Diagrammatic Highway Signs: The Laboratory Revisited

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The experiment summarized in this report was 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. It was found that the differences in two previous 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. Therefore, the methodology established in the current investigation, which controlled for methodological differences in earlier studies, was concluded to be 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 for 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.

One purpose of the research described in this report was to establish a laboratory method for the evaluation of highway signing practices that could be generalized. An additional benefit of the current 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 and 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 is probably 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. As a consequence, significant savings in time, money, and personnel would be possible if traffic response data could be obtained reliably and economically in the laboratory. Therefore, one of the major purposes of the investigation was to assess the reliability and validity of laboratory methods of evaluating guide sign information.

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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 (7). However, few of the recommended uses are based on sound empirical evidence. Several laboratory studies have been conducted to assess the effectiveness of diagrammatic guide signs (1, 2) but have produced contradictory conclusions and recommendations. On the other hand, field tests of diagrammatic signs (4, 6) have been well received but of somewhat limited use because of a lack of generalizability. However, limited recommendations have been made for the use of diagrammatics by Mast and Kolsrud (5) based on their synthesis of research findings. In this investigation, an explicit attempt has been made to assess the differences in methodology and results obtained in the Gordon (2) and Berger (1) studies.

The two major laboratory investigations that preceded the present investigation (1, 2) 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 study (2) employed lane choices, overall preferences, and latency data. The Berger study (1) 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 that result in a recommendation for conventional signs in one case and a recommendation for diagrammatic signs in the other.

Therefore, this 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 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 to thus allow a comparative analysis of methods not possible in earlier investigations. Second, it was decided that either an unlimited or an extremely brief stimulus presentation time was not a realistic representation 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 (2) were used to ensure 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 was then analyzed twice, once by using the Berger criteria and once by 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 (1) and Gordon (2) data by using their own criteria of correctness. In the third comparison, the current data were compared against themselves by 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) × 2 (practice) × 2 (type of sign) × 6 (intersection) factorial design with repeated measures on type of sign and intersections. Dependent measures included correctness of lane choice, confidence of lane choice, preference of types of signs, and latency of response to signs.

Stimulus Materials

The basic stimuli used in this experiment were eight sets of color slides. Each set consisted of 29 roadway scenes and six destination names. The slides, provided by FHWA, were identical to those used in the Gordon report (2). In brief, they depicted highway scenes along the Washington, D.C., beltway (I-495) approximately 60 m (200 ft) 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 (six slides on interchange 1),
2. Multiple-split ramp (four slides on interchange 4N),
3. Left ramp downstream from right ramp (four slides on interchange 4E),
4. Two right ramps in quick succession (six slides on interchange 16),
5. Major fork (three slides on interchange 17), and
6. Cloverleaf (six slides on interchange 29).

In addition, each interchange grouping was preceded by a destination name that served as the choice cue for the subjects. A more complete description of these intersections can be obtained in the Gordon report (2).

The roadway scenes depicted in each set of slides were identical except for the types of signs used. Signs in four of the sets were of the conventional style [in conformity with the U.S. Manual on Uniform Traffic Control Devices (7)]; signs in the remaining four sets were of the diagrammatic type, duplicating the designs used in the Berger study (1).

Because all of 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 of slides therefore made it possible to construct four different sequence combinations of destinations, which, in effect, created a counterbalancing of turn directions for the stimuli, which would control for any preference bias. Keeping the order of the six types of interchanges constant in conformity with the Berger and Gordon studies (1, 2) (1, 4N, 4E, 16, 17, 29), one set of slides depicting conventional and diagrammatic signs included only all right-turn destinations, a second set included only all left-turn or through destinations, a third set alternated with right-turn then left-turn or through destinations, and a fourth set alternated with left-turn or through then right-turn destinations.

A second set of stimuli was then prepared in which a basic set of 29 conventional and 29 diagrammatic slides was converted into color prints. Two scenes were subsequently eliminated from each set of prints (the first interchange picture for interchanges 4N and 17) because the conventional and diagrammatic signs used in the comparable scenes were identical for both. This left a total of 54 prints. These 54 prints depicted 27 pairs of highway scenes; one print from each pair showed a conventional style of sign, and the comparable print showed a diagrammatic type of sign. The two prints in each pair were then mounted side by side [positioning on the right or left was random on separate pieces of 11.4 by 31.75-cm (4.5 by 12.5-in) poster board]. Above each scene with a conventional sign was printed a number one, and above each scene with a diagrammatic sign was printed a number two. This second set of stimuli, thus prepared, provided individual pair-wise comparisons of the two types of signs within the 27 roadway scenes.

Subjects

One hundred and twenty subjects were used for this experiment, constituting a random sample of licensed drivers with varied driving experience from among the Wayne State University student body. Each subject was paid $2.00 for participating.

Experimental Procedure

The experimental procedure was basically the same for all subjects. After arriving at the laboratory, they were randomly assigned to one of four experimental conditions: (a) voice response with no practice session before the testing session—30 subjects; (b) voice response with a practice session before the testing session—30 subjects; (c) key response with no practice session before the testing session—30 subjects; and (d) key response with a practice session before the testing session—30 subjects. Subjects then sat at a table 2.4 m (8 ft) away from and facing a rear projection screen and viewed slide sets of highway scenes from six freeway interchanges, half of which depicted conventional highway signs and half of which depicted diagrammatic signs (as previously described in the section on stimulus materials). The presentation order of conventional or diagrammatic signs was counterbalanced so that half of the subjects (60) viewed conventional signs before viewing diagrammatic signs, and the other half (60 subjects) viewed graphic signs before the conventional ones. Furthermore, subjects within each of these two groups were presented one of four turn-direction orders (as described in the section on stimulus materials). Forty subjects received all left-turn or through destinations; another 40 subjects received right-turn destinations. In the last group, 20 subjects received left-turn or through then right-turn destinations; the remaining 20 subjects received right-turn then left-turn or through destinations.

Before viewing the scenes from each interchange, a destination name was presented on the screen for the subject, which he or she announced aloud. Following this, the subject was presented the highway scenes for that particular interchange one at a time for a maximum period of 5 s, approximating the amount of time sign information is paid attention 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 intertrial (slide) interval of 10 s, the experimenter recorded the subject's lane choice, the latency of that response, and the confidence level. The equipment was then reset, 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 viewed and responded to one set each of the diagrammatic and conventional signs. Practice condition subjects, on the other hand, received two presentations each of the conventional and diagrammatic signs and made the appropriate responses. Although the order of the types of signs that these latter subjects received was maintained in the second session, the turn-direction order was reversed; for example, subjects who viewed all right-turn destinations in practice viewed all left-turn or through destinations in the test session. Thus, as in the Gordon study (2), although subjects became familiar with the various sign designs, they did not become familiar with the actual problems asked in the test sessions.

Another variation in the basic procedure corresponded to the type of response condition. Half of the subjects within each of the practice and no practice conditions made their lane choices into a voice microphone, and the second half used a response key. In each case the subject's response served to stop a latency timer. The response key condition corresponded to that used by Gordon; the voice response 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 the section on stimulus materials) depicting the highway scenes that had just been viewed in slide form. Subjects viewed each of these pairs one at a time and indicated which picture of the two presented sign information that they felt was easier to use and therefore which they would prefer to see used 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 reaction time control and a 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-Hz Sonalert ready signal; and a control panel containing a four-bank timer, six response indicators, a $\frac{1}{100}$-s digital stop clock, a manual override control for advancing slides and triggering the shutter, and a mode selection switch that determines whether a slide aborts after a response. The unit is designed to automatically time an intertrial interval (ITI), a ready signal period, a delay period, and the presentation time of the slide. The stop clock is automatically initiated on slide presentation. Any response is recorded on the central control panel, automatically stops the clock, and terminates the slide presentation. During the ITI period, the experimenter must record the reaction time, reset the response indicators, and make any desired timing changes. 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, various types of agencies can acquire the capability to conduct their own exploratory investigations.

RESULTS

We shall first examine those data for which direct comparisons can be made of the results of the Gordon (1), Berger (2), and current studies. The only data on which the three studies could be directly compared was the correctness of lane choices. The data are summarized by type of interchange in Table 1. Three tests of significance were run on each interchange. First, the original Berger (1) data were compared with the current data by employing the Berger criteria. Two such tests were possible for each interchange allowing for type of sign (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 those obtained in the Berger 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 data with the current data by employing the Gordon criteria. Only 2 of 24 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 criteria were compared with the same data scored by the Gordon criteria. Fifteen of 24 comparisons were found to be significant (the means were significantly different from each other). Because no essential significant differences were found when the earlier data were compared with current data by the same criteria, only one conclusion is possible. We suggest that data obtained in earlier laboratory studies are reliable but that the criteria employed in those studies were not. A summary of correctness by Gordon criteria at exit point broken down by interchange, sign, and practice is given in Table 2. The mean proportion correct was 0.96 for conventional signs and 0.91 for diagrammatic signs. An analysis of variance of correctness of lane choice across all interchanges revealed no significant differences in correctness due to type of sign (conventional versus diagrammatic) [$F_{(1,112)} = 2.8188$] or experience (practice versus no practice) [$F_{(1,112)} = 1.0757$] when analyzed by Gordon criteria. Similar results were obtained in an analysis of variance by using the Berger criteria. Generally, the results tend to support Gordon's findings that the proportion of correct lane choice is higher for conventional signs than for diagrammatic signs although, in this investigation, this difference was not statistically significant. A result such as this is not unanticipated because most drivers are familiar with conventional signs, and consequently diagrammatic signs produce a novelty effect that initially may cause some slight deteriorations in performance. However, as data obtained in other 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 3 summarizes the comparative analyses on confidence of lane choices. Only comparisons with the Berger data were possible because Gordon did not collect confidence data. In the six possible comparisons (across interchanges) of the Berger data and the current data on conventional signs, the means were statistically different from one another only in a single instance. In the case of diagrammatic signs, none of the six mean differences was 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 are reliable. When the mean of the conventional confidences (3.43 on a scale ranging from 1 to 4) was compared with the mean of the diagrammatic confidences (3.13) for the current data, the difference between means was found to be significant both for practice [$t_{(5\,df)} = 4.098$, $p < 0.005$] and for no practice conditions [$t_{(5\,df)} = 3.88$, $p < 0.01$]. Berger obtained results that were not in agreement with the above findings (the mean confidence was 3.09 for conventional signs and 3.02 for diagrammatic signs). The findings of the present investigation are believed to be intuitively more interpretable in that individuals should be more confident of stimuli that are familiar to them and less confident of stimuli that are novel or unique. Of course, diagrammatic signs fall into this latter category. The χ^2 tests in part A of Table 4 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 or her lane choices, the more apt he or she is to be correct. Moreover, as part C of Table 4 shows, if an individual prefers diagrammatic signs, he or she is also confident of his or her 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 [$t_{(26\,df)} = 47.91$, $p < 0.0005$]. The mean percentage of preferences for each interchange is given in Table 5. Reference to Table 4, 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 (2).

Comparisons of latency data were possible only for the Gordon (2) and current data. The comparisons are summarized for overall interchanges in Table 6 and for the exit point within each interchange in Table 7. It can be observed from Table 6 that, in two out of four comparisons with the Gordon (2) 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 current 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 current investigation tend to support the earlier findings of Gordon. This sort of interpretation is supported by an examination of Table 7 where a similar pattern of results was obtained for latency at the exit point. We conclude from these comparisons that the results obtained in the current study are essentially of the same nature as those obtained in the Gordon (2) study.

In an overall analysis of variance of latency data, the main effects of type of sign [$F_{(1,116)} = 80.41$, $p < 0.001$] and type of interchange [$F_{(5,580)} = 8.89$, $p < 0.001$] were found to be significant. 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 employed. Surprisingly, the interchange that 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 because this type of interchange is neither the most geometrically complex nor the one that 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 Gordon 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 and all the others require an exit judgment that 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 [$F_{(1,116)} = 14.63$, $p < 0.001$]. The magnitude of this difference was approximately 0.50 s. Practice [$F_{(5,580)} = 8.55$, $p < 0.001$], type of response [$F_{(5,580)} = 4.52$, $p < 0.001$], and type of sign [$F_{(5,58)} = 13.71$, $p < 0.001$] also were found to interact significantly with type of interchange. The basis for the interaction with practice was that, in several instances, mean latencies increased when practice was given and in others it decreased. We suggest that this effect is both uninterpretable and of little practical significance. A similar analysis can be made for the interaction of type of response with type of interchange. The type of sign 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. 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.

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, type of sign, and type

Table 1. Comparative analyses of lane choice data.

	No Practice Group						Practice Group					
	Conventional Sign			Diagrammatic Sign			Conventional Sign			Diagrammatic Sign		
Type of Interchange	A	B	C	A	B	C	A	B	C	A	B	C
Lane drop	<0.01	NS	NS	NS	NS	NS	—	NS	NS	—	NS	NS
Multiple-split ramp	NS	NS	<0.001	<0.05	<0.05	NS	—	NS	<0.001	—	NS	NS
Left ramp downstream from right ramp	NS	NS	NS	NS	NS	<0.001	—	NS	<0.001	—	NS	<0.05
Two right ramps in quick succession	NS	NS	<0.001	NS	NS	<0.001	—	<0.05	<0.001	—	NS	<0.001
Major fork	<0.05	NS	<0.001	NS	NS	<0.001	—	NS	<0.01	—	NS	NS
Cloverleaf	NS	NS	<0.001	<0.01	NS	<0.001	—	NS	<0.05	—	NS	<0.01

Note: A = Berger study versus current study by Berger criteria; B = Gordon study versus current study by Gordon criteria; C = current study by Berger criteria versus Gordon criteria; and NS = not significant.

Table 2. Correctness of lane choice at exit point.

		Conventional Sign			Diagrammatic Sign			
Interchange	Group	Number Correct	Number Incorrect	Proportion Correct[a]	Number Correct	Number Incorrect	Proportion Correct[b]	Significant Difference
1	No practice	118	2	0.983	115	5	0.958	NS
	Practice	60	0	1.000	60	0	1.000	NS
4N	No practice	113	7	0.942	113	7	0.942	NS
	Practice	60	0	1.000	60	0	1.000	NS
4E	No practice	114	6	0.950	96	24	0.800	—[c]
	Practice	56	4	0.933	54	6	0.900	NS
16	No practice	113	7	0.942	109	11	0.908	NS
	Practice	60	0	1.000	56	4	0.933	—[c]
17	No practice	113	7	0.942	109	11	0.908	NS
	Practice	58	2	0.967	55	5	0.917	NS
29	No practice	115	5	0.958	107	13	0.892	NS
	Practice	60	0	1.000	51	9	0.850	—[c]
Total	No practice	686	34	0.953	649	71	0.901	
	Practice	354	6	0.983	336	24	0.933	

[a]Mean proportion correct = 0.96. [b]Mean proportion correct = 0.91. [c]0.05 significance level.

Table 3. Comparisons of confidence of responses.

	No Practice Group			Practice Group		
Type of Interchange	A	B	C	A	B	C
Lane drop	NS	NS	<0.025	—	—	<0.05
Multiple-split ramp	NS	NS	<0.05	—	—	<0.05
Left ramp downstream from right ramp	NS	NS	NS	NS	NS	<0.005
Two right ramps in quick succession	NS	NS	<0.05	—	—	<0.05
Major fork	NS	NS	<0.005	—	—	<0.01
Cloverleaf	<0.05	NS	NS	—	—	<0.05

Note: A = Berger conventional versus current study conventional; B = Berger diagrammatic versus current study diagrammatic; C = current study conventional versus current study diagrammatic; and NS = not significant.

Table 4. χ^2 tests of variable interrelationships.

Part	Group	Sign	χ^2	df	p	C	N
A	No practice	Conventional	67.68	3	0.001	0.6004	120
		Diagrammatic	127.10	3	0.001	0.7130	120
	Practice	Conventional	38.807	3	0.001	0.6266	60
		Diagrammatic	75.97	2	0.001	0.7434	60
B[a]	No practice	Conventional	11.024	1	0.001	0.2685	120
		Diagrammatic	159.86	1	0.001	0.7557	120
	Practice	Conventional	2.002	1	0.250[b]	0.1794	60
		Diagrammatic	11.777	1	0.001	0.4049	60
C[a]	No practice	Conventional	4.86	3	0.250[b]	0.1972	120
		Diagrammatic	53.10	3	0.001	0.5538	120
	Practice	Conventional	0.739	3	0.500[b]	0.1100	60
		Diagrammatic	36.897	3	0.001	0.6170	60

Note: Part A contains tests for correctness of lane choice to conventional and diagrammatic sign by degree of confidence in lane choice; part B contains tests for correctness of lane choice to conventional and diagrammatic signs by preference for conventional or diagrammatic signs; and part C contains tests for preference for conventional or diagrammatic signs by degree of confidence in lane choice.

[a]Preference for slide 1 for interchanges 4N and 17 not included. [b]Not significant.

Table 5. Mean percentage of preferences for conventional and diagrammatic signs.

Interchange	Conventional Sign	Diagrammatic Sign
1	69.17	30.83
4E	67.07	32.93
4N	76.40	23.60
16	78.48	21.51
17	62.90	37.10
29	84.05	15.95
Exit point only	75.15	24.85

of response. However, latencies also were found to differ significantly as a function of their position in the entire sequence of signs. In general, 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; consequently, it required little processing. This would be reflected in relatively low latencies. The signs in the middle of a sequence are those that communicate information relevant to the driving task and thus require somewhat longer responses because of the information processing required. The final sign in the sequence is a simple announcement that 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 -0.79, $p < 0.001$, which suggests that the more confident the individual is of his or her judgment, the more quickly he or she will re-

Table 6. Comparative data on mean latency of response in seconds.

Group	Type of Sign	Study	N	Interchange 1	4E	4N	16	17	29	Average	Significance Test
No practice	Conventional	Gordon	60	3.18	3.19	3.04	3.22	3.15	2.91	3.12	NS
		Current	60	3.14	2.89	3.01	3.14	3.39	2.74	3.05	NS
	Diagrammatic	Gordon	60	3.80	3.33	3.46	3.59	3.32	3.51	3.50	NS
		Current	60	3.54	3.21	3.18	3.55	3.64	3.50	3.44	NS
Practice	Conventional	Gordon	60	2.60	2.68	2.56	2.70	2.66	2.48	2.61	<0.005
		Current	60	2.78	2.98	3.10	3.24	3.25	2.89	3.04	<0.005
	Diagrammatic	Gordon	60	2.92	2.81	2.83	2.90	2.83	3.16	2.91	<0.005
		Current	60	3.20	3.50	3.36	3.61	3.59	3.78	3.51	<0.005

Note: NS = not significant.

Table 7. Comparative data on mean latency at exit point in seconds.

Group	Type of Sign	Study	Interchange 1	4E	4N	16	17	29	$\bar{x}$	Significance Test Between Means
No practice	Conventional	Gordon	1.94	2.57	2.47	1.86	3.20	1.81	2.31	NS
		Current (key)	2.14	2.27	2.65	1.95	3.32	2.07	2.40	NS
	Diagrammatic	Gordon	2.37	2.96	3.05	2.12	2.24	2.57	2.55	<0.05
		Current (key)	2.18	2.62	2.98	2.28	3.63	2.99	2.78	<0.05
Practice	Conventional	Gordon	1.64	2.32	2.19	1.67	2.78	1.57	2.03	<0.005
		Current (key)	1.92	2.69	2.67	1.88	3.64	2.03	2.47	<0.005
	Diagrammatic	Gordon	1.87	2.69	2.43	1.88	2.83	2.29	2.33	<0.0005
		Current (key)	1.95	3.35	3.30	2.48	3.78	3.54	3.07	<0.0005

Note: NS = not significant.

Table 8. Postexperimental interview comments.

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	Diagrammatic signs as clear as conventional signs with practice
5	Prefer long curved arrows at exit point if they are not too complicated
3	Sign preceding exit should include only distance to exit and sign at exit should indicate where to go
2	Sign preceding exit should be diagrammatic and sign near exit should be conventional
1	With multiple arrows on signs information is needed to indicate which lane goes with each arrow

spond. The average correlation between correctness of lane choices and latencies of response was -0.43, $p < 0.02$, 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 that 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, no significant difference [$t_{(5\,df)}$ - 0.77] was found between conventional ($\bar{x}$ = 195.17) and diagrammatic ($\bar{x}$ = 189.17) signs, but 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 or she desired with respect to the advantages or disadvantages of conventional or diagrammatic signs. These comments are summarized in Table 8. The categories are nonindependent; that is, one person may be included in a number of categories. The experimenter collapsed comments into categories with essentially synonymous 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. This view, freely translated, is that users require a logical sequence of information that is presented with a minimum of complexity and that is specifically relevant to the particular type of decision required for that choice point.

DISCUSSION OF RESULTS

As previously stated, the purpose of this experiment was to assess the differences in methodology and results obtained in the Berger (1) and Gordon (2) studies of diagrammatic signs. The specific goal was the development of a reliable laboratory method for the evaluation of highway guide signs. We believe that this experiment has accomplished these goals. The analysis of correctness of lane choices demonstrated that the results of the current investigation could be made to match the results of the other two studies depending on the criteria employed. When the effects of employing the different criteria 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 that validity requires an independent field check because the data analyses did differ significantly.

It should be pointed out that we prefer 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 commitments are made. This would seem to be a reasonable alternative to current practices in guide sign decision making.

Again 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 our opinion, the stimuli employed in this study, which were identical to those employed in earlier investigations, were not of a particularly high quality. This is to be expected in pioneering research because of a lack of guidelines. It is anticipated that with more tested and trustworthy methodology, and with a selection of sites that have unexpected visual or geometric components, diagrammatic signs may prove to be beneficial.

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