DRIVER TENSION RESPONSES AND INTERSECTION ILLUMINATION

By

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Research Report Number 5-6

Intersection Illumination
Research Project 2-8-57-5

Sponsored by the
Texas Highway Department
in cooperation with the
U.S. Department of Commerce, Bureau of Public Roads

April 1964

TEXAS TRANSPORTATION INSTITUTE
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College Station, Texas

SYNOPSIS

Galvanic skin reflex (GSR), which is a measure of the change in the electrical resistance of the skin due to perspiration, proved to be an adequate means of determining driver reaction to different illumination and geometric conditions at intersections.

Nighttime use of different drivers and comparison of their tension patterns as recorded by the GSR instrument showed that increase in illumination brought decrease in tension responses and that greatest tension occurred with no illumination. Also, complexity of the intersection caused increase in tension responses. Although the drivers reacted differently to the various intersection situations, their over-all response patterns were similar. Familiarity with situations brought reduced tension.

INTRODUCTION

Under the traffic conditions of two generations ago the requirements for highway lighting were adequately fulfilled by lanterns and lamps. Today, greatly increased traffic volumes and speeds at night have necessitated an increase in lighting standards. The major purpose of roadway lighting as formulated by the Illuminating Engineering Society (7) may be stated as follows:

"To promote safety and convenience for vehicular and pedestrian traffic through adequate visibility during darkness."

The construction of the National System of Interstate and Defense Highways has accentuated the need to evaluate highway illumination and its value in providing comfortable driving. Special visibility problems are created by nighttime driving. This is especially true of highway intersections.

Although the driver's task is more critical at night, illumination does not appear to produce significant changes in vehicular operations. Taragin and Rudy (13) found that neither average speed, placement, headway, nor lateral clearance showed any consistent change by virtue of highway illumination.

The night accident rate is twice that of the day rate. It is generally agreed that illumination decreases the accident rate, but the optimum illumination design is not agreed upon. The ultimate solution would be to illuminate highways at night to the same intensity that exists during daylight, but this is impractical.

Little is known of the effectiveness of highway lighting with respect to driver behavior. With some quantitative measure of driver comfort, a possibility exists that driver behavior could be used as an aid to future illumination designs.

Galvanic Skin Reflex

In seeking a quantitative measure of driver behavior, it is believed that tension created by complex decisions might be measurable. From psychology there were several behavioral measures that could be used (9). A measure of tension that could be related to driving was desirable and the galvanic skin reflex (GSR) most nearly fulfilled this requirement. The GSR is a measure of the changes in conductivity occurring in the sweat gland.

In 1888, Fere' (9) passed a weak current through electrodes on the forearm of a subject. A galvanometer in the circuit responded with a quick deflection as the subject was stimulated by the sound of a tuning fork, the smell of an odor, or the sight of colored glass. Since that time there have been numerous research studies relating to the GSR.

A tension response is induced in a subject by the activity of the autonomic nervous system and is initiated by unexpected stimuli that may be startling or tension-inducing (11). Aveling (1) indicated that a GSR response is characteristically the consequence of conation or the aspect of striving. Cattell (2) concurred with this idea.

The GSR, indicated Lindsley (9), is a better index of high-level mental functions than any other measure of bodily change. It appears as a decrease in skin resistance, and the magnitude is proportional to the intensity of the inducing stimuli (5). According to McCurdy (10) there is a correlation between the magnitude of the GSR and the conscious experiences of the subject.

The majority of research relating to the GSR has been in the field of psychology and, only recently has there been any application in the field of highway and traffic engineering.

In a California study, Hulbert (6) found a relationship between driver GSRs and changes in the traffic pattern. His findings indicated that a GSR results when the driver is forced to alter his "idealized path" due to an unexpected traffic event.

Michaels (11) of the Bureau of Public Roads related driver tension responses to the traffic events which caused a change in speed or lateral placement of the test vehicle. This study indicated that events involving a speed differential produce greater tension response than fixed object events.

Cleveland, and Franklin (3) related driver tension responses to illumination at a rural intersection. A minimum lighting design was compared with no lighting. Their findings indicated 20 percent less tension is produced with illumination present.

PURPOSE AND SCOPE

The purpose of this study was to evaluate the reliability of using the galvanic skin reflex (GSR) to measure the effects of different lighting designs on driver tension responses.

The scope of the study was limited to experimental lighting studies at a rural intersection. Comparisons were made among levels of illumination, among variations in geometric design, and among several driver subjects.

The Texas Transportation Institute is conducting a study of rural intersection illumination. This project is jointly sponsored by the Texas Highway Department and the Bureau of Public Roads and has the objective of determining the effect of intersectional illumination on safety, comfort, and operational characteristics. The study reported here is a phase of this project.

PROCEDURE

Study Site

The GSR field studies were conducted at a rural wye-type intersection located about 45 miles southeast of Houston, Texas. The site, known as the Texas City Wye, is located at the intersection of Texas State Highways 3 and 146 and Loop 197. A plan of the study site is shown in Figure 1 and two photographs of the intersection are shown in Figure 2.

The Texas City Wye provides a desirable study area for illumination research for two reasons. First, the relatively undeveloped area around the intersection provides little conflicting illumination. Second, traffic is light and scattered after 10:00 P.M., and thus, experimental changes in the lighting or traffic control devices will have an insignificant effect on normal traffic operations at the intersection.

The study site is located in a flat coastal region. Highways in this area have little gradient and there are no sight distance problems. The combination of State Highways 3 and 146 is a four-lane divided facility with a bituminous surface, while Loop 197 is a two-lane undivided facility with a portland cement concrete surface.

The illumination consists of 15 Type III 400-watt mercury vapor luminaires mounted 30 feet above the pavement of the locations shown in Figure 1. Each luminaire is equipped with an individual switch. With this arrangement numerous lighting patterns can be developed.

A combination of signing and channelization provides traffic control at the intersection. Channelization along with stop and yield right-of-way signs are shown in Figure 1. Type D-1A destination signs are used for route designations on the approach from Galveston. Signs facing the other two approaches are D-1 destination signs. The messages on D-1A and D-1 signs are composed of 7-inch and 4-inch capital letters respectively.

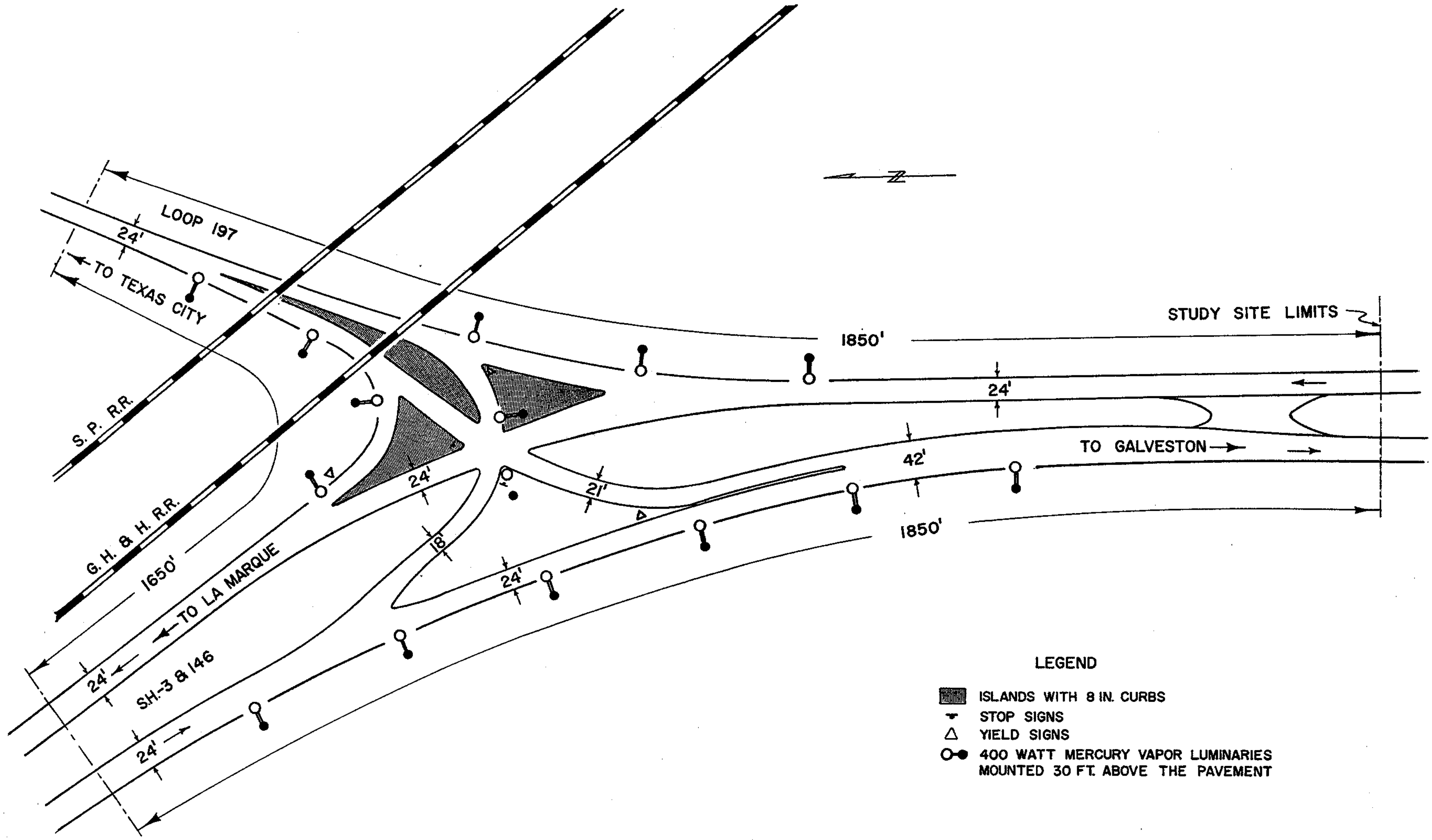
Two criteria were used to establish the length of each test section. First, study limits were selected in such a manner that there would be a minimum of 500 feet beyond the luminaire in each direction. It was believed that within these limits all significant reactions attributable to illumination would occur. Secondly, for a good comparison, similar paths were assigned the same total distance. The study limits as selected from the above criteria are indicated on the schematic drawing of the intersection shown in Figure 1.

Field Studies

A test driver, the GSR operator and two assistants formed the field team, with the GSR operator serving as team leader. The driver rode alone in the front seat of a 1961 station wagon with the GSR operator and one assistant in the back seat. The other assistant was inconspicuously placed at the test intersection. The GSR instrument, a recording speedometer, and other associated equipment were placed in the rear of the station wagon.

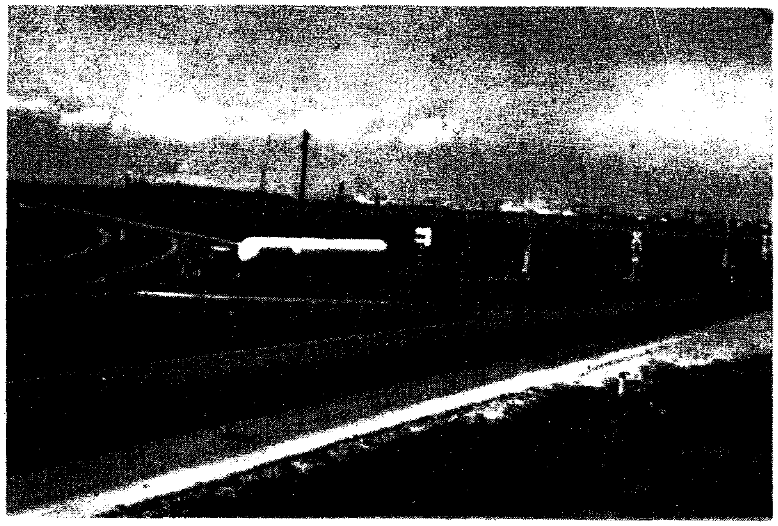
The test driver was told to assume he was alone in his own car and to drive at his usual rate of speed. He was assured that his driving ability was not being measured. He was asked not to talk and not to travel in a group with other traffic moving in the same direction. Before reaching each intersection, the team leader gave the driver directions using a town or route designation. Following these instructions, the driving pattern was quite similar among the test drivers.

The team leader operated the GSR instrument during all field studies. He observed the driver's reaction to various traffic conditions and recorded these on the graphic record. He gave directions to the driver. Also, he was responsible for communicating during each test run with the assistant at the study site.



PLAN OF STUDY SITE

FIGURE 1



LOOKING TOWARD LA MARQUE

FIGURE 2
TEXAS CITY WYE
STUDY SITE

The associate in the car located the beginning and end of each run through the test site using the event pen on the GSR and recording speedometer. He was also responsible for coding the time on the graphic record at various intervals.

The other assistant regulated the lighting conditions at the test site according to a prearranged schedule and communicated with the team leader during a test run.

Tension responses were measured using a commercial galvanic skin reflex instrument called Dermograph. This instrument, as shown in Figure 3, consists of a set of finger electrodes, a galvanometer, a wheatstone bridge, an event pen and a graphic recorder. Power for the GSR was supplied from a 12-volt battery. A converter changed the battery output to the 115-volt input required by the GSR.

In order to obtain an unbiased estimate of tension responses, it is necessary that the driver be unaware of the exact time and location of GSR measurements.

Test drivers were told that driving conditions were being investigated on various types of highways in the Galveston area. This area as shown in Figure 5 includes the Texas City Wye. Five intersections along the study route are illuminated with one having geometric design features similar to those at the study site. Since there were other lighted intersections within the area, the driver's attention was not focused upon the study site as being the only illuminated intersection.

Numerous combinations of test routes were available which included the test site. Since the subjects were driving over strange roads at night, the use of several routes throughout the area eliminated the feeling of traveling a particular section of roadway or passing through a certain intersection a disproportionate number of times during the course of the study.

The GSR instrument and the recording speedometer were turned on at the beginning of a study and remained on the entire study. The equipment makes a little noise detectable by the driver.

To keep the test drivers completely unaware of the role of illumination in the study, the assistant who regulated the lights traveled to the study site in a separate vehicle and stayed at a different motel. The test subjects did not suspect that anyone was required to conduct the study other than the GSR operator and one assistant.

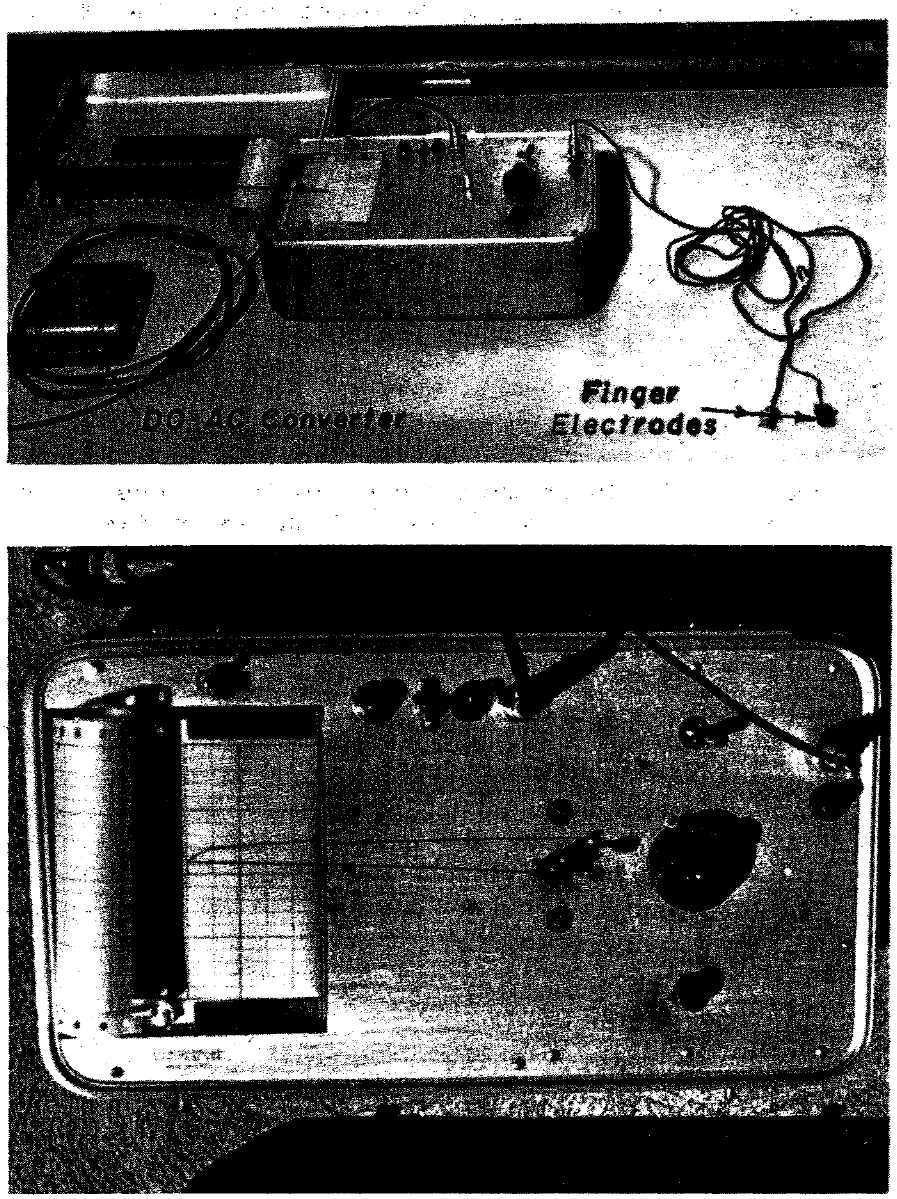


FIGURE 3
GSR RECORDING INSTRUMENT

Once a study was started in the evening, it was necessary for the GSR operator and the assistant at the test site to communicate during each passage of the test vehicle through the intersection. Before beginning the study each evening, a yellow tail light was mounted on the rear bumper of the test vehicle and removed each evening after the completion of the study. With this light the GSR operator signaled to his associate by using a series of dots and dashes. The assistant acknowledged the signal with dots and dashes from an ordinary flashlight. This was satisfactory for indicating which run was successful and which run was unsuccessful.

However, this system was not satisfactory in all cases. If, for example, there was equipment failure or a luminaire should burn out, the GSR operator and the assistant at the site should be able to talk to one another. On a prearranged signal from either one, the test vehicle was stopped for "coffee" at a restaurant. As the test vehicle stopped, the GSR operator, would tell his assistant in the car that he would turn off the equipment and be in shortly. Once the test driver and the assistant were inside, the GSR operator would call his other assistant from an outside telephone booth. In this manner unforeseen emergencies could be handled without disrupting the field procedure. During the field studies equipment failure on the second night of observer 4 caused the only need to follow this procedure.

At the beginning of each night the electrodes were attached to the driver as shown in Figure 4. During the field studies, the driver was asked to place his hand in his lap and use only the other hand for driving. With automatic transmission the driver could operate the test vehicle with a minimum amount of restriction since the driving was primarily rural in nature. This electrode placement was found to be very satisfactory in previous studies (11, 3).

With the driver in the operating position, a normal resting level of skin resistance was determined. A startle stimulus was used to establish a sensitivity setting for full scale deflection. This value was about one-third of the maximum sensitivity setting for all drivers. It provided an adequate range for severe reactions and at the same time detected more minor reactions than some lesser sensitivity setting. Once the sensitivity level had been determined, it was not changed for the remainder of the night. This helped to reduce a driver's variability between runs, but it did not eliminate the variability between test drivers.

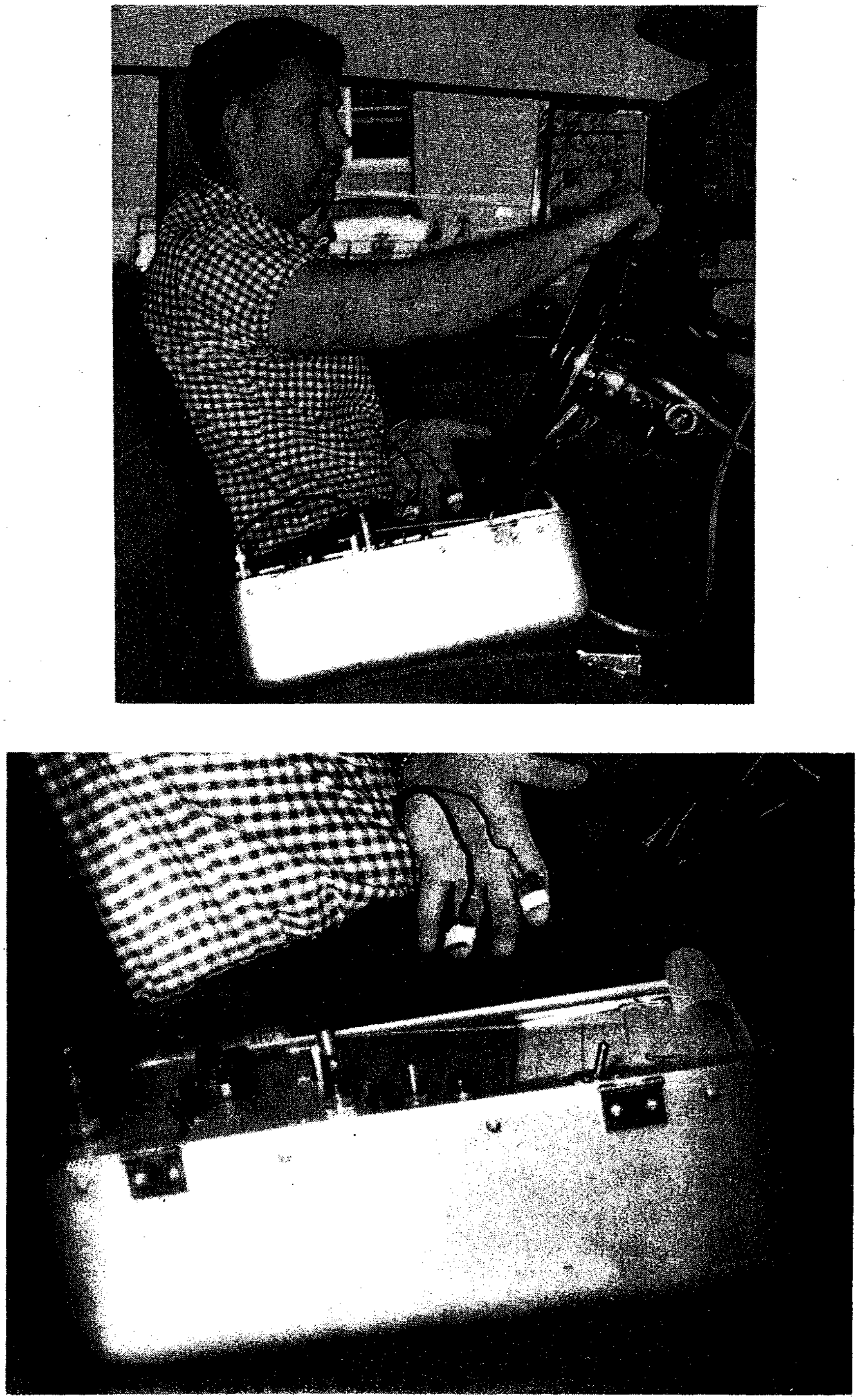


FIGURE 4

GSR RECORDING INSTRUMENT
OPERATING POSITION

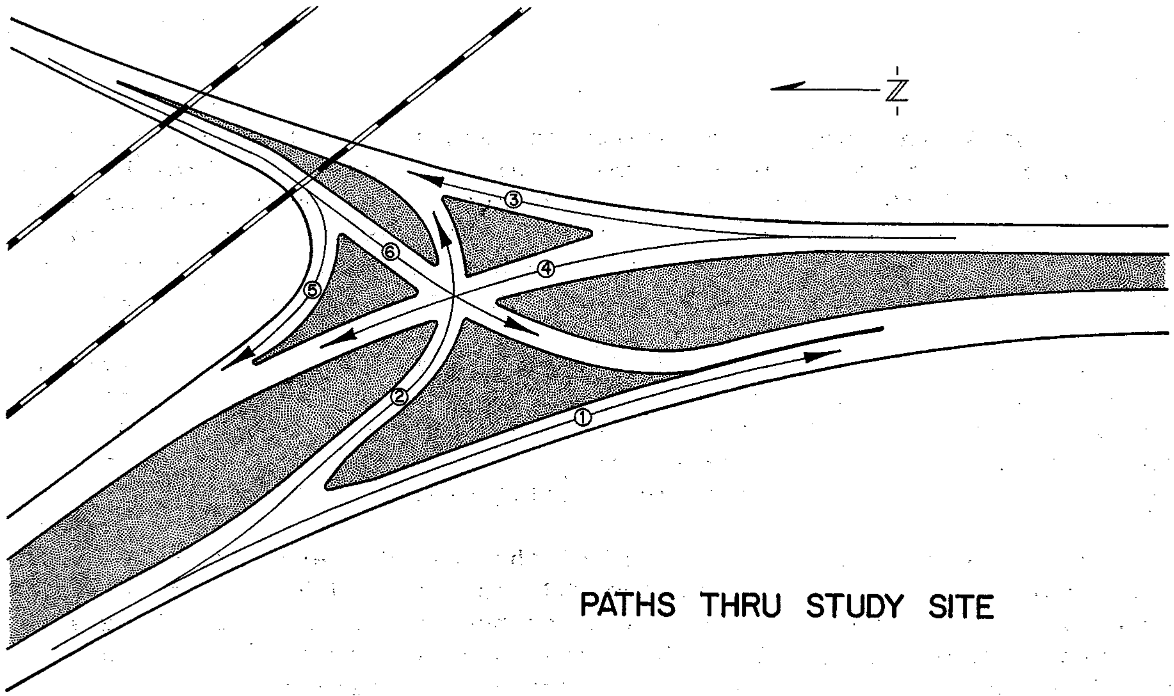
The study runs were made between the hours of 10 P.M. and 5 A.M. A set of nine runs along with reruns required from two to three hours to complete. Each driver made his study runs on two succeeding nights at the same time each night. The experimental design did not provide rest stops for each driver. However, each driver was observed closely and if it appeared he was becoming fatigued, a short rest was taken.

A typical test run was conducted as follows. The run was started some distance from the test site. The driver was given directions in advance of each intersection. These directions eventually led to the test site. The driver passed through the study site and would return again according to the experimental design.

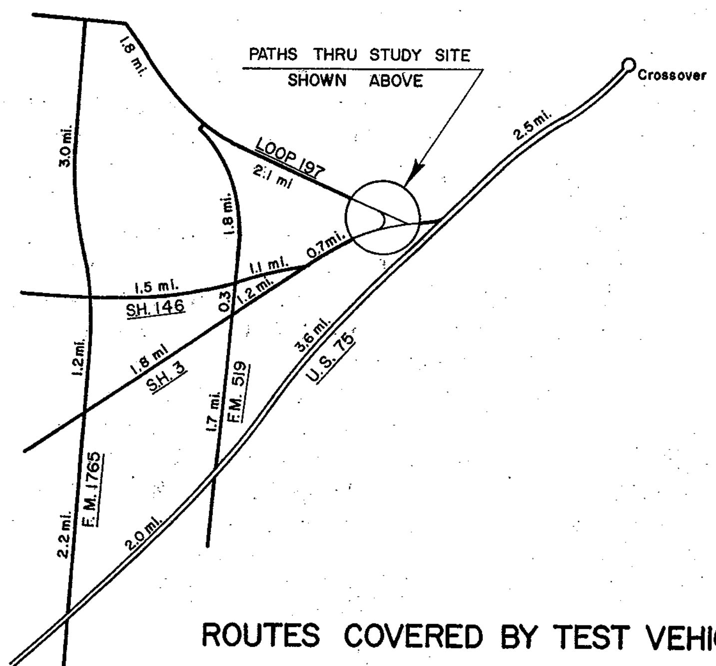
After two nights of study none of the test drivers suspected that another person was helping the GSR operator and his assistant. None had noticed the extra tail light on the car or the signalling at the test intersection. Also, the trips each evening to "check equipment" and the one "coffee break" did not arouse suspicion in any test driver. Two of the drivers noticed a difference between lighted and unlighted conditions at the test site, but neither thought that the study centered around one intersection.

There are six possible paths through a wye-type intersection. Numbers that will be used to identify these paths throughout this study are shown in Figure 5. These six paths have a varying degree of complexity due to the geometric layout as shown in Figure 1.

The movements between Galveston and LaMarque, paths 1 and 4, are free-flowing. Path 3 is free-flowing, but traffic must cross a pair of railroad tracks as it leaves the intersection. Traffic on the free-flowing movements, paths 3, 4, and 5, can travel through the intersection without reducing speed. Vehicles on path 5 must yield the right of way when merging with path 4. Due to the curvature on this path, vehicles must slow down considerably to make the turn toward LaMarque. Traffic on paths 2 and 6 must stop and cross a major movement. Only paths 3, 4, and 5 were studied. The selection of these paths provided comparison of the three main movements through the intersection: free-flowing condition, free-flowing condition with some restriction, and yield right of way condition.



PATHS THRU STUDY SITE



ROUTES COVERED BY TEST VEHICLE DURING STUDY

STUDY ROUTES AND INTERSECTIONAL PATHS

FIGURE 5

Experimental Design

An experimental scheme was desired that would provide the maximum information with a minimum of experimental error. Practical considerations for controlling the scope of the research' limited that design to relating driver tension at night to the following three independent variables:

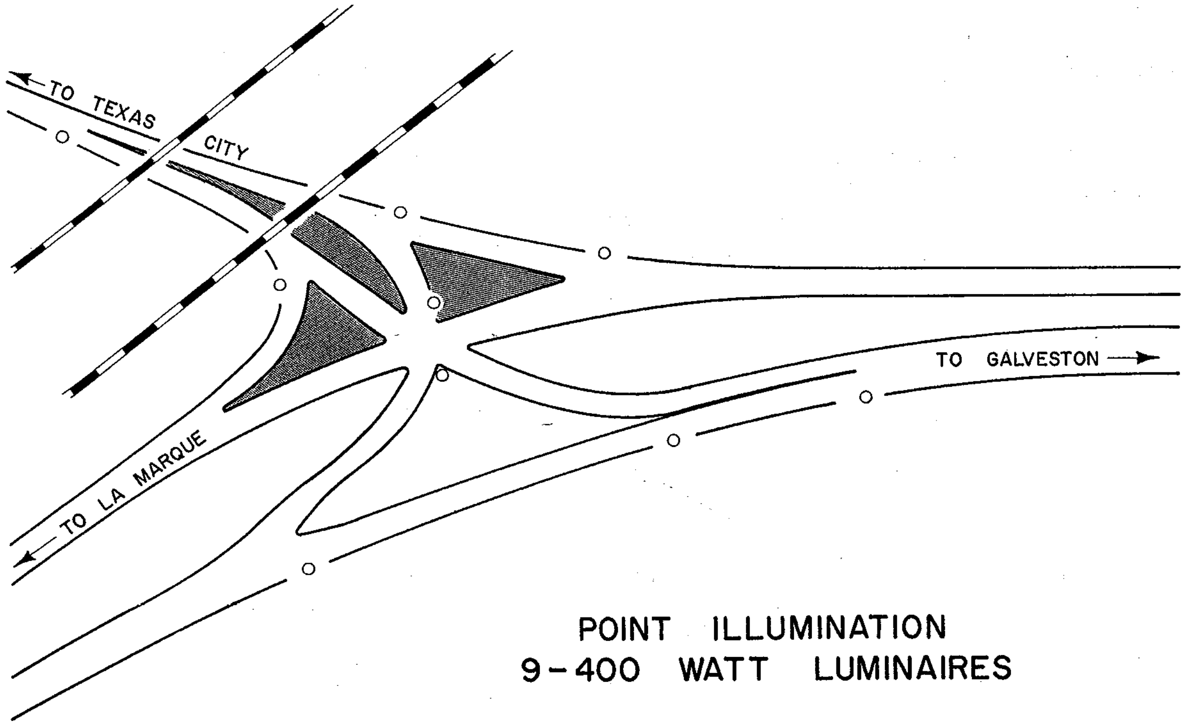
1. Three levels of illumination.
2. Three paths through the intersection.
3. Four male engineering students.

A preceding study (3) provided the best prior knowledge of the errors involved. This earlier investigation considered differences between minimum illumination (five luminaires each placed at a major conflict area) and no illumination, among ten driver subjects, among the six possible paths through the intersection and the interactions between these factors.

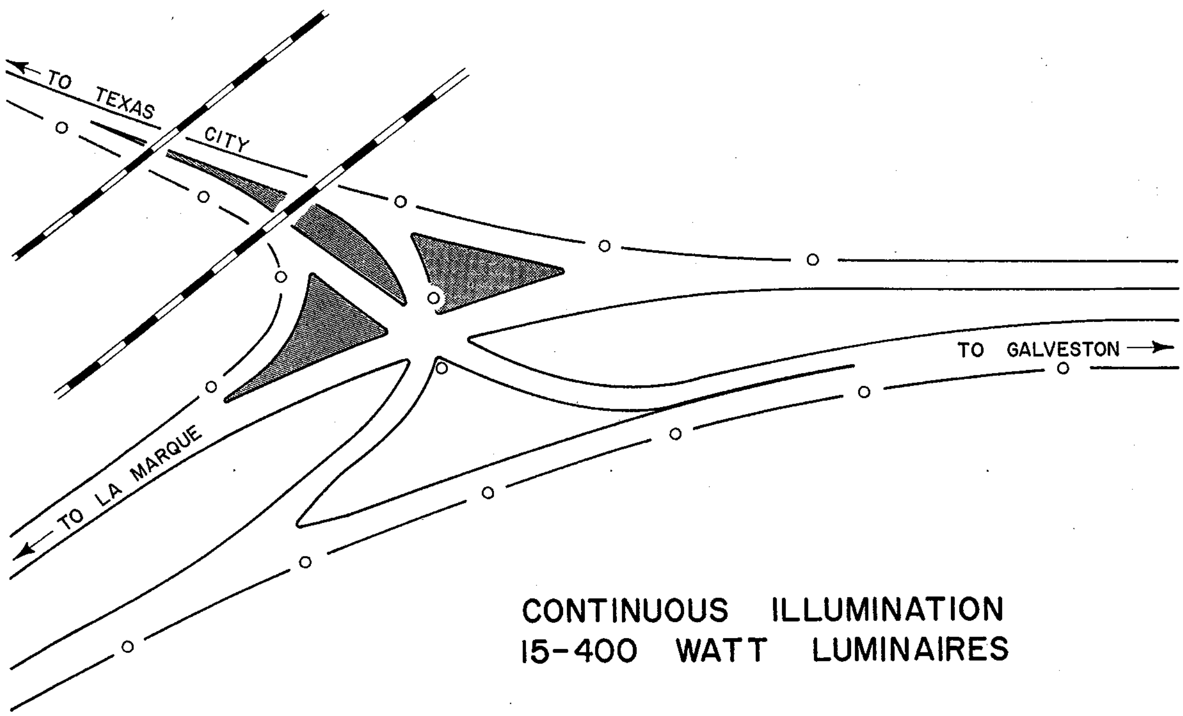
For the later research study described in this report illumination specialists established point and continuous lighting arrangements for the Texas City Wye using a 1:60 scale model. The point arrangement, composed of nine luminaires, supplies point lighting over the intersection and at major locations of decision. The fifteen luminaires of the continuous system furnish continuous lighting over the entire intersection. Differences between no illumination, point illumination and continuous illumination were compared in this study. The placement of luminaires for these illuminations schemes is shown in Figure 6.

Four male engineering students at Texas A&M University were selected as drivers for this study. Their ages varied from 21 to 26 years, and their driving experience ranged from 7 to 12 years. None of the observers had any prior knowledge of the objects of this investigation. Drivers were selected who were unfamiliar with the study area. They were taken to the study area two at a time and stayed for two nights of study.

A prior study (11) indicates that the presence of other vehicles within the vicinity of the test vehicle usually results in a GSR. This other traffic must be eliminated in order to say with any degree of certainty that the tension responses generated are attributable to the lighting arrangement and/or the geometric design. To keep the driver unaware of the actual site, a chance was taken that the test vehicle would pass through the intersection at a time when no other traffic was in the vicinity. This was considered



POINT ILLUMINATION
9-400 WATT LUMINAIRES



CONTINUOUS ILLUMINATION
15-400 WATT LUMINAIRES

ILLUMINATION CONDITIONS

FIGURE 6

a successful run. If there was another vehicle within the intersection then the run was unsuccessful. The unsuccessful runs were rerun at the end of a night's study until there was no traffic present as the test vehicle passed through the intersection.

To increase the precision of the experiment and to detect any major field errors, it was decided to repeat each field observation. Two successive nights of the study would also give some indication of familiarization effect.

A complete 3 x 3 x 4 factorial design with 2 replications was used. On each evening each driver made nine successful runs through the intersections, three times on each path, once with the lights off, once with point lighting and once with continuous lighting. The order of presentation was randomized to eliminate bias. The experimental design for this study is shown in Table 1.

Data Reduction

The graphic recorder measures a tension response as the logarithm of conductance. The divisions on the graphic recorder represent equal increments of GSR. These will be referred to as reaction units. The absolute value of conductance depends upon the sensitivity setting for a particular driver and was not determined in this study.

The appropriate unit for specification of the GSR, according to Lacey and Siegel (8), should be independent of a base level in order to compare the magnitudes of GSR of different subjects. They further state that the unit should be distributed normally since a basic assumption of most statistical techniques is that the parent population is normally distributed. In using the logarithm of conductance as a unit of measure, both criteria are satisfied.

The GSR operator and his assistant worked together in reducing the original data. The magnitude of each measurable response along with the travel time through the study site was recorded. A sample GSR record is shown in Figure 7.

During the collection of field data, the study limits were located on the graphic record by using the event pen on the GSR. By looking at the graphic record it was possible to tell which run number, but not which path or which lighting condition, was associated with each test run. The magnitudes were calculated separately by both the GSR operator and his assistant without knowing the factors present during a specific test run. The magnitude of each response was determined by considering each division on the graphic record as one reaction unit and counting the units for each response.

TABLE 1

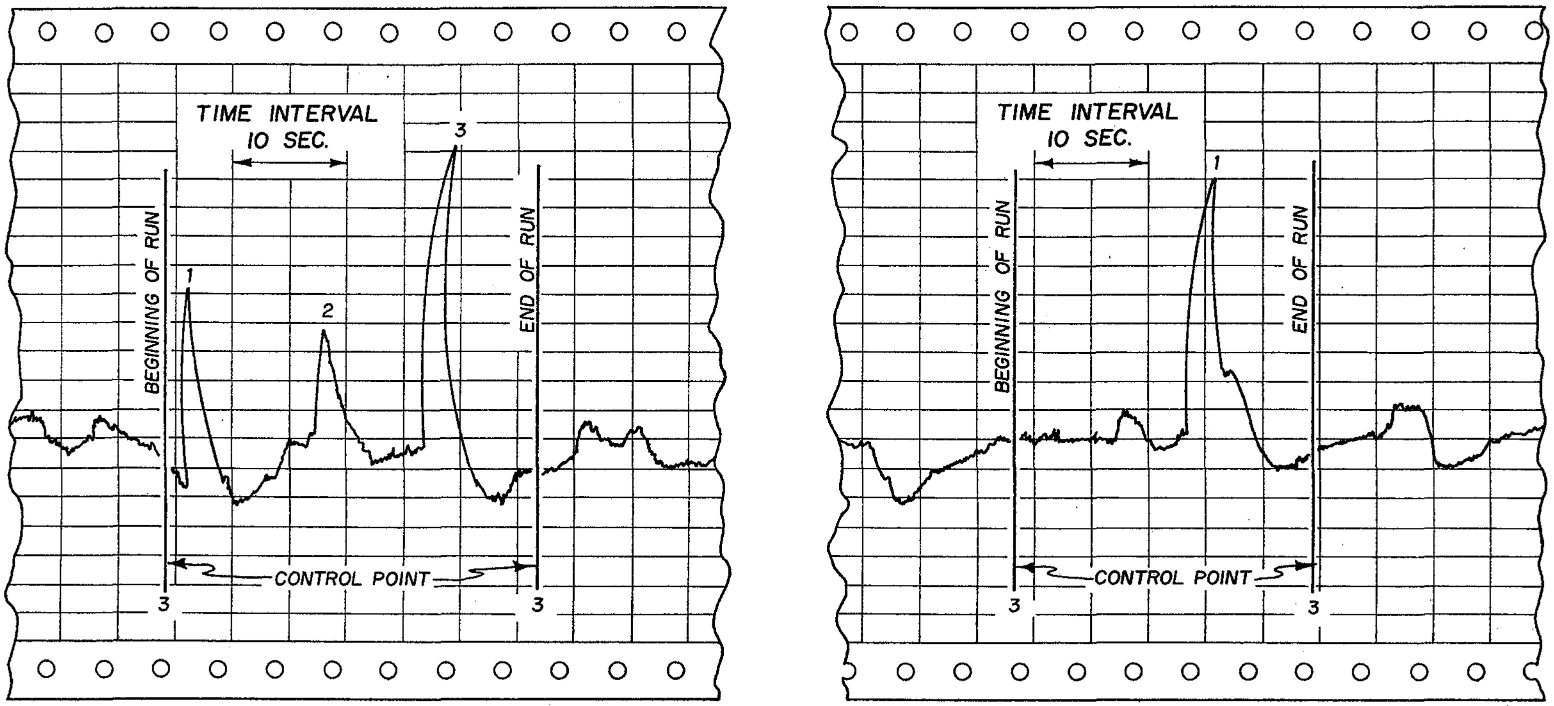
EXPERIMENTAL DESIGN

		OBSERVERS							
		1		2		3		4	
		Night							
Illumination	Path	1	2	1	2	1	2	1	2
None	3	5	5	3	7	9	1	1	9
Point	3	9	1	5	5	1	9	9	1
Continuous	3	2	8	8	2	5	5	3	7
None	4	8	2	1	9	3	7	7	3
Point	4	4	6	6	4	2	8	5	5
Continuous	4	6	4	9	1	7	3	2	8
None	5	1	9	7	3	6	4	6	4
Point	5	3	7	4	6	4	6	8	2
Continuous	5	7	3	2	8	8	2	4	6

Travel time through the test site was obtained by scaling the distance between the study limit marks. The graphic record moves at a constant rate or 6 inches per minute. A check was made to see that the GSR roll moved at a constant rate and variations were found to be negligible.

To provide a convenient permanent record, the original data were coded on McBee Keysort cards. The magnitude of each response and the total travel time through the intersection along with identifying information--lighting condition, path of travel, driver subject, night and time of evening--were placed on these cards. The McBee cards proved very useful because of the speed at which various factor combinations could be sorted for preliminary analysis.

The IBM 709 digital computer to the Texas A&M Data Processing Center was used to perform routine analysis.

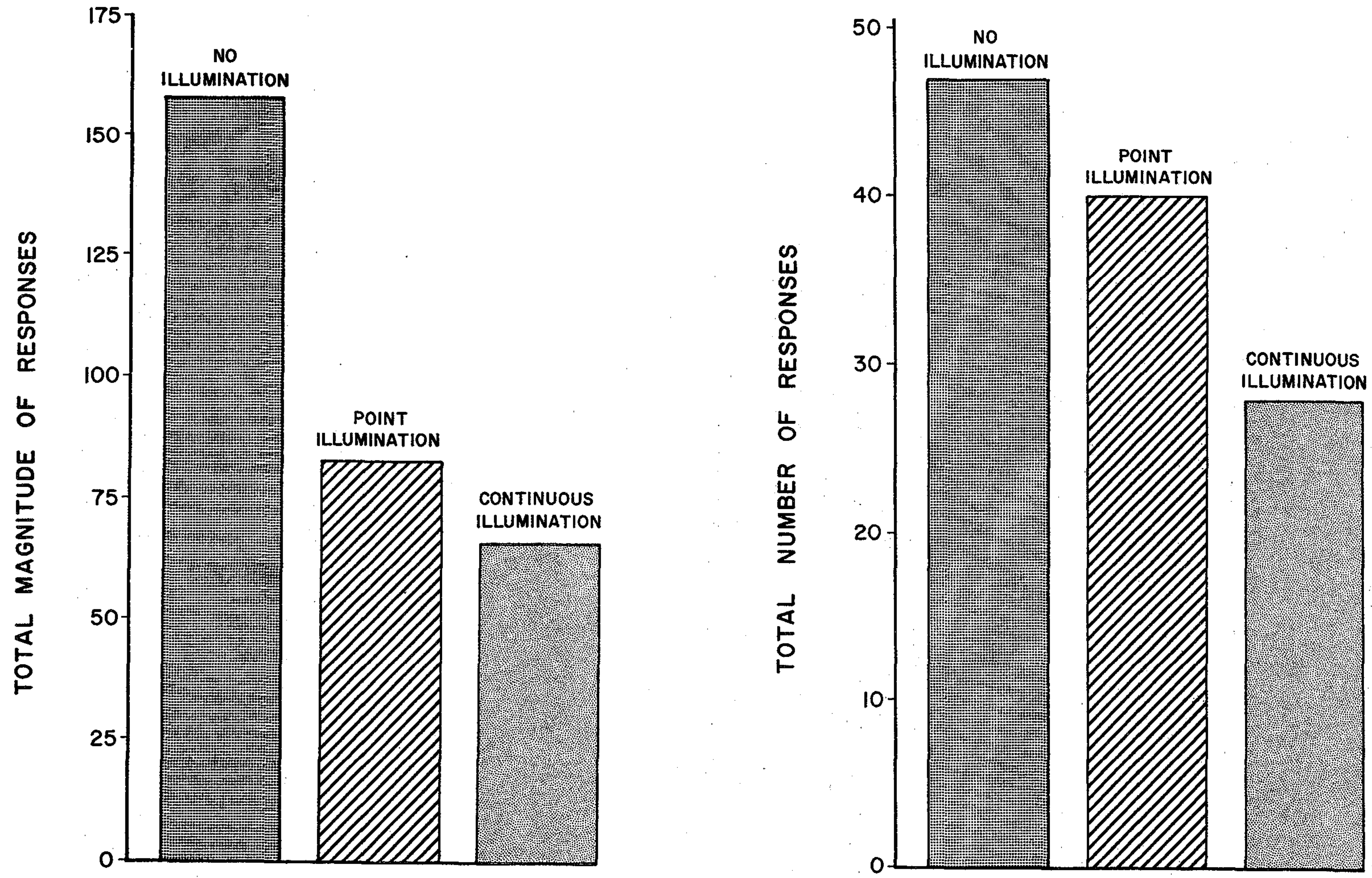


WITHOUT ILLUMINATION
GSR MAGNITUDE - 22

WITH ILLUMINATION
GSR MAGNITUDE - 10

SAMPLE GSR RECORDS
SHOWING GSR MAGNITUDE AND RESPONSES
WITH AND WITHOUT ILLUMINATION

FIGURE 7



TOTAL RESPONSES

FIGURE 8

DISCUSSION OF DATA

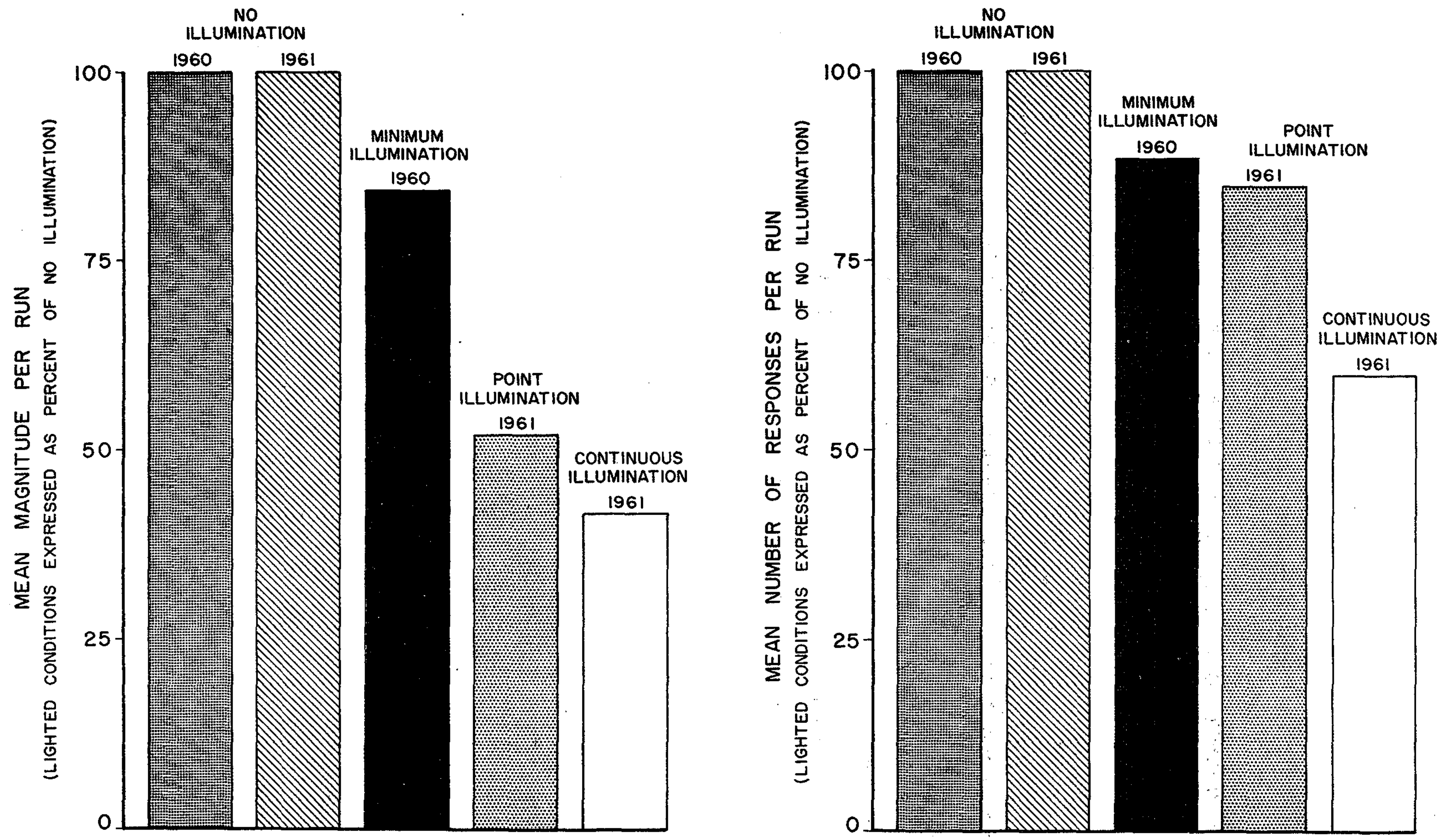
Several analyses were made using as measuring variables both the total number of galvanic skin responses and the total magnitude of these responses during any single run.

There was a substantial difference between the number of responses and the total magnitude of responses as the illumination conditions at the intersection were changed. This decrease with additional illumination is shown in Figure 8 for three observers and the average for all four observers is given in Table 2. Considering the total number of responses for three drivers, there were 47 responses under no illumination, 40 galvanic skin responses under point illumination, and 28 under continuous illumination. These reductions from the no illumination condition represent a 15 and 40% reduction, respectively. Considering the total magnitude of the galvanic skin responses, there was a 48 and 60% reduction in total magnitude, respectively, with point continuous illumination compared to no illumination.

Table 3 presents the average response for individual operators to illumination differences using as measures both the magnitude and the total number of galvanic skin responses. For both measures there were significant differences between drivers (inherent in the nature of the study and the GSR device). In general, each driver recorded a substantial decrease in galvanic skin response when point illumination was compared with no illumination at the intersection. Also, in general, there was a further decrease when the continuous illumination response was compared to that associated with the point intersection illumination.

Table 4 shows the average response to illumination and path differences for the two measures of galvanic skin reflex. From the study of the results, it is apparent that there is a substantial difference between path 5, the tight right-hand turn, and path 3 and 4, the smooth flowing paths from Galveston. For all three paths, the galvanic reflex decreased with increasing levels of illumination. The improvement for the tight turn was substantially more than for the smooth flowing turns.

The GSR Studies conducted in 1960 (3) under the direction of present authors and the 1961 studies were conducted at the same location. Each study compared no intersection illumination with some form of lighted condition. The responses to the three levels of illumination were expressed as a percentage of the average response to the unilluminated intersection for both the 1960 and 1961 studies. The results are shown as a bar graph in Figure 9. They indicate a response decrease with additional illumination. The continuous lighting arrangement produced the least amount of tension, followed by the point, and then the 1960 minimum illumination scheme.



CORRELATION BETWEEN THE 1960 AND 1961 GSR STUDIES

FIGURE 9

TABLE 2

AVERAGE RESPONSE TO ILLUMINATION DIFFERENCES
(4 Observers)

Illumination Condition \ Measure	Number of Responses	Magnitude of Responses
No Illumination	2.9	9.6
Point Illumination	2.5	4.9
Continuous Illumination	1.7	3.8

TABLE 3

AVERAGE INDIVIDUAL RESPONSE TO ILLUMINATION DIFFERENCES

Illumination Condition \ Driver	Magnitude of Responses 1	2	3	4
No Illumination	8.5	9.0	8.8	14.5
Point Illumination	3.0	3.8	6.9	7.0
Continuous Illumination	3.6	3.2	4.2	4.5

Illumination Condition \ Driver	Number of Responses 1	2	3	4
No Illumination	3.5	2.5	1.8	4.3
Point Illumination	2.2	2.0	2.5	4.3
Continuous Illumination	2.2	1.3	1.2	2.7

TABLE 4

AVERAGE RESPONSE TO ILLUMINATION AND PATH DIFFERENCES

Illumination Condition \ Path	Magnitude of Responses 3	4	5
Off	6.33	6.53	16.39
Point	3.70	2.65	8.60
Continuous	2.20	2.02	7.08

Illumination Condition \ Path	Number of Responses 3	4	5
No Illumination	2.7	1.9	4.0
Point Illumination	2.3	1.6	3.7
Continuous Illumination	1.4	1.3	2.4

TABLE 5

AVERAGE RESPONSE TO ILLUMINATION AND NIGHT DIFFERENCES

Illumination Condition \ Night	Magnitude of Response 1	Magnitude of Response 2
No Illumination	8.8	8.7
Point Illumination	4.6	4.6
Continuous Illumination	3.8	3.5

Illumination Condition \ Night	Number of Responses 1	Number of Responses 2
No Illumination	3.1	2.1
Point Illumination	2.3	2.1
Continuous Illumination	1.8	1.3

FINDINGS

Galvanic skin reflex (GSR), which is a measure of the change in the electrical resistance of the skin due to perspiration that psychologists employ as a technique, proved to be an adequate means of determining driver reaction to different illumination and geometric conditions at intersections at night.

Use of different drivers and comparison of their tension patterns as recorded by the GSR instrument showed that increase in illumination brought decrease in tension responses and that greatest tension occurred with no illumination.

Both the number of responses and total magnitude of responses for each run as measuring variables showed progressive reduction when darkness was changed to point and then to continuous illumination at the intersection. Also, complexity of the intersection such as a tight turn compared to a smooth flowing turn caused increase in tension responses. Although the drivers reacted differently to the various intersection situations, their over-all response patterns were similar. Familiarity with situations brought reduced tension.

Appraisal of the findings indicates that the galvanic skin reflex can serve as a quantitative measure of driver comfort at intersections at night. Data from its use can have application in design of lighting systems for intersections.

TABLE 6

SUMMARY OF DATA

			Observer 1		Observer 2		Observer 3		Observer 4	
		Night	No. of Resp.	Mag. of Resp.	No. of Resp.	Mag. of Resp.	No. of Resp.	Mag. of Resp.	No. of Resp.	Mag. of Resp.
Path 3	No. Ill.	1	3	4.5	2	9.5	2	6.0	6	9.0
		2	2	7.0	3	6.0	1	1.5	*	*
	Point Ill.	1	2	2.5	1	1.5	2	7.5	5	4.0
		2	1	1.0	3	5.0	2	4.0	*	*
	Cont. Ill.	1	3	6.0	0	0.0	1	3.0	2	2.5
		2	2	2.5	1	0.5	1	1.5	5	8.0
Path 4	No Ill.	1	4	4.0	1	5.5	1	6.0	2	12.0
		2	2	6.5	2	5.0	1	5.0	*	*
	Pt Ill.	1	2	2.5	1	2.0	2	4.5	2	4.0
		2	1	1.0	1	2.0	2	3.0	*	*
	Cont. Ill.	1	3	3.0	1	0.5	1	3.0	2	4.0
		2	1	2.0	1	1.0	0	0.0	0	0.0
Path 5	No Ill.	1	7	11.5	4	14.5	4	18.0	5	22.5
		2	3	17.5	3	13.5	2	16.0	3	14.5
	Pt Ill.	1	5	4.5	3	7.5	3	8.5	6	13.0
		2	2	6.5	3	5.0	4	14.0	*	*
	Cont. Ill.	1	2	3.5	3	9.0	2	6.5	4	7.0
		2	2	4.5	2	8.0	2	11.5	5	8.5

* No Data Available.

BIBLIOGRAPHY

1. Aveling, F.,"The Conative Indications of the Psychogalvanic Phenomenon," 8th International Congress of Psychology, 1926, pp. 227-234.

2. Cattell, R.B.,"Experiments on the Psychical Correlate of the Psychogalvanic Reflex," British Journal of Psychology, Vol. XIX, 1928-29, pp. 357-382.

3. Cleveland, D. E., and Franklin, W.W.,"Rural Intersection Illumination and Driver Tension Response," a paper presented at the 40th Annual Meeting of the Highway Research Board, Washington, D.C., January 1961.

4. Duncan, A. J., Quality Control and Industrial Statistics, Richard D. Irwin, Inc., 1959, Homewood, Illinois.

5. Hovland, C. I., and Riesen, A. H.,"Magnitude of Galvanic and Vasomotor Response as a Function of Stimulus Intensity," Journal of General Psychology, Vol. 23, 1940, pp. 103-121.

6. Hulbert, S. F.,"Drivers' GSRs in Traffic." Perceptual and Motor Skills, Vol. 7, 1957, pp. 305-315.

7. IES Lighting Handbook (Third Edition), 1959, Illuminating Engineering Society.

8. Lacey, O. L., and Siegel, P. S., "An Analysis of the Unit of Measurement of the Galvanic Skin Response," Journal of Experimental Psychology, Vol. 39, 1949, pp. 122-127.

9. Lindsley, D. B., "Emotion," pp. 473-516, in Stevens, S. S. (Ed.) Handbook of Experimental Psychology, Wiley, 1951, New York.

10. McCurdy, H. G., "Consciousness and the Galvanometer," Psychology Review, Vol. 57, 1950, pp. 322,327.

11. Michaels, R. M., "Driver Tension Responses Generated on Urban Streets." Public Roads, Vol. 31, No. 3, Aug. 1960, pp. 53-58.

12. Steel, R. G., and Torrie, J. H., Principles and Procedures of Statistics, McGraw-Hill, 1960, New York,

13. Taragin, A., and Rudy, B. M., "Traffic Operations as Related to Highway Illumination and Delineation," Public Roads, Vol. 31, No. 3, August 1960, pp. 59-66.

14. Venables, P. H., "Some Findings on the Relationship Between GSR and Motor Task Variables," Journal of General Psychology, Vol. 55, October 1956, pp. 199-202.

PUBLICATIONS

Project 2-8-57-5

Intersection Illumination

1.	Research Report 5-1,	"Roadside Sign Legibility and Roadway Illumination" by Donald E. Cleveland.
2.	Research Report 5-2,	"Lighting Studies at the Texas City Wye" by D. M. Finch.
3.	Research Report 5-3,	"Rural Intersection Illumination and Driver Tension Response" by Donald E. Cleveland and Weldon C. Franklin.
4.	Research Report 5-4,	"Overhead Signing and Traffic Operations" by S. N. Van Winkle and H. H. Bartel, Jr.
5.	Research Report 5-5,	Unpublished paper - "Roadside Sign Studies - II by S. N. Van Winkle and Donald E. Cleveland.
6.	Research Report 5-6,	"Driver Tension Responses and Intersection Illumination" by Weldon C. Franklin and Donald E. Cleveland.