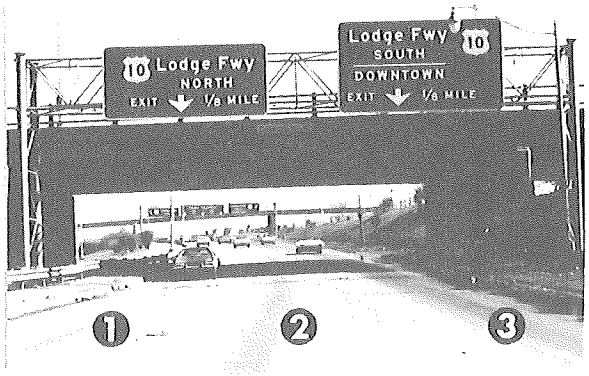
AFTER

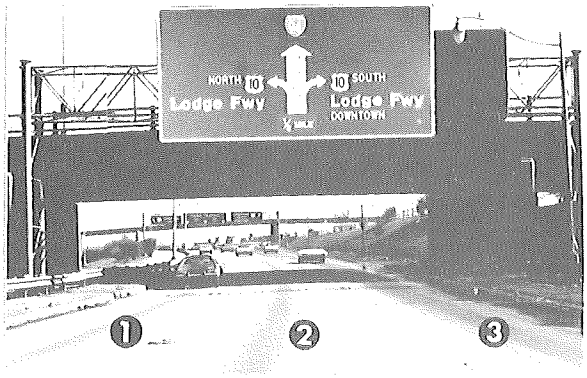


ADVANCE SIGN 2 (Diagrammatic only)



ADVANCE SIGN 4



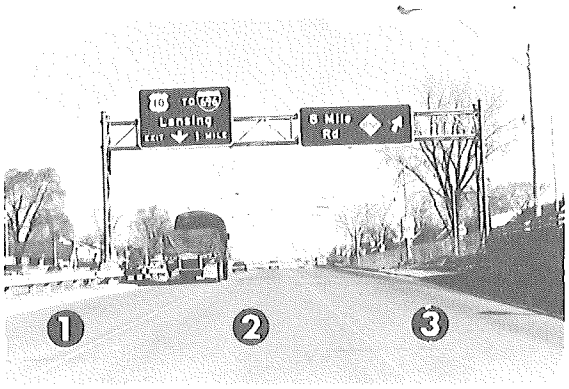


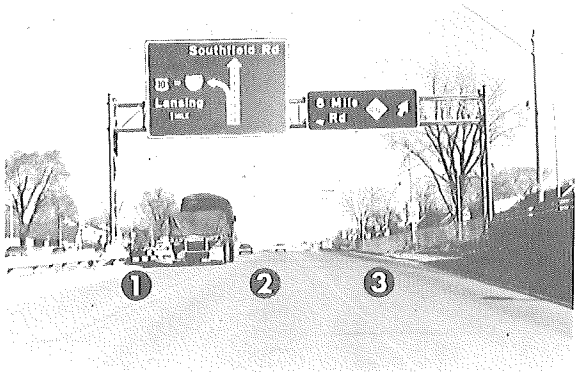
ADVANCE SIGN 5

FIG. 10 Before/After Signs for Interchange 4 of Experiment III.

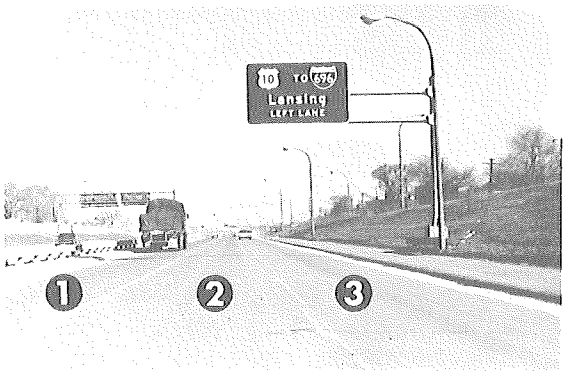
BEFORE

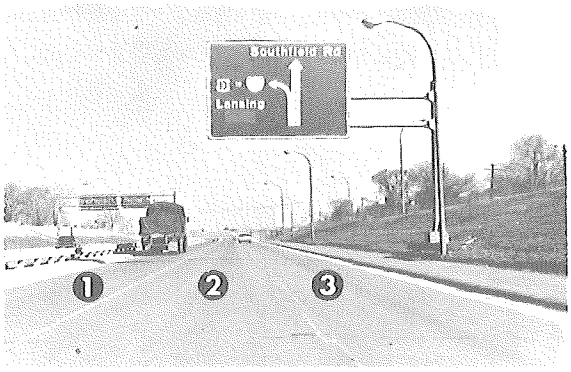
AFTER





ADVANCE SIGN 2

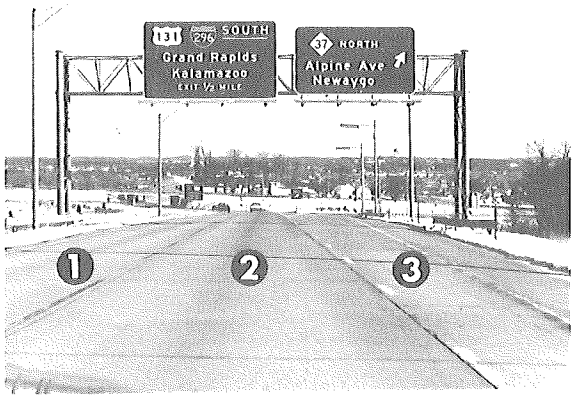




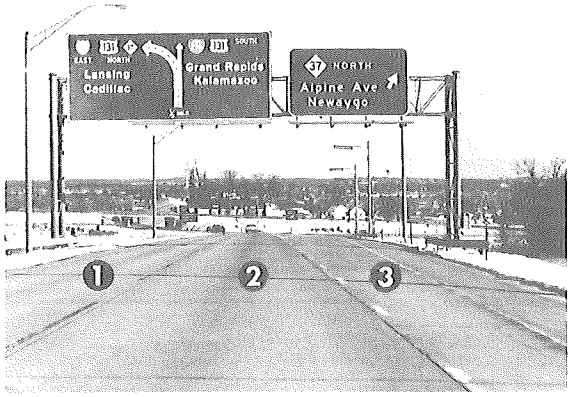
ADVANCE SIGN 3

FIG. 11 Before/After Signs for Interchange 5 of Experiment III.

BEFORE



AFTER



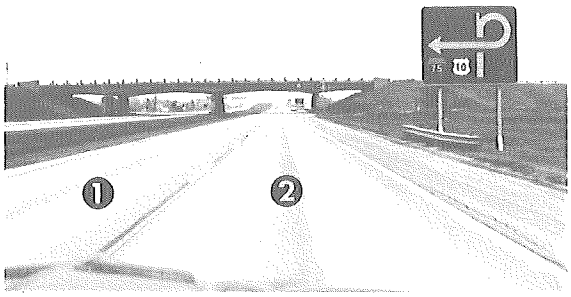
ADVANCE SIGN 1

ADVANCE SIGN 2

FIG. 12 Before/After Signs for Interchange 6 of Experiment III.

BEFORE

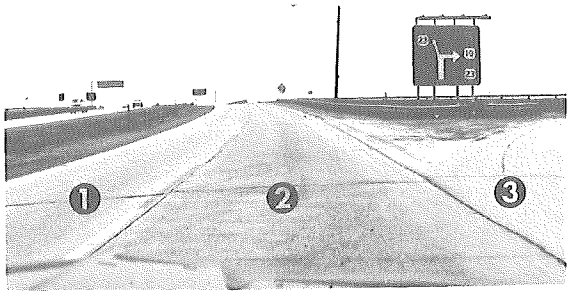
AFTER



ADVANCE SIGN 6 (diagrammatic only)

FIG. 13 Before/After Sign for Interchange 7 of Experiment III.

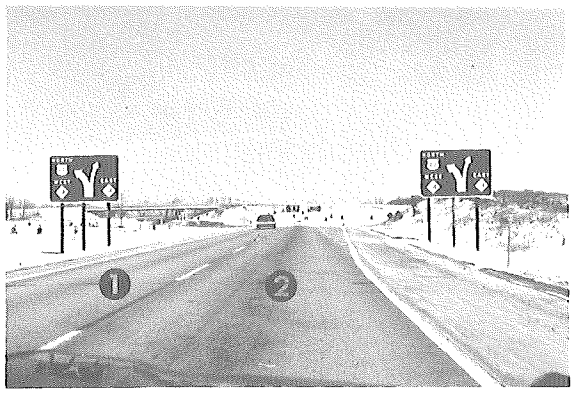
BEFORE AFTER



GORE SIGN ONLY (Diagrammatic only)

FIG. 14 Before/After Sign for Interchange 8 of Experiment III.

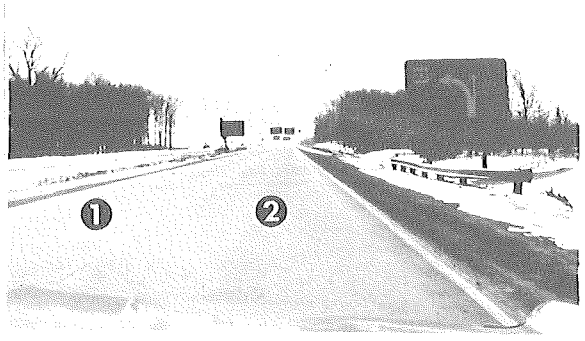
BEFORE AFTER



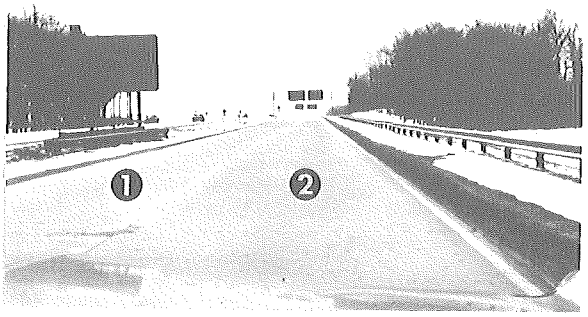
ADVANCE SIGN 2 (diagrammatic only)

FIG. 15 Before/After Sign for Interchange 9 of Experiment III.

BEFORE AFTER



ADVANCE SIGN 3 (diagrammatic only)

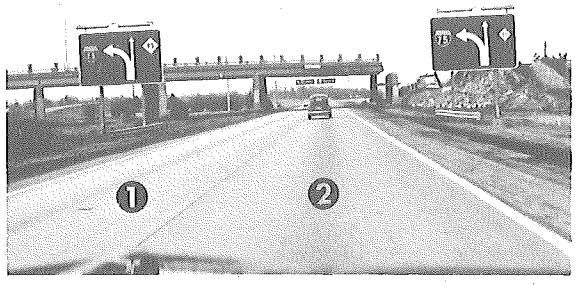


ADVANCE SIGN 4 (diagrammatic only)

FIG. 16 Before/After Signs for Interchange 10 of Experiment III.

BEFORE

AFTER



ADVANCE SIGN 2 (Diagrammatic only)

FIG. 17 Before/After Sign for Interchange 11 of Experiment III.