READING TIME AND ACCURACY OF RESPONSE TO SIMULATED URBAN FREEWAY GUIDE SIGNS

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ABSTRACT

This paper presents the results and sets forth the methodology used in a laboratory study to determine motorists time required to read urban freeway guide signs and the accuracy with which they read the signs. The study was performed using licensed drivers as subjects. The subjects ranging in age from 18 to 79 years were taken along a hypothetical urban freeway route where 2, 3, 4 and 5 panel signs were used. A sign bridge typically has between one and four sign panels which have a green background and a white border around each panel. Each panel will contain one or two route designations, one or more destination cities and additional action messages. Each panel contained either 2, 4, 6, 8 or 10 units of information.

The results of this study indicate that the optimum accuracy level was about 6 units of information per panel. When the information level was less than 16 units, 100% of the subjects could read the signs acceptably, when the level was between 16-30 units, 51% could read the sign acceptably, and when the level was between 31-50 units, only 33% could read the sign acceptably. It is apparent that route selection accuracy decreases as the number of route choices increases. On a large sign (3 or more panels) the information content should not exceed 16 units of information per sign bridge. The time required to read a sign also increases with the number of route choices and total information on the sign.

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Background

Extensive research in the area of sign reading has been performed beginning in the late 1930's and continuing today. These efforts have mainly been concerned with the physical dimensions of the lettering, types of sign, illumination and reflectorization, recognition and effectiveness, message content, and placement in relation to the driver's cone of vision and line of sight. These research efforts have led to the development of standards which apply to alphabets and numerals used on the signs. The Federal Highway Administration (FHWA) has a standard alphabet which dictates the letter series to be used in the design of exit direction signs. The standard alphabet used on overhead exit direction signs is the series-E(M) alphabet. These letters are designed in such a way that they can be seen by a person with 20-20 vision at a distance equal to 60 ft/inch of letter height. This means that if the sign has 15 inch letters, it can be read at 900 feet.

These factors have been related to both lateral and longitudinal sign placement locations. The implication of research in this area for longitudinal sign placement is that an effective sign affords a longer sign reading distance, and maneuvering can be initiated earlier. Hence, the greater the distance at which the sign can be read, the shorter the distance it needs to be placed upstream of decision point.

Forbes and Holmes (1) studied legibility with regards to letter height, width and reflectorization in the laboratory situation. Tests of series B (narrow) and series D (wide) letters were made during daylight and at night. The daylight visibility distance for subjects with 20/40 visual acuity (average) was 33 feet per inch letter height for the B series letters and 50 feet per inch for the D series letters. At night there was a 10-20 percent loss in legibility for both letter series. They also found, that at night, reflectorized letters against a dark background were as legible as floodlighted letters, however, there was a 30-40 percent loss of legibility distance when the signs were lighted by low beams.

Richards (2) reviewed research concerned with visibility of signs during night driving. Night visibility of signs depends on their size, reflectivity and illumination. Reflectorized signs depend on the amount and the angle of illumination for the sign to be most effective with regard to legibility.

Straub and Allen (3) in a laboratory study investigated the effects of vehicle headlight illumination on sign placement. The laboratory studies consisted of several types of reflective signs which were illuminated by a vehicle headlamp. The sign position was changed corresponding to different placement locations on a highway. The level of illumination reflected for each type of sign was determined by using a light meter. For overhead signs, the study showed that heights of five to eight feet above the pavement were more easily read than those higher. For roadside signs it was found that signs should be no more than six feet from the road edge for optimum headlight luminance. The authors found that both beams result in the highest sign luminance between 200-300 feet from the sign.

Allen (4) performed a field study to compare day and night legibility of different types of static highway signs. The subjects were placed in a vehicle traveling on a straight flat section of rural highway in which a test sign had been erected. The sign contained several four-letter words which the subjects were told to read. These same 48 subjects participated in both the day and night observations. The letters were standard series-E with a widened stroke. Letter heights were 8, 12, 15 and 18 inches. These signs were illuminated by a rheostat controlled bank of tungsten lamps placed on the side of the roadway at levels of 0.1, 1.0, 10.0 and 100.0 foot-Lamberts. The findings were that the average daytime legibility distance was about 88 feet per inch of letter height. On the average, optimally illuminated signs (10 foot-Lamberts) were approximately 15 percent less than daylight legibility.

Roberts (5) also studied the effects of roadside placement of signs on legibility distance. He found that if the signs were placed less than 30 feet from the edge of the road, the legibility of the sign was greater than 50 feet per inch of letter height. Signs farther than 30 feet from the edge had a legibility of less than 50 feet per inch of letter height.

Ivey (6) performed a field test of the effects of rain on visibility and the operation of the motor vehicle. The author used four different targets selected to be representative of highway obstacles to determine the visibility distances from inside an automobile during natural rainfall. The simulated rainfall represented 0.5, 1.0, 1.5 and 2.0 inches of rain per hour. This test indicated that object size and contrast with road surfaces were factors having a significant effect on visibility during various levels of rainfall.

Messer (7) performed a controlled field study to determine the legibility distance for words on a matrix changeable message sign. Three four-letter words with 18 inch letter heights were used in the study. All tests were performed during the day and the drivers were not task loaded. The results of the test indicated a mean legibility distance of 46.6 feet per inch of letter height or 830 feet, only slightly less than the 50 feet per inch "rule of thumb" for static signs.

One of the critical elements in motorists usage of urban freeway guide signing is the time they require to read and react to navigational messages presented to them. Surprisingly, there is little literature specifically related to the subject. King (8) presented an analytical analysis of signing in 1970 in which the sign reading literature was summarized. Two equations for determining the time required to read a sign were presented. King pointed out that Mitchell and Forbes recommended using the following equation (1) when the sign contained more than 3 words. One (1.0) second was recommended as the time required to make a single glance. Forbes also stated that an ordinary person can read three or four familiar words during a single glance.

$$t = \frac{N}{3} + 1.0 \qquad (1)$$

Referencing work by the British Road Research Laboratory presents an alternative equation (2) which calculates reading time to determine letter size requirements. This equation is:

$$t = 0.31N + 1.94 \qquad (2)$$

In both of these equations t is the reading time, and N is the number of familiar words on the sign.

Abramson (9) expanded this definition of N to include numerals together with familiar shapes and symbols such as route shields and lane assignment arrows. No experimental evidence for this expanded definition was given. One may conclude that the time required to read a familiar word is assumed to be about 0.31 seconds per word.

As is evidenced by the previous equations, it is generally believed that unfamiliar motorists require more total time to read the information on a sign as more "words" are added to the message. It is assumed in the models that the increase in time is a linear constant with the number of words, although this assumption is questionable. Using King's expanded definition of "N", the reading time required of a 4-panel overhead guide sign might require a total of 14.3 seconds to read, assuming each panel had 10 "words" on it. Personal driving experiences would suggest that 14.3 seconds is an unreasonably long required reading time.

Mourant, et al, (10) used an eye-marker camera to record driver's visual search and scan patterns under three levels of route familiarity (mediated by instructions) and two driving conditions (open driving and steady-state car following). The drivers drove on an expressway route for which they had memorized a set of directions. They were instructed on Trial 1 to read all road signs as a driver who is unfamiliar with the route must do; on Trial 2 to read only those signs necessary; and on Trial 3 to try not to read any signs as the driver who is very familiar with the route does. The results showed that for open driving the visual patterns shifted to the left and down and showed more compactness as a function of trials. In addition, the percent of time spent viewing road signs and the saccadic travel distance to fixations on other traffic, road and lane markers, and bridges and road signs decreased as the driver became more familiar with the route. For car following, the increase in compactness of the visual pattern over trials was pronounced but there was no change in the center of location of the visual pattern. Compared with open driving, the travel distances for car following were greater when looking ahead and at bridges, road signs and other vehicles. However, drivers in the car-following condition spent less time reading road signs, indicating that they used the lead car as an aid for route guidance. Possible visual aids for decreasing the driver's visual workload under today's driving conditions were discussed.

Bhise and Rockwell (11) conducted a study to develop a methodology to evaluate signs by determining the degree of "match" between the characteristics of the sign, the abilities of the driver and other components of the highway such as traffic and road geometrics. An eye-marker camera was used to obtain data on driver eye movements while reading 400 Interstate highway signs. The authors employed both laboratory and field studies to obtain the required data. By use of the eye marker-camera it was determined that the drivers eyes do not continually sample information but make successive discrete "fixations". A driver acquires information only during a fixation which is between 100 and 600 msec. in length. For the information to be available to the driver, it must be resolvable. A computer program SEADEN (Sign Evaluation by Analysis of Driver Eye Movements) was developed to determine the eye fixation that provides resolvable information about the sign to the driver using eye-movement data, roadway geometry, velocity profile and path, sign characteristics and visual acuity. The computer program also computed various time distance relationships concerning the resolvability of the information on the sign.

The results indicated that the drivers first obtained this resolvable information from the awareness of the legibility of the maximum-sized letters. When the ratio between the distances at which the sign becomes legible and the distances of the drivers first fixation is 1.0 then the driver acquires information as soon as the sign becomes visible. This ratio decreases when the drivers visual load increases. When there is a sequence of signs the driver spends more time in acquiring information on the first and last sign. As the driver becomes more familiar with the sign he requires less time to obtain the information, and the driver time-shares between the sign and the road while obtaining the information. The author also found that when drivers were searching for the mileage to a given destination, it required between 1.6 and 2.2 seconds when there was between 2 and 4 words on the sign and between 2.2 and 2.3 when the information load increased from 4 to 10 words present. When the driver was searching for a particular destination which was presented on the sign they required between 1.7 and 2.2 seconds for 2-4 words and 2.2 to 2.4 seconds for 4-10 words, and when the driver was searching for a destination not presented on the sign, the driver required between 1.65 and 2.6 seconds for 2-4 words and from 2.6 to 2.9 seconds for 4-10 words per sign. These studies indicate that various researchers have done some studies in the area of information loading, however, a great deal more needs to be accomplished. It is not only sufficient to know how a driver acquires the information and the time and distance required. It still remains to be determined at what information level does the driver become so inundated with information that he cannot possibly acquire it and therefore starts making errors in his control and navigation tasks of driving. This research will focus on that problem.

RESEARCH OBJECTIVES

The objectives of this study were: (1) to determine the time required to find and read the correct test sign panel (that sign which gives the subjects information about their destination) embedded on a simulated urban freeway sign bridge structure, and (2) to determine the accuracy of the selection process as related to sign design (information presented) and reading time. The research objectives were addressed in a laboratory environment using licensed drivers as test subjects. The responses of these subjects to 35 mm slides of signs projected on a screen were recorded and evaluated.

STUDY VARIABLES

The specific magnitudes and variables studied during this phase of the research effort were as follows: (a) the number of panels per overhead sign structure (2, 3, 4 and 5 panels), (b) the number of "units" of information on each panel (2, 4, 6, 8 and 10 units), (c) the display time available for subjects to "read" the signs (2½, 4 and 6 seconds), and (d) the percent of the subjects giving the correct response. A discussion of these variables follows.

Number of Panels

The number of panels selected for study includes almost all likely overhead sign designs. Most overhead guide signs in large cities have 3 or 4 sign panels per sign structure. A very few signs have 5 panels on them. In the fringe areas of cities and in smaller cities and towns, 2 and 3 panel signs are more common. A typical sign panel has a green background (route guidance information) and a white margin around it and usually contains an exit number, route number, cardinal direction, two destinations, and an exit direction for a total of 6 "units" of information. Sign panels having up to 10 units of information have been observed at major interchanges.

Units of Information

The following list illustrates what is defined in this study as a unit of information:

- place name (Denver)
- street name (Lamar St.)
- route number (I-95)
- cardinal direction (North)
- exit number (Exit 243A)
- command (Exit)
- distance (1/2 mile)
- lane use arrows (↓)
- junction (Jct)
- Exit Only

Some differences of opinion and need for discretion are to be expected in applying these measures. For example, all lane use arrows to the same destination are counted as one unit of information. Some complex traffic facility names, particularly freeways (like Central Expressway or Santa Barbara Freeway) may be considered two (2) units of information because of their size and possible confusion with a destination city.

The sign presented in Figure 1 illustrates a simulated sign used in this study having 3 panels per sign structure with 4 "units of information" per panel. One should keep in mind that information rates in reality are only those messages which are needed and evaluated by the driver and may not be accurately reflected by the total content of all the words, numerals and symbols on a sign.

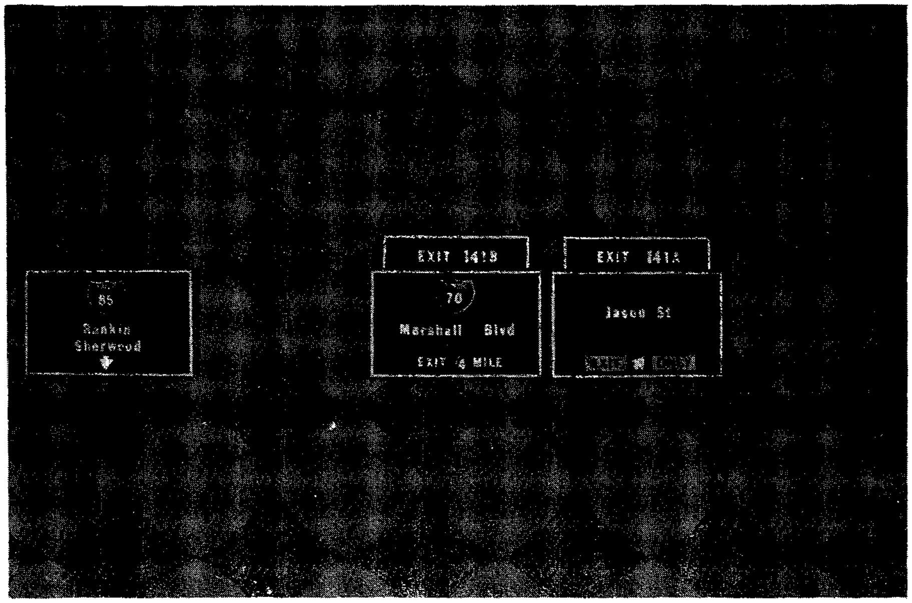

Figure 1. 3 Panel 4 Units Per Panel Test Sign.

Display Time

The projection or display times of the slides of the signs in the laboratory simulated the total time a motorist may have available to read freeway guide signs in a typical urban freeway traffic environment. The reading time is only a portion of the total time that the sign is visible. It is also less than the total static legibility distance (or time), which is less than the visibility distance (or time). The reason for this latter reduction is that motorists must time-share reading signs with the other driving tasks such as lane tracking and avoiding adjacent traffic. In addition, the last 150 feet or so immediately in advance of the sign is likely to be difficult to read due to the large vertical angle and relative motion of the sign with respect to the driver's visual scene.

The display times provided for reading the signs in the laboratory were selected to represent extreme, minimum and desirable traffic (and design) conditions. High-quality guide signs are readable for most people in the absence of obstructions, beginning about 900 feet away, or about 11 seconds of lead time. Deducting 2 seconds for clearance of the sign and 50% of the remaining time as required for conducting other driving tasks leaves 4.5 seconds available for sign reading. From a conservative design viewpoint, it would be desirable to provide freeway motorists with perhaps 6 seconds of unobstructed reading time in an unloaded driving task condition for each overhead freeway guide sign. The motorists would take a portion of that time (perhaps 4 seconds) to select the appropriate sign panel by locating and reading the route number, cardinal direction and destination. Some additional confirmation time might be allowed. A minimum acceptable design criterion might assume that the overhead guide signs were readable for at least 4 seconds, reflecting higher traffic congestion, more critical alignments, and higher probabilities for vehicle blockage of the signs. As the previous calculations showed, the laboratory display times of 2½, 4 and 6 seconds seem to reasonably reflect extreme (unacceptable), minimum (acceptable), and desirable available reading times.

Accuracy

Accuracy of subject responses (selection of the proper sign panel giving destination information) was measured in addition to reading times. The percent correct response based on the total laboratory subject population was determined for each test condition. It was expected that as the total information load increased and as the display time decreased for the same level of experience, accuracy levels would drop. An uninformed (or first-try) accuracy rate of 85% was arbitrarily selected as the minimum acceptable accuracy level.

RESEARCH METHODOLOGY

Two similar laboratory studies were conducted in an effort to accomplish the study objectives. In both studies, laboratory subjects were asked to follow a hypothetical route through an unfamiliar city based on: (1) navigational directions provided by a schematic map of the area and (2) simulated guide signing presented by 35 mm slides at 22 locations along the route. A total of 87 subjects participated in the first laboratory study. The second study, conducted one year later contained 70 subjects taken primarily from the same subject pool. The subjects ranged in age from 18 to 79 years with a medium age of 34 years. Approximately 60% were male and 40% were female. We were not controlling for visual acuity and we wanted a representative sample of the driving public. We did not determine the visual acuity for all of the subjects. A discussion of the components of the research methodology follows.

Trip Scenarios

Subjects approached the city of "Denver" from the southwest on the I-50 freeway. They were then directed to follow the south loop around the city, and then were directed to take I-25 freeway to Omaha. The subjects were advised of their trip before testing began. The loop route was selected to maximize the number of interchanges that could be conveniently studied.

A set of 22 test signs having preselected design attributes was developed for testing as the subjects "drove" along the route. The 22 signs were composed of 4 types of panels by 5 levels of information unit rates (or 20 test signs) plus duplicates of the 4x10 and 5x10 panels. An artist developed the test signs following the style (to some extent) of overhead freeway guide signs found in the urban centers of Texas. Photographs of the simulated signs were taken and converted into 35mm 2x2 inch slides. One example of the 22 test signs was presented in Figure 1. The colors of the various sign elements were as close to the correct colors as could be obtained. The background for all the signs was sky blue.

The laboratory scenarios called for the slides to be projected in a sequence consistent with the simulated trip. The slides were projected upon a built-in wall screen in the laboratory using rear projection techniques. Viewing conditions and legibility of the signs shown to the subjects were controlled to approximate the average legibility requirements of signs on freeways. The design, placement and display of the test signs along the route were selected such that large differences between the amount of information on each sign were not placed on consecutive locations. One practice slide was provided at the start of the trip to acquaint the subjects with the laboratory testing procedure. Map slides, similar to Figure 2 but showing the present location of the trip, were alternated between the 22 test signs so that the subjects hopefully knew the information needed to navigate along the route. These slides were presented for two seconds and then advanced to the next test slide.

The subjects were asked to select that sign panel which provided information to the final destination from the set of panels on the sign bridge. It was assumed, and stated in the laboratory, that the sign panels would be placed immediately overhead of the corresponding freeway lane to drive in. The lane (or sign) number selected was given in the slides for each panel. At the bottom of each sign panel a number representing that panels position on the bridge was printed on the slide.

Some subjects may have been confused in a few cases where the signing sequence (from the left) did not correspond to the lane assignments. For example, the first sign from the left may have been over lane 2 and the associated sign panel number would have been 2. To aid the subjects the relative positions of sign panels over specific lanes were consistently maintained throughout the study.

Measurements

Estimates of subject reading times of the signs were obtained from electronically timed measurements of the time the slide became visible (human operator input) until the time each subject activated his recorder

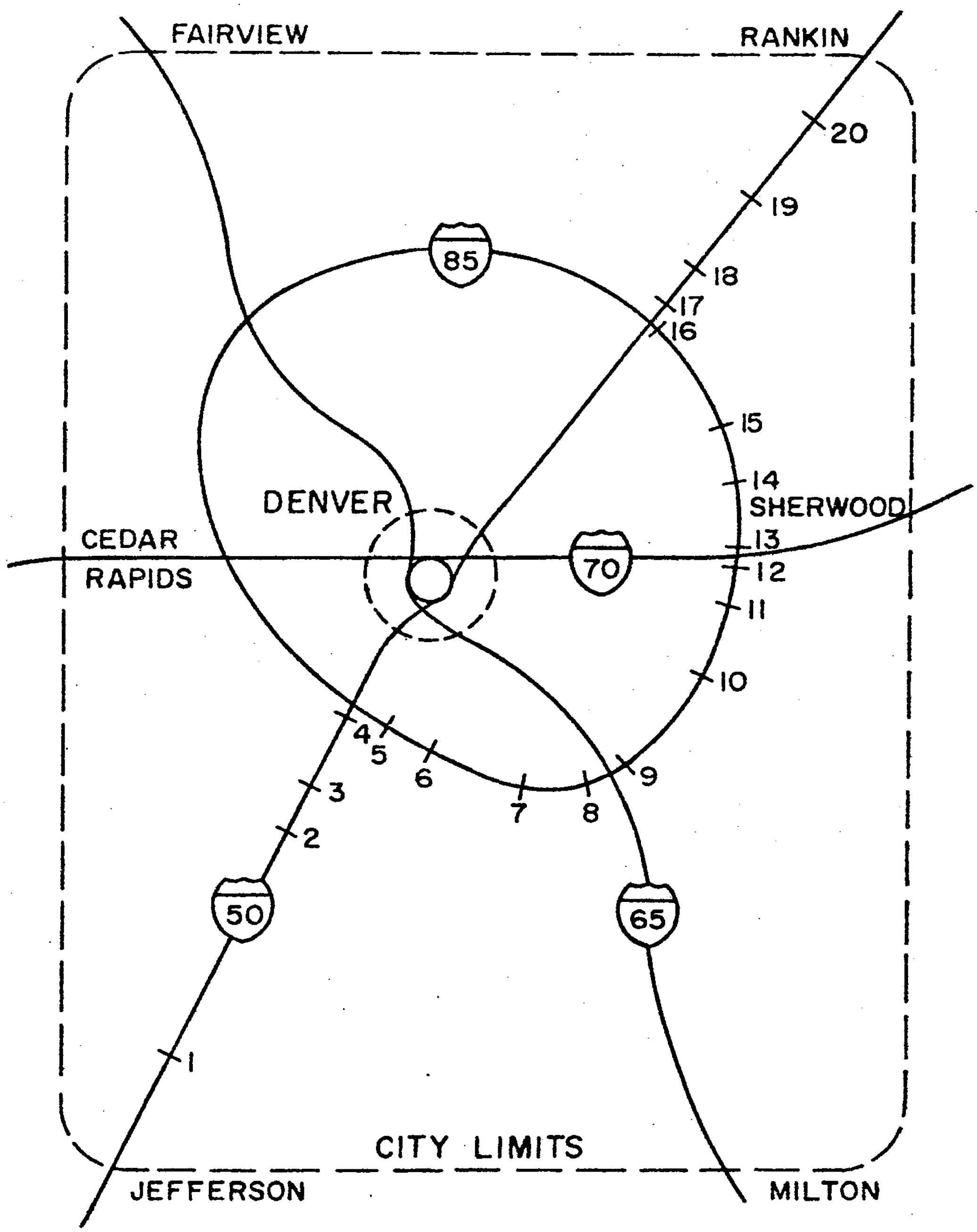

Figure 2. Map of Hypothetical City and Route Used in the Sign Reading Study.

unit. A student responder was used in the laboratory study for the subjects to indicate which sign panel contained the information he needed to follow his route. There were five (5) buttons located on this responder corresponding to the five possible positions for the sign panels. Under each sign panel was a number, and this number was then entered into the responder system by each subject if that panel contained the required information. A recorder was at a master console at the back of the room recording the number entered by each subject. One of five numbered buttons could be selected with the correct choice varying with each test sign. Subjects were asked to respond as soon as they were confident of their lane assignment answer by pushing the corresponding numbered button on their data recording unit. The accuracy of each response was also recorded for each subject. A maximum of five subjects could be tested at one time.

The subjects' average reaction time to a zero-level information sign was developed such that this reaction time could be subtracted from the overall response times so that the reading time could be estimated. The zero-level information slides were slides having distinct red background with the message "Push Button No. 1" on them. The subjects were shown one of the slides prior to the testing, were informed of its purpose, and permitted to practice responding to it one time. The subjects were told that four of these slides would be randomly distributed through their trip, and to respond to it accordingly. From these signs, it was determined that an average subject population reaction time of 1.0 seconds existed. This time was subtracted from all measured response times to determine sign "reading times".

Test Sequence

The 6 and 4 seconds display times were tested in the laboratory during March 1978. The sequence of projection times began with 6 seconds and the subjects "drove" the trip not knowing that, after a 10 minute break, the trip would be redriven using the same set of signs but displayed at 4 seconds. This procedure did result in some learning effect and improvement in response skill due to the previous experience. This was as expected since the repeat test was conceptualized as a simulation scenario of semi-familiar urban freeway motorists who are experienced with the types and locations of decisions required.

The 2½ second rate was a test to see how the same subjects would perform under anticipated and expected high-stress levels. This study was conducted one year after the previous tests. Some 8 improvements to the original 22 signs were made to improve route following and were used during all three (2½, 4 and 6 seconds) display time tests. Some of these signs were creating biased results due to the location of the sign, the complexity of the sign, or the location of the sign panel on the bridge.

RESULTS

The results of the 6, 4 and 2½ second display times are presented in the following paragraphs. The results show that the faster the display time, the faster the subjects responded. The results also show that, in general, the greater the information load, the slower the reading time. It is also important to note that the faster the display rate of the greater the information load on a sign, the lower the percent correct response. Most anomalies in the results to follow can be explained by either the simplicity or complexity of determining the correct sign panel (and lane) of a particular sign as tested in the laboratory. The subjects were told to select the sign which presented the information to their destination and then respond. They were not required to respond in a set length of time, therefore, the traditional speed-accuracy trade-off did not take place. However, after the test slide was removed from the subjects the longer it took to respond the less accurate the response would be.

Display Time of 6 Seconds

A summary of the results for the 6 second display time, as presented in Figures 3 and 4, shows that the median (50%-ile) reading time was 2.9 seconds and the 85%-ile was 4.6 seconds. The average percent of correct responses is 75% for 84 usable subjects. Some of the subjects did not answer within a reasonable time as compared to the other subjects. Therefore not to bias the time data we proceeded to the next situation. Those subjects responses we did not take into consideration when determining the reaction time or the accuracy of the responses.

There are some important trends to be noted resulting from this study. As the amount of information units per sign panel (and total on the sign structure) increased, increased reading times and decreased accuracy levels generally were the result. These inverse trends are interrelated as the following comparisons show. The average values of the 50%-ile reading times and 85%-ile accuracy levels for all 2-panel signs, are 2.2 seconds and 89%, respectively. On the other hand, the average values of the 50%-ile reading times and 85%-ile accuracy levels for all 5-panel signs are 3.3 seconds and 70%, respectively. Assuming 80%-ile correct response is selected as the minimum acceptable value, then 4 of 5 of the 2-panel signs would be acceptable,

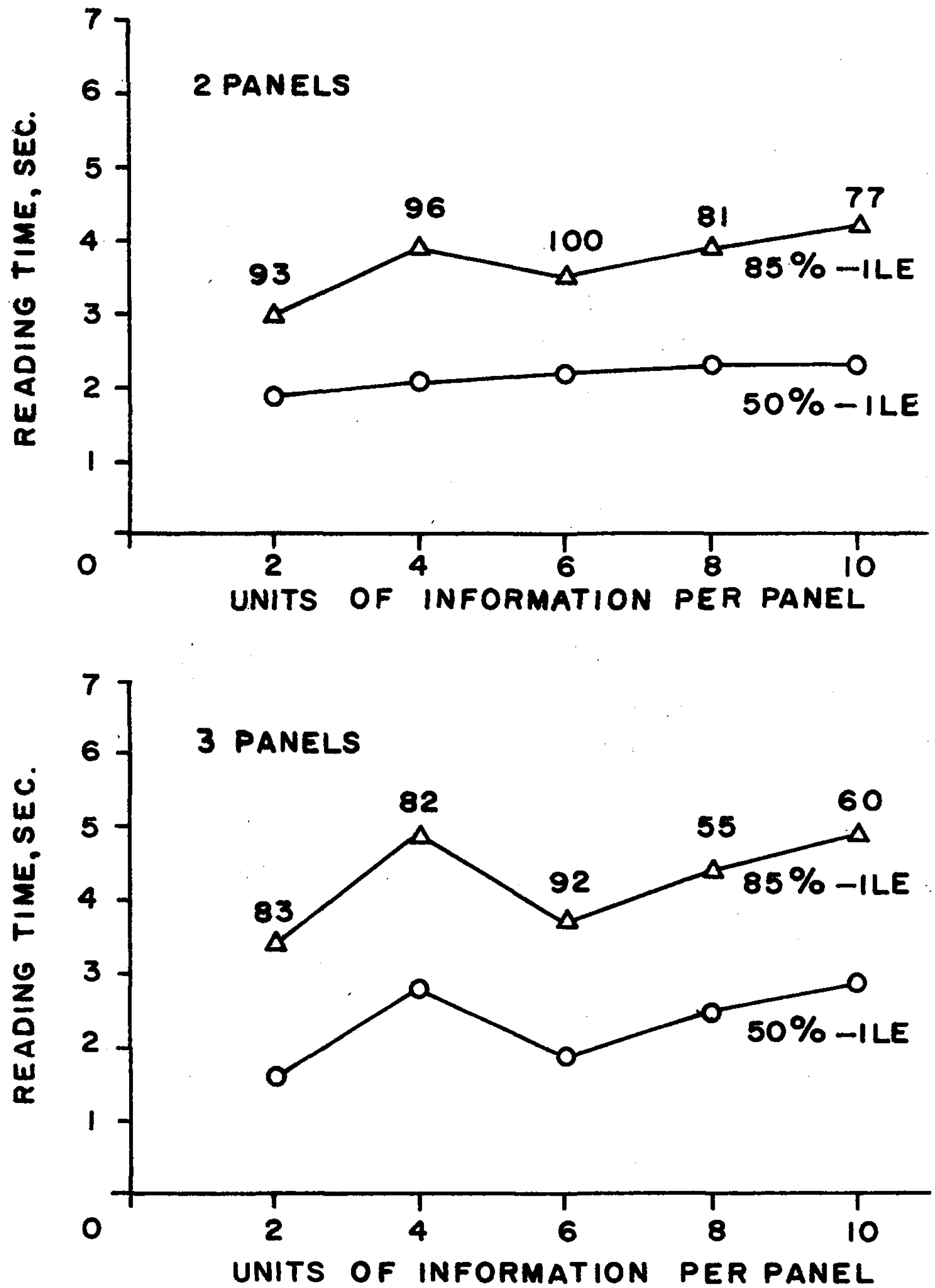

Figure 3. Reading Times and Percent Correct Responses for 2 Panel and 3 Panel Signs at 6 Second Display Times.

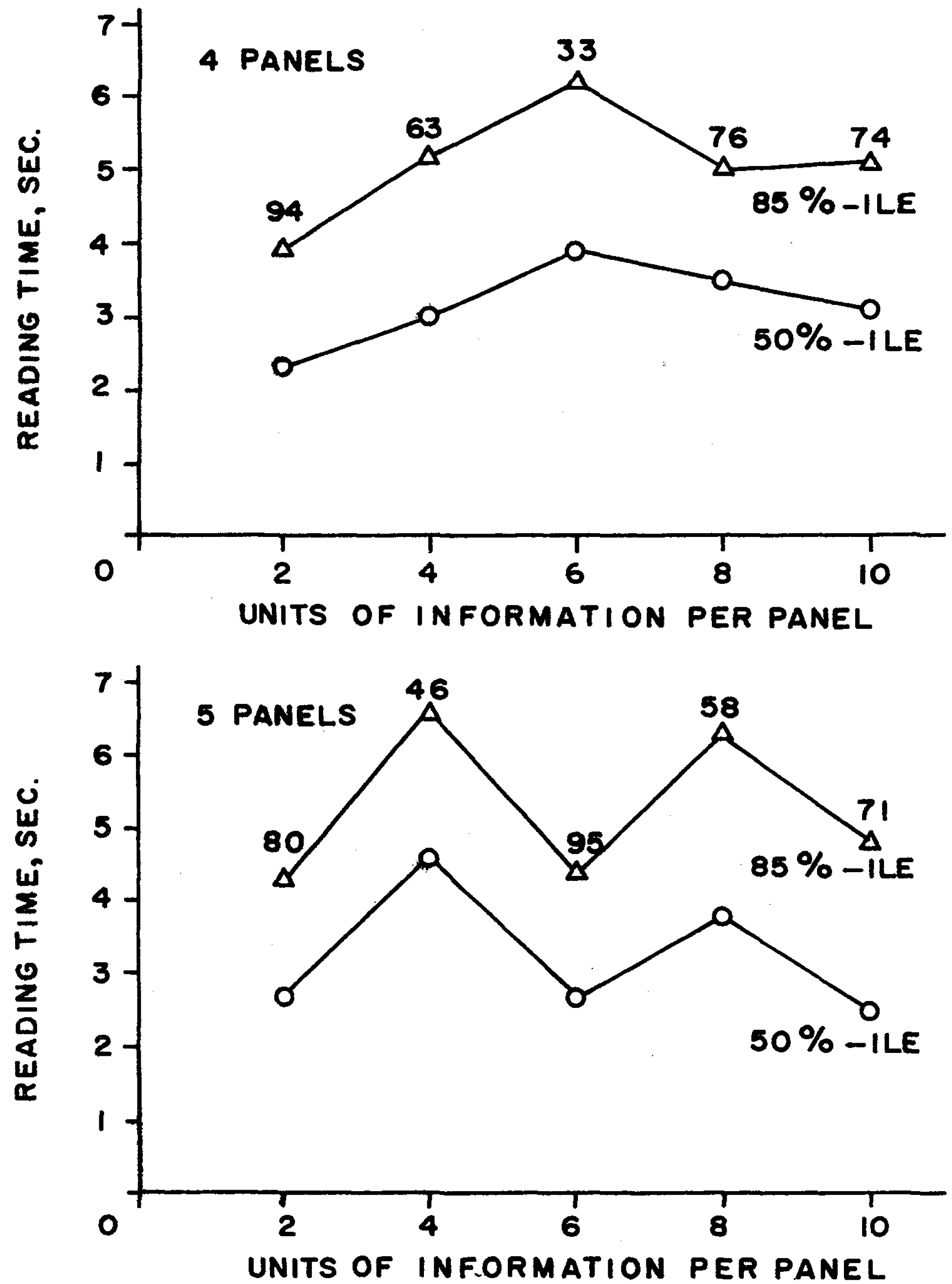

Figure 4. Reading Times and Percent Correct Responses for 4 Panel and 5 Panel Signs at 6 Second Display Times.

whereas only 1 of 5 of the 5-panel signs would be acceptable. The 6 unit 3 panel and 5 panel signs were selected very accurately and with unusual speed, as a result of the location during the trip scenario. The location of the test signs were randomly selected resulting in a certain amount of bias in the results. This was also the cause of the very poor accuracy rate of the 6 unit 4 panel sign. These were 3 of the 8 changes made in the signs before the start of the second study as described on page 13.

Display Time of 4 Seconds

The 4 second display test was a repeat of the same 22 signs used in the 6 second study. As noted previously, a break of about 10 minutes separated the two simulated trips. The subjects were given no advance clues that the second study was going to be a repeat of the first run. Some learning effects and skills improvement were expected. The reason for the repeat lab was that it might more readily simulate a semi-familiar motorist, who has driven the facility in the recent past.

A summary of the 4 second display test as presented in Figures 5 and 6. The median (50%-ile) reading time was determined to be 2.0 seconds, the average 2.3 seconds, and the 85%-ile 3.5 seconds. A mean percent correct response of 78% was obtained for 84 usable subjects. This is a 3% increase above the intitial run and illustrates the subject improvement due to learning and experience.

The inverse relationship between reading time and accuracy continued with the 4 second display experiment. For example, the average values of the reading times for all 2-panel and 5-panel signs were 1.7 and 2.3 seconds, respectively. That is, reading times increased with increasing information

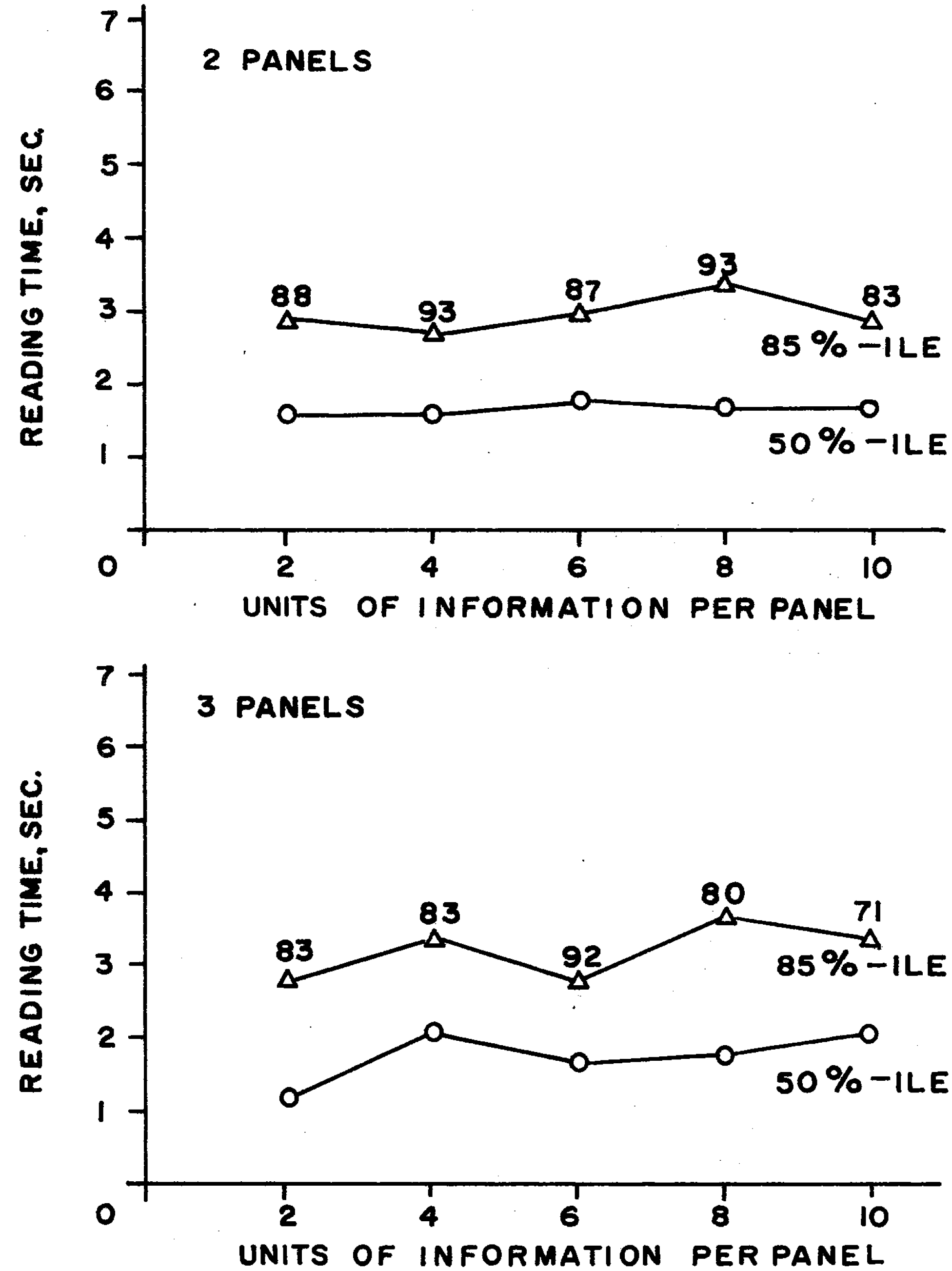

Figure 5. Reading Times and Percent Correct Responses for 2 Panel and 3 Panel Signs at 4 Second Display Times.

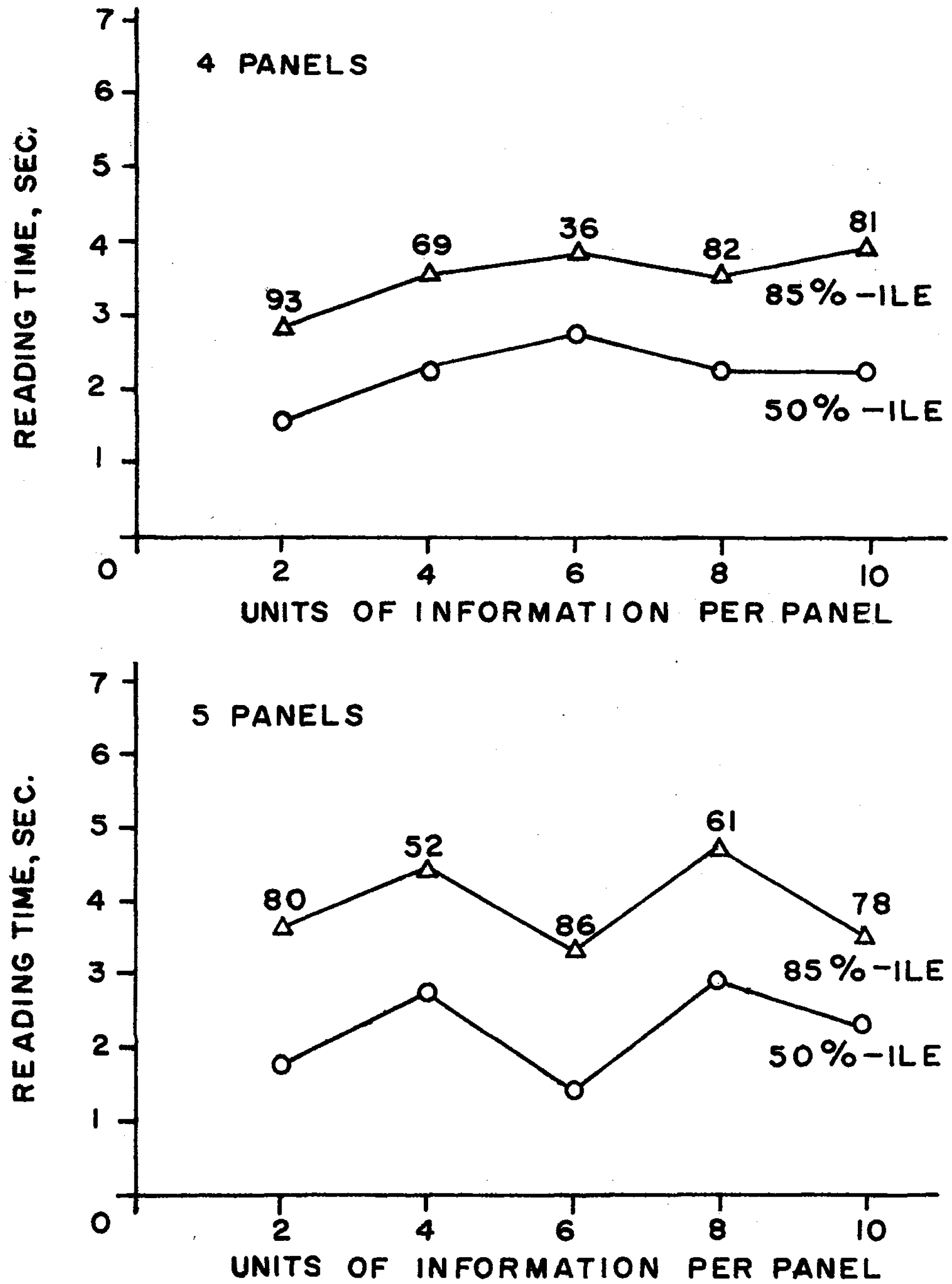

Figure 6. Reading Times and Percent Correct Responses for 4 Panel and 5 Panel Signs at 4 Second Display Times.

load. The respective accuracy levels, on the other hand, decreased from 89% to 71%. Again using 80% as a minimum acceptable accuracy level, then all 5 of the 2-panel signs performed acceptably. Only 2 of the 5 5-panel signs had acceptable accuracy levels.

Display Time of 2½ Seconds

The 2½ second display time laboratory was conducted one year after the previous two studies. Of a total of 70 subjects, 67 usable subject responses were evaluated. Some improvements to the design of 8 of the initial 22 test signs were made in addition to rearranging the test sequence for several of the modified test signs to improve the logic of the signing sequence. As will be shown later, these modifications produced significant improvements in route selection accuracy and clouded the aggregate accuracy results.

A summary of the 2½ second display test results are presented in Figures 7 and 8. The median (50%-ile) reading time was calculated to be 1.7 seconds, the mean 1.8 seconds, and the 85%-ile 2.8 seconds. An average percent correct response of 78% was determined for 67 usable subjects.

The inverse relationship between reading time and accuracy level continued to be observed in this subsequent experiment. The average of the 50%-ile reading times was determined to be 1.7 seconds for all 2-panel signs and 1.9 seconds for all 5-panel signs. The average percent correct response for all 2-panel signs had accuracy levels above 80%. However, only 2 of 5 5-panel signs performed acceptably.

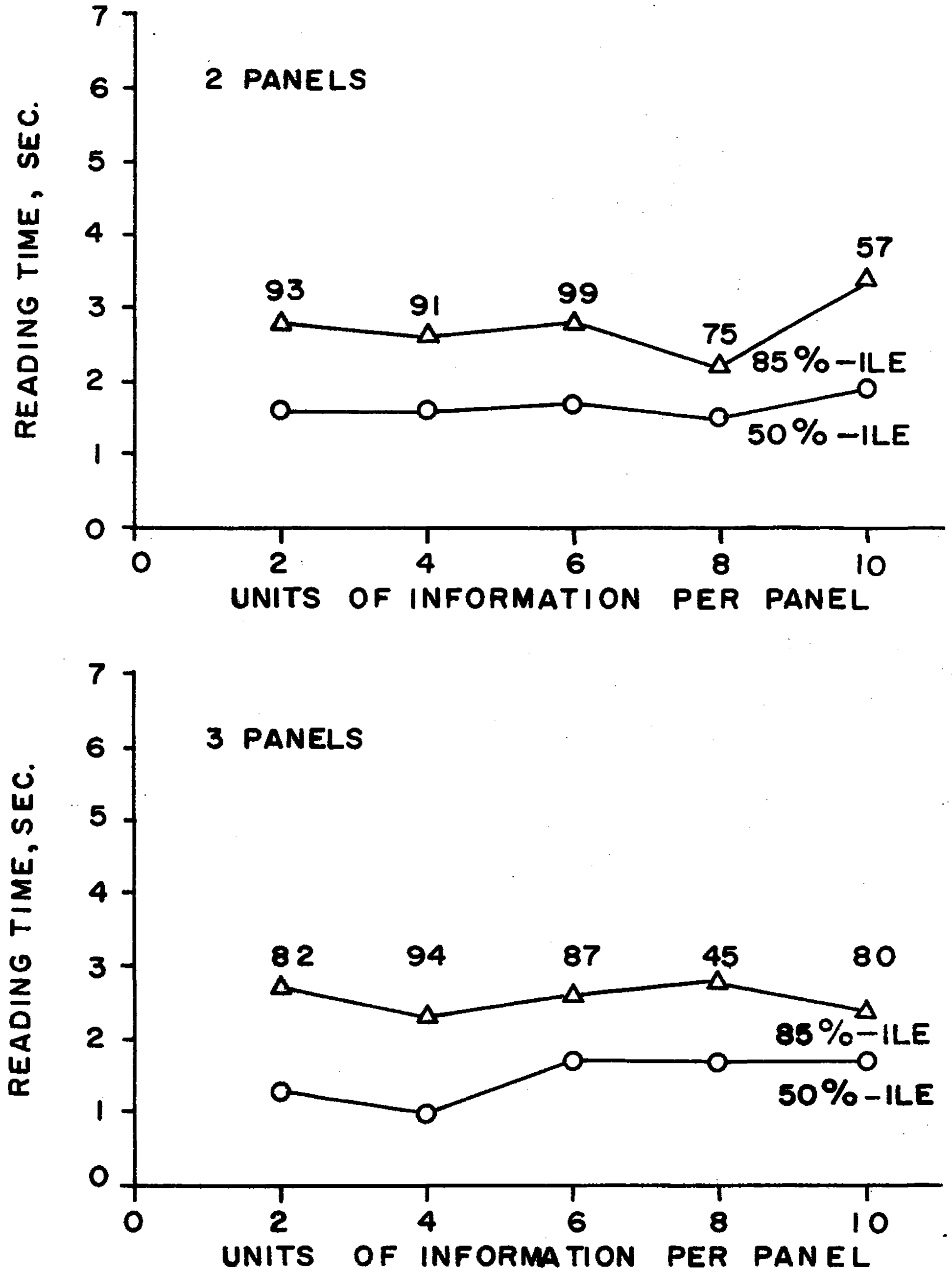

Figure 7. Reading Times and Percent Correct Responses for 2 Panel and 3 Panel Signs at 2½ Second Display Times.

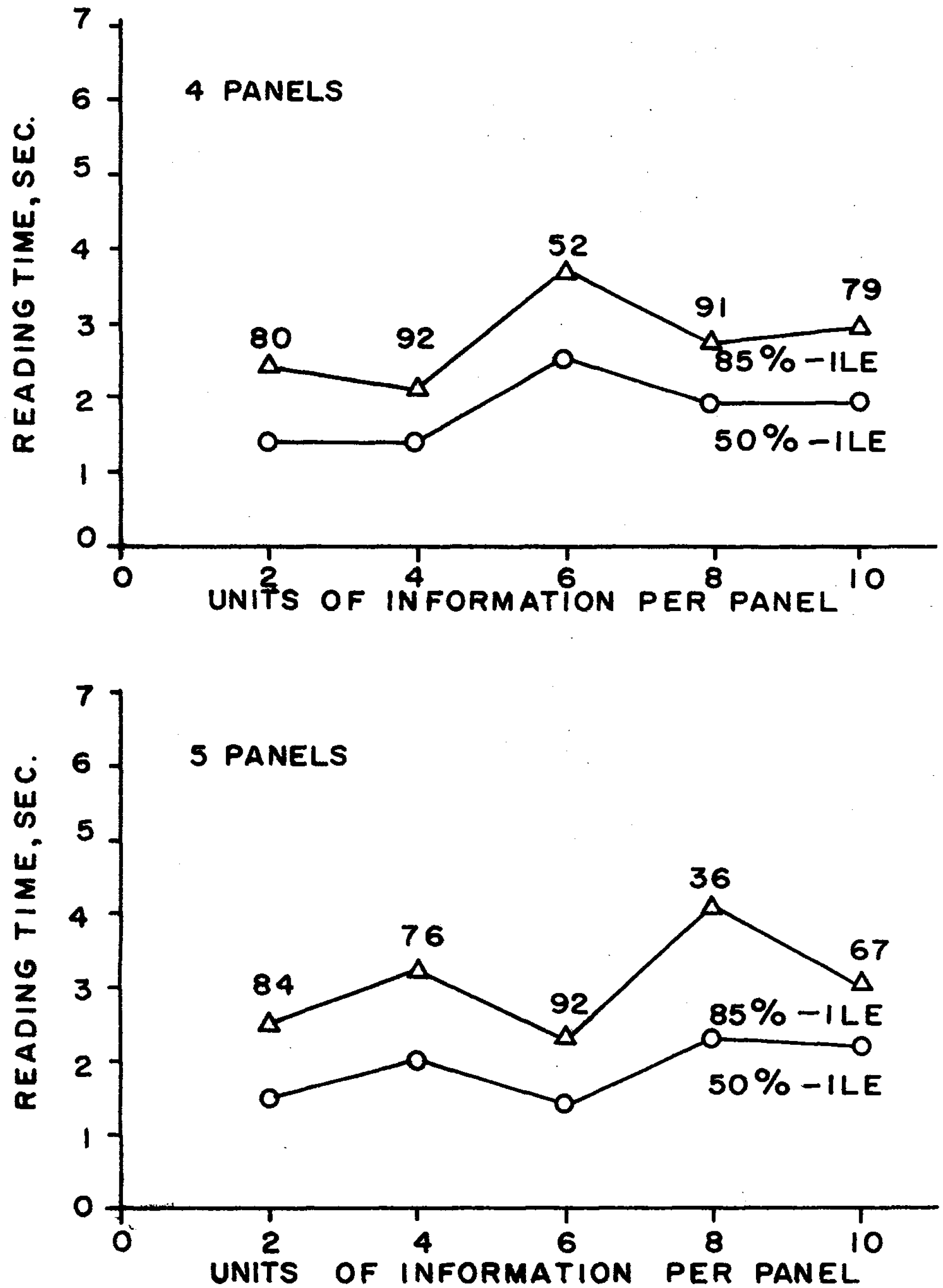

Figure 8. Reading Times and Percent Correct Responses for 4 Panel and 5 Panel Signs at 2½ Second Display Times.

DISCUSSION OF RESULTS

A discussion of the results of the three display time experiments follows. Comparisons will be made from among the accuracy and reading time results. Useful research findings will be drawn from these comparisons and analyses.

Accuracy

The ability of the laboratory subjects to select the correct sign panel was found to depend on several variables; namely, total units of information on the sign, display time and experience. Sign modifications also were found to impact the accuracy results.

Information. A summary of the average percent correct responses results by the sign information test variables - number of sign panels per sign structure and information units per test panel - are presented in Table 1. At the outset, the sign modification impacts between the 6 second and 2½ second display rates should be noted from Table 1. Of the 14 test signs not modified, 11 of them showed reductions in accuracy levels, 1 was unchanged, and 3 experienced slight accuracy increases. The mean percent correct response of the data set dropped 5 percentage points on the average from 82% to 77%. Of the 8 signs that were modified, all 8 showed increases in percent correct response. These 8 modified signs accuracy levels increased 13 percentage points from 64% to 77%. While there was no objective originally to suboptimize the sign designs, these findings do show that suboptimal sign designs can be significantly improved.

If it is assumed that the 6, 4 and 2½ second display test results represent samples of existing sign designs, reading requirements and representative driver experiences for design evaluation purposes, then the results of the 66 tests (3 display rates by 22 test signs) may be pooled to analyze

TABLE 1. SUMMARY OF AVERAGE PERCENT CORRECT RESPONSES BY NUMBER OF PANELS AND INFORMATION PER PANEL.

Information Per Panel (units)	Display Rate (seconds)	Number of Panels Per Sign 2	3	4	5
2	6	93	83	94	80
	4	88	83	93	80
	2½	83	82	80	84
	Mean	91	83	89	81
4	6	96	82	63	46
	4	93	83	69	52
	2½	91	94*	92*	76*
	Mean	93	86	75	58
6	6	100	92	33	95
	4	87	92	36	86
	2½	99	92	52*	92
	Mean	95	90	40	91
8	6	81	55	76	58
	4	93	80	82	61
	2½	75	45	91*	36
	Mean	83	60	83	52
10	6	77	60	82,65	71,70
	4	83	71	88,75	83,73
	2½	57	80*	81,78	55*,79*
	Mean	72	70	78	72

* Modified before 2½ second laboratory.

combined accuracy results. The following analyses are conducted under this assumption.

The pooled accuracy results of Table 1 suggest that 6 units of information per panel is about optimum recognizing that 2 units is not a practical value. This conclusion is drawn from a consideration of the average accuracy levels of the 2, 4, 6, 8 and 10 unit signs in Table 1, (i.e., 86, 78, 79, 70 and 73%, respectively). It can also be determined from Table 1 that the average percent correct response decreased with increasing number of panels and with total information load I, where I is the product of number of panels, P, by average number of units of information per panel B, or $I = P \times B$. The average percent correct response for 2, 3, 4 and 5-panel signs in Table 1 is 87, 78, 73 and 71%, respectively. The average percent correct response for I-levels of 8, 12, 16, 24 and 40 units of information is calculated from the average of two cells for each I-level to be 91, 91, 79, 51 and 65%, respectively.

An analysis of the 66 individual data points from the three display time experiments further reveals the reduction in accuracy rates with increasing total information levels on a sign. From Table 1, it can be determined that all 21 test signs having I-levels of 12 units or less had accuracy levels of 80% correct or better. Again, 80% correct response is assumed to be the minimum acceptable level per test for this laboratory. These results are reflected by the upper curve in Figure 9. This curve shows the percent of all data points (i, p) having $i \leq I$ which also have accuracy levels $p \geq 85\%$. Ninety percent (90%) - 27 of 30 - of all samples having I-levels for 18 units or less had accuracy levels of 80% or more. Only 78% (28 of 36) performed acceptably. Over the complete data set, 41 of 66 (or 62%) of

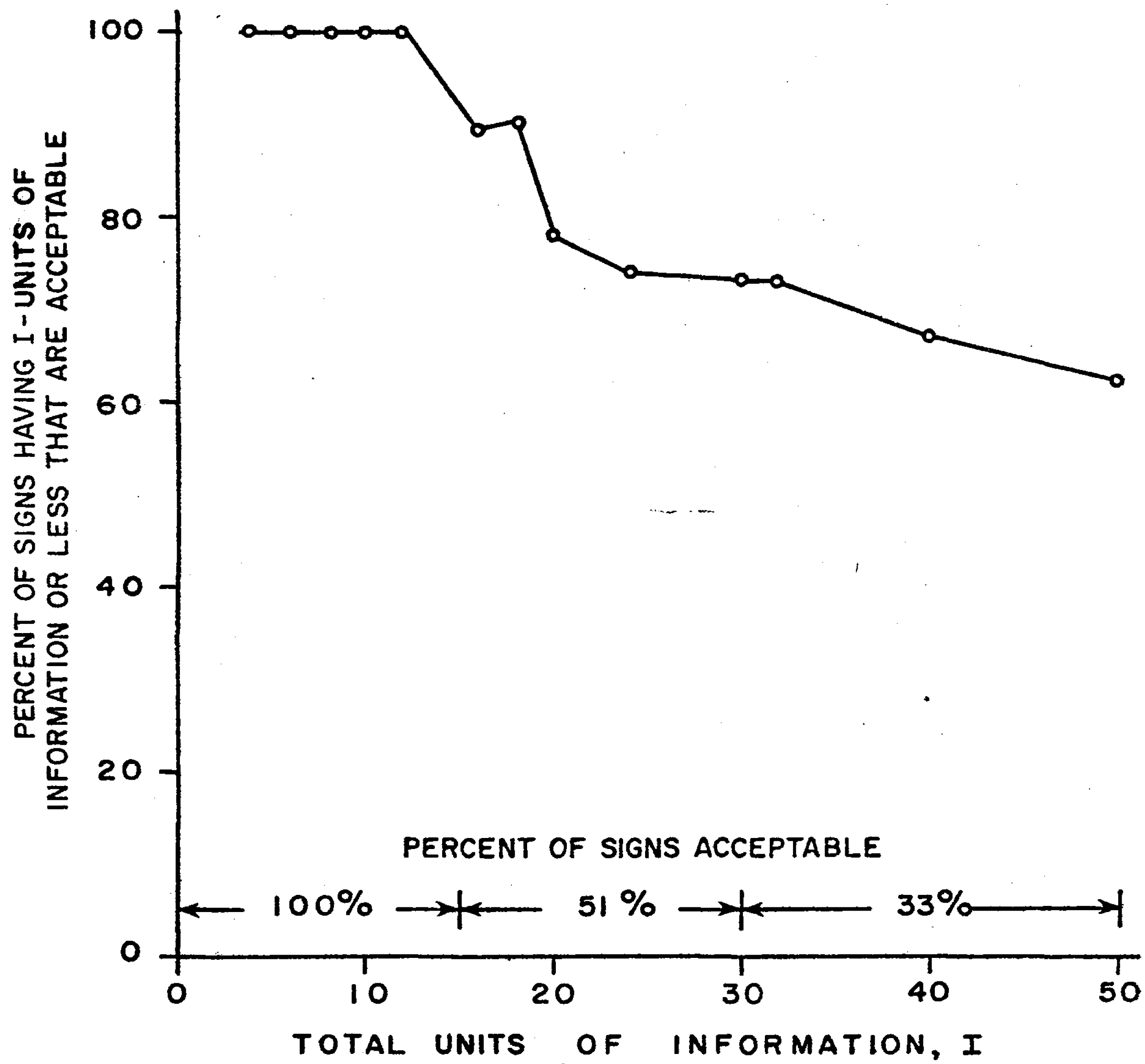

Figure 9. Acceptance Levels Related to Total Information on Sign.

the signs were acceptable, as the upper curve in Figure 9 depicts at the upper bound I-level of 50 units.

The average percent of the signs performing acceptably (i.e., 80% correct response) based on the laboratory results is given at the bottom of Figure 8 for three intervals of information load. In the interval of 1-15 units, 100% of the signs performed acceptably. In the interval from 15-30 units, 51% of the signs were acceptable. In the interval from 31-50 units, only 33% of the test signs were found to be acceptable.

Another sign design parameter which seems to affect accuracy levels to some extent is the ratio of the number of panels, (P), divided by the average information unit rate per panel, B, or R = P/B. If one analyzes the 4 and 2½ second display time results in Table 1, it will be determined that in 8 of 14 paired comparisons existing at similar total information levels up to, but not including, 20- unit I-levels that in only 1 of 6 cases did the percent correct response increase as the ratio R decreased for a given I-level. This one case was at an I-level of 16 units with 2½ second display time. However, in the 9 cases where paired comparisons were possible from I-levels of 20-bits or more, no trend is evident; 4 cases rose with decreasing R values and 4 cases dropped. Again, it is concluded that somewhere in the vicinity of 15-20 units of information (I) per sign structure. Above this level there are just too many choices (panels) or too much clutter per sign panel for efficient decision making to occur.

<u>Display Time</u>. A comparison of the 14 test signs not changed between the 6 and 2½ second display time experiments showed that this signficant reduction in display time resulted in a moderate drop in route selection accuracy from 82% to 77%. It should be noted, however, that most of the

signs that were not modified tended to be the smaller less complex signs.

Experience. The results of the 6 and 4 second display time experiments demonstrate how driver familiarity and experience yield improved driver performance. The mean percent correct response increased from 75% to 78% even though the average display time was reduced 33%. A total of 14 of the 22 test signs showed increases in percent correct response, whereas only 5 showed decreases.

Reading Time

The time the subjects took to read the signs depended not only on the sign design parameters but also on how much time was available to perform the task. This was to be expected as normal behavior. A brief review of the averages of the 85%-ile reading times for each display rate illustrates this point as follows:

Display Time, sec. (DT)	85%-ile Reading Time, sec. (RT)	Ratio DT÷RT
6	4.6	1.30
4	3.5	1.14
2½	2.8	0.89

A plot of these data shows that a 3.0 second display time would have produced a 3.0 second 85%-ile reading time, or a display time to reading time ratio of 1.00 for the 85%-ile driver. Thus, it would appear that the 4 second display time would represent a test condition which is pressurized but yet provides minimum acceptable conditions. Since the 4 second display 85%-ile reading times were 75% of the 6 second times, the 6 second display time represents what may be reasonably considered to be a desirable set of operating conditions.

TABLE 2. DESIRABLE AND MINIMUM READING TIMES IN SECONDS FOR OVERHEAD FREEWAY GUIDE SIGNS.

Units of Information Per Panel	Design and Operating Conditions	Number of Sign Panels for Overhead Sign Structure 2	3	4	5
2	Desirable	3.1	3.5	3.9	4.4
	Minimum	2.7	2.7	3.0	3.3
4	Desirable	3.6	4.2	5.0	5.7
	Minimum	2.7	3.2	3.7	4.2
6	Desirable	3.8	4.5	-	-
	Minimum	2.8	3.4	-	-
8	Desirable	3.9	-	-	-
	Minimum	2.9	-	-	-
10	Desirable	4.0	-	-	-
	Minimum	3.0	-	-	-

Linear regression analyses were performed to develop equations for estimating the reading times. The advantage of this approach is that smoothed estimates of eact test sign can be estimated based on trends and characteristics of the complete study. Estimated desirable and minimum reading times based on these analyses are presented in Table 2. Minimum reading rates were assigned to be 75% of the desirable values subject to a 2.7 second minimum. Sign structures having a total of over 20 units of information on them are not recommended and usually do not exist in the field.

CONCLUSIONS AND RECOMMENDATIONS

The results of this detailed laboratory study of urban freeway guide sign reading task form the basis for the following conclusions and recommendations.

It is apparent that route selection accuracy decreases as the number of route choices (and related sign panels) increase. It is also clear that the information content of a large sign structure should not exceed 6 units of information per panel and at no time should the total information loading exceed 20 units of information (absolute maximum), however, a more desirable maximum information loading would be 16 units per sign bridge.

The time required to read a sign also increases with the number of route choices available and total information on the signs as presented in Table 2.

The sign designs given in Table 3 represent what are recommended as desirable and minimum acceptable design parameters for overhead freeway guide signing in urban areas. The desirable and minimum design parameters

TABLE 3. RECOMMENDED MAXIMUM SIGN DESIGNS FOR DESIRABLE AND MINIMUM DESIGN CONDITIONS.

Number of Route Alternatives (Panels)	Maximum Units of Information on Sign: Condition	Bits
2	Desirable	12
	Maximum	16
3	Desirable	18
	Maximum	20
4	Desirable	16
	Maximum	20
5	Desirable	--*
	Maximum	20

* This is an undesirable design. Sign spreading, removal of redundant concurrent routing or other appropriate techniques should be examined.

were developed based on the reading times determined during the laboratory studies and personal comments from the subjects based on heavily loaded signs. The author felt that a cut-off of approximately 4.0 seconds to read any sign was critical for safe handling of a vehicle along urban freeways.

Any sign which does not provide desirable design conditions, with respect to the number of panels and the level of information in each panel should have a sign layout which optimizes all other sign design criteria. Minimization of costs should not be the only controlling consideration for the minimum condition designs. All signs which do not meet minimum conditions should not only be redesigned, but the route structure should be redesigned, to eliminate concurrent routes, unnecessary exits, etc.

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