Diversionary Signing Content and Driver Behavior

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The purpose of this study was to investigate the influence of certain diversionary highway guide sign variables on the driver's ability to process and interpret directional information. The work was conducted under controlled field conditions by using an instrumented vehicle with an in-vehicle sign simulation device. The primary independent variables consisted of message content, message severity, and message redundancy. Driver route choice behavior, information interpretation time, message preference, and interrogative responses concerning route choice decisions were the measured dependent variables in the study. Results indicated that the frequency of bypass choice was related to the severity of the message on the advisory sign and the type of information. Higher severity messages and time delay information were associated with decisions to bypass the main route. The advisory signs used in the study were interpreted as being directive, especially when congestion information was presented. Congestion information was also more familiar to the subjects and was associated with quicker information interpretation time, indicating that decisions were quicker and easier with congestion information.

Advanced forms of electronic surveillance and control systems are currently being developed to optimize traffic flow in and between cities. Variable-message signs constitute an important element in these control systems. The variable-message sign can be used to provide motorists with updated information about prevailing traffic conditions and advise them of an appropriate course of action. In other words, real-time highway information can be communicated to drivers so that they can plan ahead for safer and more efficient travel.

An effective real-time highway information system must be human engineered to ensure that motorists can understand the advisory messages within the time the signs are in view. The success of the system requires that display features such as information content and redundancy be designed as effectively as possible. To achieve this goal, human factors research is now in progress under the Federal Highway Administration's Federally Coordinated Program Project 2-C, Requirements for Alternate Routing to Distribute Traffic Between and Around Cities. The work reported here was conducted as a part of this research.

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METHOD

Subjects

The subjects tested in the study consisted of 60 paid volunteers. They were assigned randomly to three test groups; there was some matching between groups on the basis of age and sex. The mean age of the 31 males and 29 females in the sample was 22.3 years. Each subject possessed a valid driver's license and demonstrated driving competence with the instrumented vehicle before actual roadway tests.

Instrumented Vehicle

An instrumented 1970 Chrysler was used to provide an in-vehicle simulation of highway signs and to record the response and driving performance of drivers under the influence of the experimental signs.

Experimental sign displays in the form of 35-mm color transparencies were projected on a 27 by 9-cm (10.75 by 3.5-in) screen mounted on the inside of the upper right portion of the driver's windshield (Figure 1). The slide projector was mounted on a platform in the back seat behind the driver's right shoulder.

The vehicle's horn button located in the rim of the steering wheel was wired as a special response button. It was used by the subject to terminate sign presentations.

The experimenter's control panel was located in the

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back seat of the vehicle. A control button was used by the experimenter to present the test signs to the subject. A meter readout of accumulated distance values, zeroed at the beginning of the test route, was used to control the location of the sign presentation points along the road.

An on-board audio recorder was used to record verbal responses made by the subject during the test drive and during the debriefing interview.

Test Route

The test route was located on a 15-km (9-mile), four-lane divided section of the Baltimore-Washington Parkway between the Beltsville and Md-175 interchanges. A total of six interchanges were used as experimental diversion decision points on the test route.

All test drives were conducted in the fall and winter of 1974 during daylight off-peak traffic periods under dry pavement conditions. The visual environment along most of the test route was homogeneous in that the highway was continuously bordered by a heavy tree line. Furthermore, the geometrics of the test interchanges were similar, and horizontal curvature was minimal. The first three interchanges were negotiated in the northbound direction, and the last three interchanges were approached from the southbound direction.

Independent Variables

The independent variables were message content, message severity, and message redundancy. The message content variable was represented by three independent groups each of which contained 20 subjects. Message severity and message redundancy were represented by three and two levels respectively.

Dependent Variables and Measures

The dependent variables and measures considered were

1. Route choice behavior. The test subject's route choice at each of the six test interchanges was recorded. Drivers indicated their route choice by actually performing an exiting maneuver or by continuing to drive on the parkway.
2. Information interpretation time (IIT). Subjects were instructed to press the button on the steering wheel rim as soon as they understood the information on the sign. The latency between the onset of the stimulus presentation and the subject's response was recorded to the nearest 0.01 s and was called information interpretation time (IIT).
3. Interrogative responses. As soon as a driver executed his or her decision at a given interchange, he or she was orally interrogated about the reasons for his or her decision. The questions were open ended and attempted to probe into the driver's decision process associated with the route choice.
4. Sign preference. In the debriefing at the conclusion of the test drive, the subjects were shown pictures of signs differing in message content and severity and were asked to rank them according to their preference.

Experimental Signs

Drivers in the study experienced simulated real-time variable-message signs interspersed with simulated standard directional guide signs at six interchanges along the test route. Three types of variable-message content were tested: (a) time delay information, (b) level of congestion information, and (c) incident description information. Table 1 gives a description of the information content displayed on the advisory signs at the six choice points in the experiment.

The physical characteristics of the signs other than those manipulated as independent variables were held constant. Letter style and capitalization conformed to existing freeway and expressway standards as described in the Manual on Uniform Traffic Control Devices (5). Color also conformed to these standards. The place names on the guide signs all had seven letters and referred to locally fictitious places. The advisory sign displays simulated rotating drum signs with four changeable message panels (Figure 2). The messages on the first, second, and fourth panels from the top of the sign were held constant throughout the study. The message on the third panel represented the content variable. The background color was always green for the first and second panels and red for the third and fourth panels. All of the information displays simulated freeway overhead signs. The experimental signing presented at test interchange 2 is also shown in Figure 2. The signs in Figure 2 were tested with the delay time group. Those shown in the offset of Figure 2 were tested with the level of congestion group and incident description group respectively. The variable-message advisory sign was presented to the test driver 2.4 km (1.5 miles) before the interchange. The advance guide sign and exit direction sign were shown 1.6 km and 0.8 km (1 mile and 0.5 mile) respectively before the interchange. The exit sign was presented approximately 150 m (500 ft) before the exit ramp.

At the test interchanges where the advisory sign was presented twice (interchanges 1, 3, and 5), the second advisory sign presentation was positioned between the advance and exit direction guide signs. Otherwise, the rest of the signing in the sequence remained the same.

Procedure

Volunteer subjects reported to a mobile base laboratory located near the beginning of the test route. After the subjects completed a brief biographical questionnaire and were examined for vision defects, they were seated behind the wheel of the instrumented vehicle and read a set of instructions.

After reading the instructions, the experimenter guided the subjects on a practice route to familiarize them with the driving characteristics of the vehicle. The subjects were also given practice with the in-vehicle sign display and the response button on the steering wheel rim. On the practice and test routes, all sign presentations were initiated by the experimenter and were cued by a distance readout meter. Subjects were instructed to press the response button as soon as they understood the information on the sign. As soon as the subjects indicated that they felt confident driving the vehicle and understood the test procedures, their trip on the test route began.

Before entering the ramp to the test route, the subjects were given a fictitious route number for the roadway that they would travel and a fictitious place name for their destination. The advisory and guide sign displays previously described were then presented to the subjects as they traveled the test route. The subjects were instructed to ignore the real guide signs along the test route and to respond to only the signs simulated inside the car. However, they were told to obey all on-road regulatory traffic signs such as speed limit and yield signs. The test route was open to normal traffic operations and the subjects had to cope with driving in real traffic as they carried out their information processing and decision making.

On approaching each of the six test interchanges along the test route, the subjects processed the information on each of the signs and made a decision either to continue on the road on which they were traveling or to exit. Immediately after they either performed the exit maneuver or continued driving through the interchange, the experimenter asked the subjects to state the reasons for their decision and recorded their response on audio tape. A new fictitious destination and a new route number were given to the subjects before each of the six test interchanges. At interchanges where the subjects exited, the experimenter verbally directed them back onto the main route.

After completing the test drive, the subjects were directed back to the base laboratory for a debriefing that assessed their subjective reaction to the experiment, their previous driving experience on the test route, and their preference ranking of the three types of message content studied in the experiment.

RESULTS

Route Choice

Overall, the subjects took the exit to bypass the main route approximately two-thirds of the time. Table 2 gives the frequency of exiting at each of the six interchanges. There was a statistically significant relationship between the level of message severity and the frequency of exiting. Higher levels of severity were associated with higher exit frequencies ($\chi^2 = 102.0$, $p < 0.001$):

Route Choice	Low	Moderate	High	Total
Exit	39	80	114	233
Continue	81	40	6	127
Total	120	120	120	360

Approximately one-third of the route choices under the low message severity condition, two-thirds of the choices

Figure 1. Driver's view of in-vehicle display.

Figure 2. Typical signing presented before an exit.

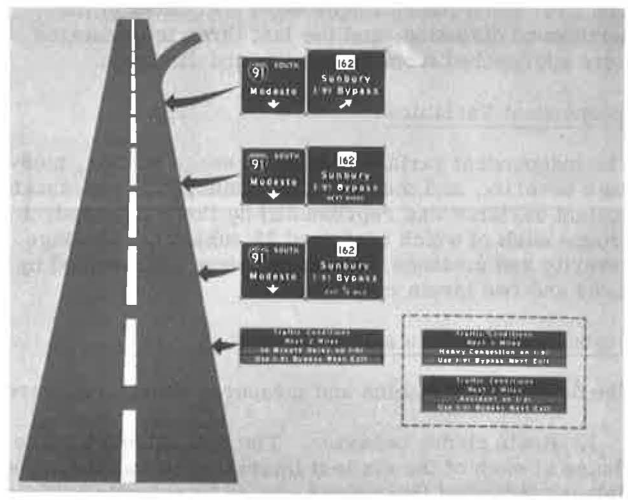


Table 1. Information content on variable-message signs.

Interchange	Time Descriptor: Time Delay (min)	Time Descriptor: Redundancy[a]	Congestion Descriptor: Congestion Level	Congestion Descriptor: Redundancy[a]	Incident Descriptor: Type of Incident	Incident Descriptor: Redundancy[a]
1	20	2	Moderate	2	Disabled vehicle	2
2	30	1	Heavy	1	Truck overturned	1
3	10	2	Light	2	Grass cutting operations	2
4	10	1	Light	1	Slow vehicles	1
5	30	2	Heavy	2	Accident	2
6	20	1	Moderate	1	Men working	1

[a]1 = one variable message advisory sign. 2 = two variable message advisory signs.

Table 2. Frequency of exiting by interchange and advisory sign content.

Interchange	Interchange Variables: Message Severity	Interchange Variables: Redundancy Present	Interchange Variables: Direction of Travel	Number of Exits by Advisory Sign Content: Time	Number of Exits by Advisory Sign Content: Incident	Number of Exits by Advisory Sign Content: Congestion	Total
1	Moderate	Yes	North	17	14	12	43
2	High	No	North	19	17	19	55
3	Low	Yes	North	9	5	3	17
4	Low	No	South	9	8	5	22
5	High	Yes	South	20	19	20	59
6	Moderate	No	South	17	10	10	37

Note: Highest possible number of exits per cell is 20.

under moderate severity, and almost all of the choices under high severity were decisions to exit.

Exit frequency was also significantly affected by type of information contained. More exits were made by those subjects in the time delay group than by those in either the incident or congestion group ($X^2 = 10.02$, $p < 0.01$):

Route Choice	Congestion	Incident	Time	Total
Exit	69	73	91	233
Continue	51	47	29	127
Total	120	120	120	360

Although both type of message content and level of severity had a significant effect on the subject's exiting behavior, a statistical test of the interaction between these two variables failed to show significance ($p \cong 0.4$, X^2).

No apparent differences were found between the frequency of exits made on the first half of the test route and the frequency of exits made on the second half (north and south directions respectively) or the frequency of exits at those interchanges where the advisory sign was repeated (redundancy present) and the frequency of exits at those interchanges where the advisory sign was only presented once.

In general, the results suggest that motorists will exhibit a differential exiting response as a function of diversionary signing message content. The absolute exiting values for the different signing conditions should be considered tenuous because the subject sample was small and made up of college students. However, the relative difference between the conditions may be consistent with the motoring public at large.

Reasons for Decisions

Responses to the open-ended question, What was the reason for your choice? were classified into one of four categories:

1. Estimative. This type of reason involved some sort of expressed quantification or estimate of the amount of delay suggested by the advisory sign.
2. Directive. A directive kind of reason suggested that the information on the sign implied a command to act. No other reason was given.
3. Hypothetical. This category pertained to reasons that derived from subjects' imagining what the situation ahead might be as suggested by the sign. Elements of past experiences were brought to bear.
4. Nonspecific. None of the previous reasons applied.

As might be expected, a significant association was found between the type of reason and the type of route choice (exit from or continue on main route). The following tabulation shows this association ($X^2 = 60.5$, $p = 0.001$):

Route Choice	Hypothetical	Estimative	Directive	Nonspecific	Total
Exit	57	52	119	5	233
Continue	67	35	15	10	127
Total	124	87	134	15	360

Directive reasons were strongly associated with exit choices. Hypothetical reasons, on the other hand, were more associated with choices to continue than with choices to exit. The distribution of choices associated with estimative reasons was similar to the overall distribution of route choices.

A significant relationship was also found between type of reason and type of information. In the following tabulation, one can see that subjects in the incident descriptor group tended to give hypothetical reasons ($X^2 = 76.6$, $p = 0.001$):

Type of Information	Hypothetical	Estimative	Directive	Nonspecific	Total
Congestion	30	21	58	11	120
Incident	71	15	32	2	120
Time	23	51	44	2	120
Total	124	87	134	15	360

Subjects in the congestion level group tended to give directive reasons, and subjects in the time delay group tended to give estimative reasons.

The relatively high proportion of drivers using directive decision reasoning is a particularly interesting finding. Clearly, drivers who gave directive reasons keyed on the bottom line of the advisory sign that said USE I-XX BYPASS NEXT EXIT and interpreted it as a command. This probably accounts for the higher than expected number of exits (39 out of a possible 120) recorded under the low message severity conditions given in the tabulation on levels of severity.

Information Interpretation Time

IIT is the length of time required by the driver to read and interpret the sign information presented on the screen (1). IIT was recorded automatically for each of the 27 signs the subject viewed at the six interchanges on the test route.

Analysis of variance (ANOVA) was used to determine the effects of the independent variables on IIT. A nested, 5-variable factorial analysis was chosen. The independent variables were message content C, subjects nested within content, level of message severity S, direction of travel D, and type of sign T. The levels of each of these variables were 3, 20, 3, 2, and 4 respectively. The variable of direction was interpreted as an indicator of practice effects because the first half of the test occurred on the northbound section of the route and the second half occurred on the southbound section.

Because IIT is a type of response latency measure, the distribution of the scores was positively skewed. A logarithmic transformation of the form $X = \log(x + 1)$ produced approximately normal distributions and was used for the ANOVA. The ANOVA source table is given in Table 3. All the main effects were significant at the 5 percent level of confidence or better. Two-variable interactions that were significant were ST and DT. A significant three-variable interaction was found among S, D, and T. This three-way interaction indicates that one or several individual slides were associated with a substantially higher or lower IIT score across content and subjects.

The untransformed cell means for each level of the main effects are shown in Figure 3. Individual comparisons between the cell means were made by using the Tukey A test, which provided a simultaneous test of all possible differences between the cell means (2, p. 87). For the Tukey test, the means and variances from the transformed IIT values were used. The results of these comparisons are also shown in Figure 3.

Based on the significant comparisons, the following main effect results were found to be significant. Among the three content conditions, the shortest IIT was found with congestion information. Of the three levels of message severity, the shortest IIT was found for high severity. With the main effect of direction, the south portion of the route, which was the last half of the test, was associated with shorter IITs.

Finally, the type of sign had a substantial effect on IIT. Generally, there was a significant decrease in IIT from the advisory sign, the first sign for a particular interchange, to the exit sign, the last sign before the route decision was made. The largest difference between any two adjacent signs was that between the advisory sign and the advance guide sign; the latter always followed the advisory sign and was the first in a series of three guide signs.

The decrease in IIT from the first to the last sign within each interchange could be interpreted as a practice effect. This is probably the case with the three guide signs, which are similar in format and content. However, the large difference between the advisory and the advance guide signs is due to the type of sign rather than to practice. The untransformed mean for the advisory signs was 4.55 s, 1.43 s longer than the mean for the advance guide signs. This is a long IIT for a freeway sign, too long when one considers that, at 88 km/h (55 mph), a motorist will travel 110 m (370 ft) in 4.5 s. Research is currently under way into methods of more quickly conveying the information on the advisory sign to motorists. One method being tested is putting the description of the traffic situation (HEAVY CONGESTION ON I-XX) and the advice on a course of action (USE I-XX BYPASS NEXT EXIT) on separate signs. Another method being tested is conveying the descriptive information with a simulated overhead sign and the advisory information with a radio message.

The influence of content on IIT turned out to be more pervasive than expected. It should be kept in mind that the guide signs remained constant across the main effect of the content. And yet, as shown in Figure 4, the shorter IIT values associated with congestion information were found not only with the advisory but also with the three successive guide signs. This may be an illustration of how an upstream sign can affect the IIT of subsequent signs downstream, a result previously reported by Mast, Chernisky, and Hooper (1). The low IIT mean for the congestion message content group on the advisory sign is consistent with the finding that there was a disproportionately large amount of directive reasoning elicited by congestion level information as shown by the tabulation on type of information. It is reasonable that directive reasoning is associated with faster IIT in comparison with estimative and hypothetical reasoning because more cognitive processing time is involved with the latter two types.

As shown by the data given in Table 3, there were three statistically significant interactions on the IIT measure: (a) level of message severity by type of sign, (b) travel direction by type of sign, and (c) level of message severity by direction of travel by type of sign. These interactions were primarily if not solely due to a longer IIT for a three-panel exit sign located at the third interchange (see Figure 5). The mean IIT for this sign across content and subjects (nested in content) was 3.41 s. The

Table 3. ANOVA source table for IIT.

Source	df	F	Source	df	F
C	2	3.9398[a]	ST	6	14.1609[b]
S	2	10.8401[b]	DT	3	5.7643[b]
D	1	78.0509[b]	CSD	4	0.7042
T	3	345.6453[b]	CST	12	1.0259
CS	4	0.8696	CDT	6	1.3126
CD	2	0.2567	SDT	6	14.5968[b]
SD	2	2.1503	CSDT	12	1.0986
CT	6	1.3506			

[a] $p < 0.05$. [b] $p < 0.01$.

Figure 3. Significant comparisons of IIT means in seconds for ANOVA main effects.

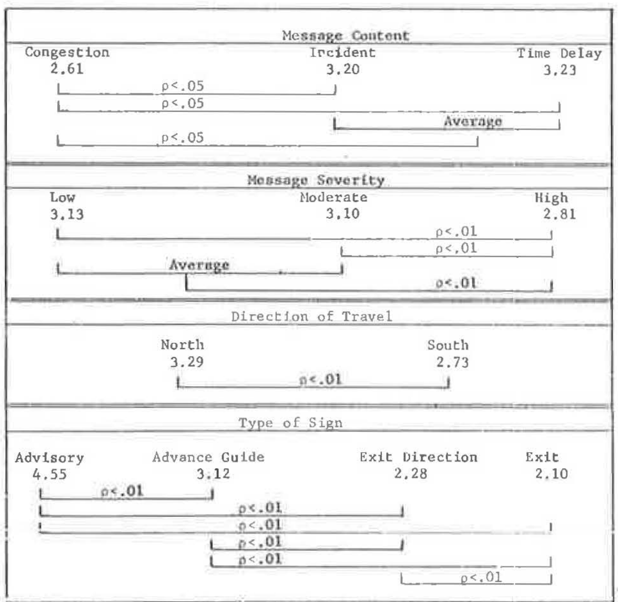


Figure 4. Information interpretation times for each type of sign within each information content group.

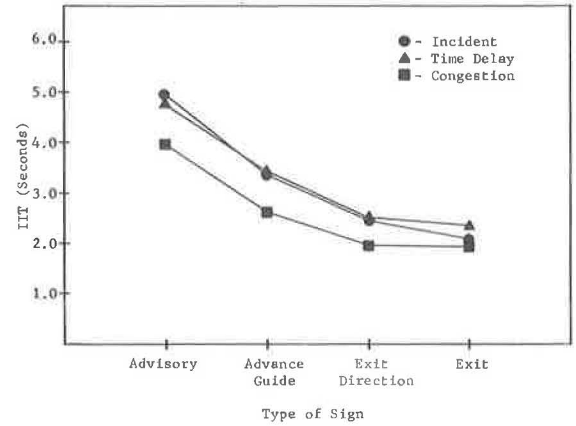
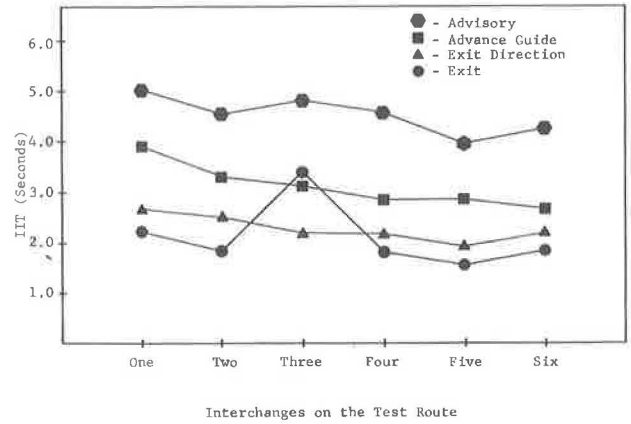


Figure 5. Information interpretation times for each type of sign presented before each interchange.



overall mean for the two-panel exit signs was 1.84 s, which indicates that the additional panel added more than 1 s to the information processing time.

Message Preference

In the debriefing questionnaire, amount of time delay was preferred over congestion or incident information (all values are average preference ranking of message content within a severity level along a scale of 1 to 3 where 1 represents the most preferred type of message):

Type of Information	Message Severity Low	Moderate	High
Time delay	1.3	1.4	1.5
Incident	2.6	2.5	2.2
Congestion	2.0	2.2	2.3

The finding that time delay information is preferred by drivers over incident information is consistent with results reported by Case, Hulbert, and Beers (3) and Beers (4). However, in this study, subjects often qualified their preference for time delay information by indicating that it must be accurate. Level of congestion was the most familiar type of information, which may be another reason why it was associated with shorter IITs. The main disadvantage to congestion information that was reported was that it was subjective. With regard to incident information, the consensus of opinion was that it satisfied the curiosity of the driver but relayed no information about how the particular incident was affecting the flow of traffic.

CONCLUSIONS

This study examined several traffic advisory sign variables that influence the decision whether to take an alternate route around a traffic delay. Three aspects of this type of decision were of primary interest: (a) what the decision was with different types of messages; (b) the reasons for the decisions; and (c) how long it takes to process the information on the signs that, in a sense, set up the decision. The study showed that a bypass route is more often chosen when the advisory signs indicate more serious situations on the primary route, a not surprising finding. The relationship between advisory sign messages and exiting behavior should be checked in an operational setting. If stable results can be validated in the field, they will be an effective guide for the real-time operation of traffic advisory signs.

The reasons that subjects gave for choosing or not choosing the bypass provided valuable insights into this decision process. The last panel on the advisory sign, which said USE I-XX BYPASS NEXT EXIT, was interpreted as a directive message and probably influenced many decisions to exit when the description of the situation hardly warranted bypassing.

Congestion information promoted directive reasoning perhaps because congestion level descriptors offered little objective information about the traffic situation and subjects had to rely on the advice to take the bypass. Time delay information was associated with estimative reasons probably because it provided an objective reference against which the likely delay on a bypass route could be evaluated. The decisions for incident information were often based on hypothetical reasons, which means that the subject made his or her decision based on prior experience. One would expect that there would be more random variation in decisions made on the basis of incident information simply because individual experiences with incidents vary greatly.

The third aspect of the decision process that was evaluated was the time required to process the information setting up the choice. The measure used, IIT, has elements of information processing and decision making and is not simply a function of reading time. The evidence for the decision-making component of IIT derives from the fact that some signs took significantly longer to process than others that, except for a word or two, were identical. Further evidence is indicated from the finding that congestion information, which was most familiar to the subjects and which promoted directive reasons, was associated with a shorter IIT not only with the advisory sign but also with the following guide signs. The guide signs were not changed from one content condition to the next; each presented the choice situation. The conclusion to be drawn is that congestion information promoted quicker and perhaps easier decisions.

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