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A BACKGROUND REPORT

ANNOTATED BIBLIOGRAPHY AND SUMMARY OF RESEARCH NEEDS of the HUMAN FACTORS ASPECTS OF DRIVER VISUAL COMMUNICATIONS

Research Report No. 606-2
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TEXAS TRANSPORTATION INSTITUTE

Texas A&M University
College Station, Texas

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ANNOTATED BIBLIOGRAPHY AND SUMMARY OF RESEARCH NEEDS IN THE HUMAN FACTORS ASPECTS OF DRIVER VISUAL COMMUNICATIONS

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This report has been prepared as a part of library research activities associated with the project entitled "Diagnostic Studies of Highway Visual Communication Systems" which is a pooled fund research project sponsored jointly by the following Highway Departments:

Alabama	Hawaii	New Mexico
Alaska	Maryland	Rhode Island
Arkansas	Michigan	South Dakota
California	Mississippi	Tennessee
Connecticut	Nebraska	Texas
Georgia	New Hampshire	Wyoming

PURPOSE

The purpose of this report is to present a literature survey and to summarize the pertinent work related to this project and to give appropriate recommendations related thereto. This effort covers two main areas:

(1) Visual input requirements in the driving task

(2) Human information-processing capability in complex tasks.

It is obvious that these two areas overlap, in that part of the visual inputs become information which the operator may have to process. (Many inputs are available to the driver. Which ones does he accept for processing? Which ones does he discard?) It is, therefore, more convenient to treat these two items together under the heading "A Visual Communication System between the Driver and His Environment". This is the approach taken in this report.

SUMMARY

By way of summarizing the findings of the literature review, this section will present the factors identified as relating directly to the problem of visual communication in the highway environment. It should be noted that there are numerous other factors which may influence the behavior of the vehicle operator, but they are considered to bear indirectly on the effectiveness of the visual communication systems.

Not only are the pertinent factors listed in this summary, but also each factor is given a rating which indicates its relative importance, as far as future research effort is concerned. The factors, together with their ratings, are presented in Table I.

The research was rated in the following manner. Each factor was given an alphabetical grade in each of three components as shown below:

Component i = Importance of the factor in visual communication.

Component j = Knowledge available concerning the factor.

Component k = Degree of application of known information in the design of current visual communication systems on the highways.

The letter grade of each component carries a subjective meaning as follows:

Grade	Component i	Component j	Component k
A	Critical	Excellent	Excellent
B	Major	Good	Good
C	Moderate	Fair	Fair

D	Minor	Poor	Poor
F	Unknown	None	None, or Unknown

In order to develop a single numerical rating for each factor, point values were assigned to each of the above grades, as shown below, and Equation 1 was utilized to obtain a numerical rating:

$$I_R = (i \quad j) + k \qquad \text{[Eq. 1]}$$

where:

I_R = Research Importance Index

and i, j, k as previously defined,

numerical rating

TABLE I

FACTORS IN VISUAL COMMUNICATION SYSTEMS EFFECTIVENESS

AND THEIR RESEARCH IMPORTANCE INDICES

FACTOR	ALPHABETICAL GRADE Importance	Knowledge	Current Use	RESEARCH IMPORTANCE INDEX
I. Psychological Factors				
1. Alertness	A	D	F	180
2. Attention	A	D	D	155
3. Experience	A	B	C	90
4. Learning	C	A	C	50
5. Motivation	B	C	F	148
6. Anxiety	B	B	F	132
7. Reaction Time	B	A	C	50
II. Physiological Factors				
1. Integrity of the Visual System				
a. Perception	A	B	D	115
b. Visual Acuity	A	A	B	25
c. Color Vision	A	A	C	50
2. General Health	C	A	F	100
3. Sex	C	B	D	99
4. Age	C	B	D	99
5. Fatigue				
a. Physical	F	D	F	172
b. Mental	F	D	F	172
III. Environmental Factors				
1. Characteristics of the Communication Device (Information Source)				
a. Intensity and Size	A	B	B	65
b. Contrast	A	B	B	65
c. Repetition	A	F	F	200
d. Movement	A	F	F	200
2. Characteristics of the Surroundings (Physical Environment)				
a. Roadway Design	A	C	C	110
b. Weather	A	B	C	90
c. Traffic Density	A	D	F	180
d. Light Conditions	B	C	B	73
e. Noise and Vibration	B	F	F	180
f. Vehicle Characteristics and Integrity	B	C	D	123
3. Social Environment	F	C	F	154
4. Economic Environment	F	D	F	154

TABLE II

Point Values for Grades

Grade	Component i	j	k
A	10	0	0
B	8	4	25
C	6	6	50
D	4	8	75
F	9	10	100

An example of the procedure followed is given by way of explanation. The factor "Alertness" was given alphabetical grades of: i = A, j = D, k = F. Point values from Table II are as follows: i = 10, j = 8, k = 100. Substituting these point values into Equation 1, the relative importance index for this factor is as follows:

$$I_R = (10 \cdot 8) + 100 = 180$$

The use of a numerical system to rank factors as to their importance as future research topics should be considered. These numbers should in no way be interpreted as absolute measures of the importance of the various factors in the problem of visual communications. The numbers simply give a rapid way of selecting factors which, from the apparent results of previous work, are those most in need of investigation.

A review of Table I reveals that in the authors' opinion, the greatest need for research lies in the following areas:

(1) Repetition and movement as related to communication devices

(2) Alertness of the driver

(3) Effects of traffic density and noise and/or vibration

(4) Effects of fatigue, both physical and mental

(5) Attention of the driver

Detailed definitions and discussion of each of the factors listed in Table I are included in the body of this report. In addition, recommendations for a general approach to the needed research will be set forth.

TABLE OF CONTENTS

1.0 LITERATURE REVIEW

1.1 INTRODUCTION

Although this report does not give an exhaustive survey of the existing literature, it does include the more pertinent and current work on the topic. (See Appendix II, Annotated Bibliography, for details of literature surveyed.) A review of these studies indicates that the primary factors which have been subjects of research are those such as automobile design characteristics - windshield shapes, tinting of windshields, etc. - (1, 2, 28, 30, 31, 47, 64, 97), highway signing and marking characteristics - lighting, painting, size, contrast, etc. - (3, 4, 8, 11, 12, 33, 60, 65, 92, 95, 102), effects of glare (34, 39, 41, 58, 71), eye height (7, 17, 35, 62), and fatigue of a certain nature (68, 69, 70, 82). Although these factors are of paramount importance to the problem of highway traffic safety, they are not considered by the authors to be the only contributors to problems of visual communications. Futhermore, it is felt that much of the previous research work in highway visual communications has dealt with only one communication element, with little regard to its interaction with other communication elements or the environment. Many studies are also subject to criticism, on the basis of the experiment procedures utilized. The following serve as examples:

a. Most of the studies have been conducted in the laboratory environment where many of the significant parameters have been either "well-controlled" or absent.

b. The number of subjects tested in most of the studies is insufficient to enable the drawing of unambiguous statistical conclusions.

c. Many "experimenters" resort to laboratory techniques in an effort to avoid the higher order interactions between variables (and thus their interpretation) which would be present in the actual driving task.

It must be noted here that the subject of prime importance is not that which happens in the laboratory, but rather that which happens on the streets and highways. There is almost a complete lack of information in the literature in this area.

This being the case, it is obvious that the existing work does not, and cannot, provide the design engineer with much in the way of criteria upon which to base his design of the visual communication systems.

1.2 A VISUAL COMMUNICATION SYSTEM BETWEEN THE DRIVER AND HIS ENVIRONMENT

The driver's environment presents him with an infinite and complex number of visual stimuli (23, 24). Discrimination among these stimuli is known as perception. One of the more obvious characteristics of perception is its selective nature (16, 23, 27, 32, 57). At any given moment the operator's sense organs are bombarded by a multitude of stimuli, yet only relatively few of these are perceived clearly at one time. Other stimuli are perceived but less clearly, and the rest form a rather hazy background of which he is partially or completely unaware. Thus, the attention of the driver is a major factor in his communication with his environment (55). Attention may be divided into the two major areas of focus and margin. In the focus of attention are the events which are clearly perceived. Because they are attended to, they stand out from the background of experience. Other events, those in the margin, are dimly perceived, and the driver may be only vaguely aware of their presence. In addition, the attention of the driver is constantly shifting focus. That which is in focus for him at one moment may be in the margin the next, and vice versa.

Regardless of the number of visual inputs that are available to the driver, the amount of information received and processed by him depends largely upon the driver's selection from these inputs (53). In other words, it is not the density of signs or markings, as such (although this is one of the important variables), which determines the degree of communication between the driver and the roadway (77). The degree of communication is, rather, dependent upon that which the operator chooses to accept as inputs, and that which he then processessess (21). The major factors involved in determining the driver's visual inputs (i.e., events which attract his attention for an appropriate period of time) are as follows:

a. The psychological state of the driver (90, 93, 104)

b. The physiological state of the driver

c. The environmental conditions (which may include the economic and social environments)

Each of these major factors is further subdivided into specific factors which are appropriate topics for research and evaluation. These factors will be defined and briefly discussed in the material following:

1.2.1 Psychological State. The psychological parameters (primarily emotions) which govern the state of a driver are described below:

a. Alertness. Alertness is the degree of readiness to perceive stimuli.

b. Attention. Attention refers to the ability to focus (attention) on specific aspects of current experience (54, 55).

c. Experience. Experience involves the task of driving under conditions similar to those which currently prevail (52, 85, 86).

d. Learning. Learning is defined as the change in behavior due to prior conditioning and experience (78).

e. Motivation. Motivation includes that part of behavior which is instigated by particular needs and goals of the driver.

f. Anxiety. Anxiety is a vague fear which may result from frustration, etc.

g. Reaction Time. Reaction time pertains to the time from stimulus onset until response is made (96).

1.2.2 Physiological State. This is closely related to the psychological state, since behavior is based to a large extent on the physiological conditions of the individual. The parameters of interest are as follows:

a. Sex

b. Age

c. General Health. This includes diseases, as well as the result of mass transfer between the individual and his environment (i.e., foods drugs, ingested gases, etc.).

d. Integrity of the Visual System

(1) Visual acuity. This is the ability to discriminate fine differences in visual detail (14, 17, 22, 74, 75).

(2) Color vision. This is the ability to distinguish differences in light wave frequencies (60, 94).

(3) Perception. This is general awareness of objects, qualities, or events which stimulate the senses (i.e., no illusions)

(6, 23, 25, 26, 40, 79, 87).

e. Fatigue

(1) Physical. This is a tendency toward inactivity brought on by physical exertion (18, 66, 67, 88).

(2) Mental. This is a tendency toward inactivity brought on by mental or nervous exertion (50,51).

1.2.3 <u>Environmental Conditions</u>. The environmental conditions affecting visual communications between the driver and the roadway may be subdivided into the following: physical environment, social environment, and economic environment.

a. Physical environment. The physical environment may be further broken into two major categories: (1) the characteristics of the communications device and (2) the characteristics of its surroundings (i.e., the environment surrounding the device at a particular moment in time).

(1) Characteristics of the communication device

(a) Intensity and size (43). The brighter the light, the more it tends to capture the driver's attention. The larger a sign, the more likely that he will notice it. In general, if two stimuli are competing for attention, the one that is most intense will be noticed first.

(b) Contrast (10, 13, 36, 63). Characteristic of human beings is the ability to adapt to common surrounding stimuli (73). As the driver proceeds in an automobile, he is not aware of the hum of the engine, but should a cylinder misfire, the noise of the engine will occupy the center of his attention. Any change in the stimulation to which he has become accustomed (adapted) immediately captures his attention. Both the onset and termination of a stimulus tend to provoke attention, because both contrast with what has preceded them.

(c) Repetition. A stimulus that is repeated has a greater chance of "catching" the driver during one of the periods when his attention to a task is waning.

(d) Movement (76). The eyes are involuntarily attracted to movement in much the same way as the moth is attracted to a flame. Movement is one of the most effective attention-getters. (Very little research in this area has been published.)

(2) The characteristics of the surroundings

(a) Roadway design (geometrical design, sign placement, etc.) (19, 61, 83, 84, 89)

(b) Weather

(c) Traffic density (80, 81)

(d) Light (day or night) (5, 29, 37, 38, 39, 45, 48, 49)

(e) Noise and vibration (100, 101)

(f) Vehicle characteristics and integrity (9, 20, 32, 44, 46)

As noted earlier, some of these factors have been researched more than others, but not enough emphasis has been placed on the way in which they relate to the visual communication problem per se. It is suspected that these factors exert a great deal of influence on the ability of the driver to focus his attention, and thus communicate with his environment. Because of this, the authors feel that these factors should be studied.

b. Social environment. The upbringing of a particular driver is considered to have some effects on his general behavior, including the interpretation of messages from communication devices (information sources). As such, it is felt that the social environment of the operator will contribute to his information reception and processing characteristics.

c. Economic environment. In much the same manner as social environment, there is a possibility that a driver's economic conditions contribute to his driving habits. However, it should be noted that efforts to corroborate these assumptions in relation to accident records have thus far shown little, if any, correlation.

1.3 CONCLUSION

Based on the literature surveyed, it can be stated that the total research effort that has been applied to date to the problems of visual communication systems is insufficient for the designer's needs. The present body of information does not provide an understanding of the problems involved. None of the factors influencing the communication problem has been investigated in sufficient detail to permit effective and efficient action by those responsible for highway systems design. A more scientific approach to all levels of this problem is needed.

To reiterate, the visual inputs available to the driver are numerous, but the input accepted for processing depends on that upon which the operator is focusing his attention at that particular instant in time (42). Only those events in the center of focus (note that the focus of attention should not be confused with the focal vision of the eyes) are the ones that receive adequate attention to be subsequently processed by the driver (15, 16, 21, 27). Once the input is accepted in the focus of attention, it is ready for processing. However, this is no guarantee that it will be processed. That which is processed depends upon the channel capacity of the visual system (56, 57, 59) and the degree of noise (distortion) associated with the transmision (71, 72). (See Appendix for a brief discussion of information theory.)

2.0 RECOMMENDATIONS FOR FUTURE STUDY

Officials responsible for the design, construction, maintenance, and operation of the nation's highways are continually faced with the problem of devising effective techniques for communicating with the driver and informing him about his location. The two major areas that need intensive investigation are: (1) how to attract the driver's attention to an information source (sign) for a sufficient period of time to insure the transfer of information; and (2) how to keep the driver alert. The problem is further complicated by the fact that drivers encounter highway signs in a multiplicity of various circumstances (for example, in urban, suburban, or rural settings; at irregular intervals in both space and time; in an assortment of geometric and geographic configurations; carrying a wide range of information; and so on). Still another difficulty is imposed by the transitory nature of the physical environment, such as day versus night, and inclement versus clear weather.

As a consequence, there is a lack of uniformity in the circumstances under which the driver is expected to perceive and respond to highway signs. At the same time, however, current traffic engineering emphasis is on uniformity of signs, signals, and markings (98, 102). The problem seems to be one of placing the proper emphasis on special situations. Such situations should be treated so that attention is called to them without causing disregard of other controlling elements of the driving task. This conflict has been the subject of many discussions in the literature.

The development and use of basic principles which allow sufficient latitude for the application of sound engineering judgment is preferable to rigid adherence to handbook rules. Thus, signing uniformity should be a uniformity of basic principles, designed to provide motorists with information necessary to achieve two goals: (1) to follow a pre-selected route with an absolute minimum of uncertainty; a driver may know where he is going and how to get there but may be forced to operate in an unsafe manner by the signing, and (2) to maintain orientation with respect to prominent points along the route.

Understanding how to attract the driver's attention and how to maintain his alertness will then provide an appropriate setting for the recommended research. In the opinion of the writers, the vehicle, driver, and roadway should be treated as a closed-loop control system with feedback, and adequate experiments should be conducted as outlined below.

3.0 RECOMMENDED RESEARCH APPROACH

The recommended research approach to be followed in general considers a number of factors: (1) information acquisition or how the operator takes in information from visual and other sensory sources; (2) information processing or what intervening variables operate on this "physical" information to produce some response from the operator; and (3) information output or the motor output, if any, that is associated with the feedback of information into the system of which the operator is a part.

The main concern here should be the treatement of man (the operator) as if he were part of a definable physical system, and the determination of useful specifications of an input-output characteristic for the improvement of the total system performance.

A number of statistically designed experiments should be conducted to investigate the factors involved in the communication system, in an attempt to isolate those of significant importance. It is noteworthy to point out that the number of variables in situations like this can become very large. However, there exist known techniques (for example, random balance experimental design; factor analysis; etc.) well-suited to handling problems of this nature.* It is the recommendation of the authors that such techniques be utilized in future research projects.

*See Technometrics, Vol. 1, No. 2, May 1952. (Special issue on random balance design).

4.0 CONCLUSION

The focus of this study was not on the development of a detailed list of recommended actions or on the design of experiments to accomplish the same, but rather the focus was on the assessment of the current state of knowledge regarding the factors which affect visual communication systems on the highways. A number of general recommendations are included which, if applied, should aid in resolving much of the asperity and specious debate which currently characterizes the traffic problem.

Use of the random balance experimental design will require more information than is presently available. Existing information, however, is probably adequate for preliminary investigations under actual driving conditions utilizing the technique of factor analysis. These preliminary investigations should allow determination of the variables which are most critical in their contributions to the performance of the total man-machine system. With this knowledge, a more direct approach using more exact measurement techniques (i.e., random balance design) should be feasible, thus furnishing some parameters which will be useful to the designer of visual communication systems. Furthermore, these scientific approaches, should serve to focus more clearly on additional research needed, as well as the specific information requirements in each area. In addition, they should foster more effective use of the total body of information, which will be developed in addition to that which is presently available.

5.0 APPENDIX I

COMMUNICATION SYSTEMS AND INFORMATION THEORY*

5.1 INTRODUCTION

The word communication may be used in a very broad sense to include all of the procedures by which one mind may affect another. This involves not only written and oral speech, but also music, the pictorial arts, the theater, the ballet, and in fact, all of human behavior. It may be desirable to use a still broader definition of communication, namely, one which would include the procedures by means of which one mechanism affects another mechanism.

5.2 THREE LEVELS OF COMMUNICATION PROBLEMS

Relative to the broad subject of communication, according to Shannon and Weaver, there seem to be problems at three communication levels:

a. Level One. How accurately can the symbols of communication be transmitted (the technical problem)?

b. Level Two. How precisely do the transmitted symbols convey the desired meaning (the semantic problem)?

c. Level Three. How effectively does the received meaning affect conduct in the desired way (the effectiveness problem)?

The technical problems are concerned with the accuracy of transfer from sender to receiver of sets of symbols, or of a continuously varying signal, or of a continuously varying two-dimensional pattern, etc.

*Claude E. Shannon and Warren Weaver, "The Mathematical Theory of Communication." The University of Illinois Press, 1964.

Mathematically, the first involves transmission of a finite set of discrete symbols; the second, the transmission of one continuous function; and the third the transmission of many continuous functions of time or of one continuous function and two space coordinates.

The semantic problems are concerned with the identity, or satisfactorily close approximations, in the interpretation of meaning by the receiver, as compared to the intended meaning of the sender or senders. This is a very deep and involved situation, even when one deals only with the relatively simple problems of communicating through speech.

The effectiveness problems are concerned with the success with which the meaning conveyed to the receiver leads to the desired conduct on his part. It may seem, at first glance, undesirably narrow to imply that the purpose of all communication is to influence the conduct of the receiver. But with any reasonably broad definition of conduct, it is clear that communication either affects conduct or is without any discernible and probable effect at all.

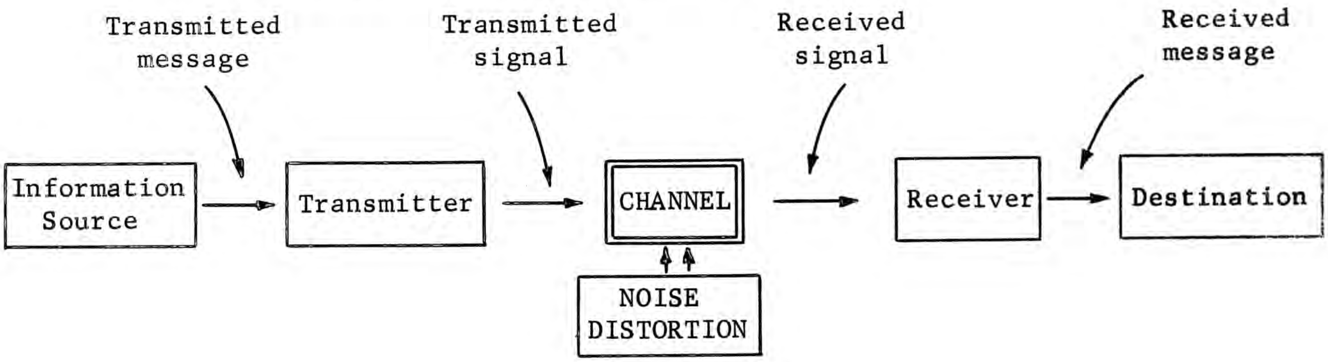
The problem of effectiveness involves aesthetic considerations in the case of the fine arts. In the case of speech, written or oral, it involves considerations which range all the way from the mere mechanics of style, through all the psychological and emotional aspects of propaganda theory, to those value judgements which are necessary to give useful meanings to the words "success" and "desired" in the opening sentence of this section on effectiveness.

The effectiveness problem is closely interrelated with the semantic problem and overlaps it in a rather vague way. There is, in fact, overlap between all of the suggested categories of problems.

5.3 A COMMUNICATION SYSTEM AND ITS PROBLEMS

The communication system considered may be symbolically represented as follows:

BASIC ELEMENTS OF A COMMUNICATION SYSTEM



The information source selects a desired message from a set of possible messages (this is a particularly important remark, which will require considerable explanation later). The selected message may consist of written or spoken words, or of pictures, music, etc.

The transmitter changes this message into the signal which is actually sent over the communication channel from the transmitter to the receiver. In the case of telephone, the channel is a wire; the signal is varying electrical current on this wire; the transmitter is the set of devices which changes the sound pressure of the voice into varying electrical current. In oral speech, the information source is the brain; the transmitter is the voice mechanism producing varying sound pressure (the signal) which is transmitted through the air. In the highway driving situation, the sign on the side of the road is the information source. The message is transmitted as electromagnetic signals by reflections through the air space (channel) to the driver's eye (receiver). The destination is the driver's brian.

The receiver is a sort of inverse transmitter changing the transmitted signal back into a message, and handing this message on to the destination. When one person talks to another, the speaker's brain is the information source; the listener's, the destination; the speaker's vocal system is the transmitter, and the listener's ear and the associated eighth nerve is the receiver.

In the process of being transmitted, it is unfortunately characteristic that certain things are added to the signal which are not intended by the information source. These unwanted additions may be distortions of sound or static, or distortions in shape or shading of pictures, or errors in transmission, etc. All of these changes in the transmitted signals are called noise.

The kinds of questions which one seeks to ask concerning such a communication system are as follows:

a. How does one measure amount of information?

b. How does one measure the capacity of a communication channel?

c. The action of the transmitter in changing a message into the signal often involves a coding process. What are the characteristics of an efficient coding process? When the coding is as efficient as possible, at what rate can the channel convey information?

d. What are the general characteristics of noise? How does noise affect the accuracy of the message finally received at the destination? How can one minimize the undesirable effects of noise, and to what extent can they be eliminated?

e. If the signal being transmitted is continuous (as in oral speech or music), rather than being formed of discrete symbols (as in written speech, etc.), how does this fact affect the problem?

5.4 A MEASURE OF INFORMATION

Briefly, the amount of information which is contained in or conveyed by the occurrence of an event is a monotonic function of the number of equally likely alternative events which could have occurred. Thus, the amount of information contained in a particular event is not determined by what happened, but rather by what could have happened. For example, when a particular stimulus occurs, more information is obtained if the stimulus is one of 20 possibilities than if it is one of two possibilities. In this sense, information is equivalent to uncertainty; the more uncertain it is that an event is going to occur, the more information is obtained when it does occur. (If it is known that an event is going to happen, no information at all is obtained when it does happen.) Practically speaking, the terms <u>information</u> and <u>uncertainty</u> can be used interchangeably, although there are times when it seems more appropriate to use one rather than the other. But in terms of the measurements, a measure of uncertainty is the same as a measure of information, and the unit of measure is called a bit.

A bit is defined as the logarithm to the base two of the number of equally likely alternatives. This measure states, in effect, the number of two-choice discriminations which must be made in order to specify one event from a number of alternatives . For example, if an event is one of eight equally likely alternatives ($p = 0.125$), the amount of information (H) is 3 bits. Mathematically:

$$H = \log_2 \frac{1}{P} = - \log_2 P = 3.0$$

The three, two-choice discriminations involve specifying which of two groups of four, then which of two groups of two, then which of the two in the last group.

If the alternative events in a group do not have equal probabilities of occurrence, then the amount of information in the occurrence of a particular one of the events is still computed by taking the logarithm of the reciprocal of the probability of occurrence. If the amount of information conveyed by the long-run average of the entire set is desired, however, then the various amounts of information are averaged. In the averaging process, each computed amount is weighted according to its probability of occurrence. Thus, the following results:

$$H - \Sigma_i P_i \log_2 \frac{1}{p} = -\Sigma_i P_i \log_2 P_i$$

The measure does not require that the alternative events be on a single continuum. Futhermore, if two events are different, there is nothing in the computation which is concerned with the degree of difference that exists. This is not to say that the measure cannot be applied when a metric difference is known, but rather that the measure can be used whether or not the metric is known. For many cases of qualitative judgment, in which it would be impossible to obtain a true correlation, the amount of information can be computed and can convey important implications about the data.

6.0 APPENDIX II

ANNOTATED BIBLIOGRAPHY

PROJECT RF 606
DIAGNOSTIC STUDIES OF HIGHWAY VISUAL COMMUNICATION SYSTEMS

6.1 VISUAL REQUIREMENTS IN THE DRIVING TASK

1. Allen, Merrill J. "Certain Visual Aspects of the Average Modern American Automobile." Journal of the American Optometric Association. Vol. 34, No. 5. (December, 1962). pp. 380-383.

   Study four major American car manufacturers' cars to learn the position of the drivers' eyes in the vehicles and the location and size of visual obstructions.

   Pictures taken of cars on a freeway to locate drivers' eyes in the cars. Camera mounted at drivers' eye positions.

   American Motors' products have the least obstruction in 180° vision. No American auto meets English SMMT standards for left front corner posts. Corner posts are in line of vision.

2. Allen, Merrill J. "Daytime Automobile Windshield and Dash Panel Characteristics." American Journal of Optometry and Archives of American Academy of Optometry. Vol. 40, No. 2. (February, 1963). pp. 61-71.

   Text - the visual environment of American cars.

   Subject - 56 cars to check the drivers' abilities to see through their windshields without reduction of contrast, to read instrument panel at a glance, and to not have glare from the car (1959-62 cars).

   All cars had faults as far as visibility of the highway and dash panel. Amount of light reflected from dash into drivers' eyes is about 15%. Chrome in field of view caused glare on all cars tested. Dash panel lighted too low for day use. ("I did not see him" may be a valid excuse due to the way cars are built.)

3. Allen, Terrence M. "Night Legibility Distances of Highway Signs." Highway Research Board. Bull. 191. (January, 1958). pp. 33-40.

   Validate in the field what lab studies had determined about distance, size of letters, illumination of signs, and reflectivity.

   2,800 observations were made. Car's speed was 15 mph. Reaction time was considered 0.7 sec.

Daytime legibility showed that there was no difference in legibility between the two alphabets. Optimum illumination was about 10 foot-lamberts. Use stroke width of about 0.20 of the height of the letter. Overhead signs are generally best.

4. Allen, T. M. "Night Legibility Distance of Highway Signs." Highway Research Board. Bull. 191. (1958). pp. 33-40.

Study of sign legibility (night and day), lighting and size of letters, to validate lab studies on the field.

Study Procedure: 1) Flat highway, 2) speed 15 mph, 3) speak when you can read the sign. Location of signs (20 feet over lane, 20 feet right of highway). Five types of reflective materials.

Day: Legibility 88 feet per inch of letter.
Night: proper luminance 10 foot-lamberts (higher in urban areas). Takes brighter material for overhead than roadside signs.

5. Arnulf, A. "Research and Visual Problems in Night Driving." (London: Pergamon Press, 1963. "Lighting Problems in Highway Traffic." Wenner-Gren Center International Symposium Series, Volume 2, 15-24; Rd. Abstr., August, 1964, 31, 187).

Problem of a minimum visual acuity level, below which it is dangerous for a person to drive, is considered. The establishment of such a value would make it possible to remove from the roads drivers incapable of minimum performance, and also to serve as a basis for determining adequate lighting for night traffic.

6. Bartlett, N. R., Bartz, A. E., and Wait, J. V. "Recognition Time of Symbols in Peripheral Vision." Highway Research Board. Bull. 330. (1962). pp. 87-91.

1) Develop transportable recording system that could be used in moving vehicles to record eye movement, 2) investigate human response time to signals in peripheral vision.

Increase the number of signals. Record eye movements in complicated situations.

Response time longer for complex visual situations; greater the angle in periphery, the longer the response time. More signals mean longer response time.

7. Barlett, N. R. and Cozan, L. W. "Perceptual and Field Factors Causing Lateral Displacement." Public Roads. Vol. 32, No. 11. (1963). pp. 233-240.

Analysis of the underlying factors that cause the lateral displacement of a vehicle away from a roadside object.

Conducted during the daylight hours under free field conditions. Variables of object location and vehicle speed were used.

Lateral displacement is a special case of visual velocity perception. The object moves effectively across the observer's retina with a definable angular velocity. Drivers react to this by determining when and how much they should displace on the basis of the time and distance at which the velocity increases sharply.

8. Bergstrom, S. S. "Visible Distances During Night Driving." (London: Pergamon Press, 1963. "Lighting Problems in Highway Traffic." Wenner-Gren Center International Symposium Series, Volume 2, 73-78; Rd. Abstr., August, 1964, 31, 191).

Some results from investigations carried out at the Psychological Laboratory, University of Uppsala, Sweden, are described and illustrated. Full headlights and symmetrical dipped headlights as meeting lights are compared, using visible distances as a criterion of their efficiency. Four reflectances (grey-black, dark grey, light grey, and white reflectorized tape) were used to test effect of different reflectances of lights on visible distance. Full headlights gave farther visible distances when meeting (for all reflectances) than dipped headlights. If dipping takes place it should be done at much later stage than is now practiced. If visible distance is taken as only criterion of efficiency for meeting lights, dipping should not take place at all.

9. Biggs, N. L. "Directional Guidance of Motor Vehicles - A Preliminary Survey and Analysis." Ergonomics. Vol. 9, No. 3. (May, 1966). pp. 193-202.

A theoretical discussion of the driving task with special reference to the visual information required by the driver in steering. The visual field of the observer in motion is considered in detail, and some suggestions are made as to the method by which drivers follow the road.

Some possible applications of the theory developed to practical situations are presented. These indicate a need for clearly defined curb lines and lighting arrangements (delineators) for use at night or in fog, etc.

10. Blackwell, H. R. "Contrast Thresholds of the Human Eye." Journal of the American Optometric Association. Vol. 36. (1946). pp. 624-643.

Determine the contrast threshold of the normal human observer under a wide variety of experimental conditions.

Project a spot of light on a white screen some 60 feet from a group of observers who individually reported whether the stimulus had been seen. Stimulus brightness was varied. Stimuli size and screen brightness were changed.

450,000 responses reported on contrast $= \dfrac{\text{B screen} - \text{B object}}{\text{B object}}$

Threshold by urban method = 50% probability of seeing. At high brightness, especially for large stimuli, contrast becomes constant with respect to adaptation brightness. Several curves and charts for determining threshold under different conditions.

11. Blackwell, H. R., Prichard, B. S., and Schwab, R. N. "Illumination Requirements for Roadway Visual Tasks." Highway Research Board Bull. 255. (1960). pp. 11-127.

Reports on the establishment of illumination levels required for the performance of typical visual tasks involved in night driving.

Seeing a mannequin and black dog, at various distances.

1.9 footcandles of horizontal illumination when the object is in the lane 200 feet ahead. Light required depends on geometry of visual tasks.

12. Botha, B. and Shurtleff, D. "Studies of Display Legibility. II. The Effect of the Ratio of Widths of Inactive to Active Elements Within a TV Scan Line and the Scan Pattern Used in Symbol Construction." (Bedford, Mass: Mitre Corp., 1963, Rep. ESD-TDR-63-440, 25 pp.).

This continuation of an earlier study in which the effects on legibility of the number of scan constructions per symbol height were examined determined the effects of (a) ratio of widths of inactive to active elements within a TV scan line, (b) scan pattern (the path of the scan element over the symbol) used in symbol construction, and (c) method of symbol illumination (reflected light vs. transilluminated light). Two groups of subjects viewed tachistoscopically transilluminated capital letters at a 0.03 second exposure for each of three different ratios of the widths of inactive to active elements within a TV scan line. Each group viewed letters constructed by a different scan pattern. The results showed that both accuracy and speed of response in letter identification decreased as the ratio of the widths of inactive to active elements increased. The scan pattern used in the construction of letters had a progressively greater effect on response accuracy as the ratio of the widths of inactive to active elements within a TV scan line was increased. The method of symbol illumination had no effect on either response accuracy or speed.

13. Bowman, M. A. "Peripheral Contrast Thresholds of the Human Eye." Journal of the American Optometric Association. Vol. 40. (1950). pp. 825-832.

Determine the effects of time and target size on contrast.

A circular spot of size (d) between 6.6' and 8° was protected 7° nasal from the fovea. Stimulus exposure (t) time from 0.02 to one second. Green light was used for the background and test spot.

For small d and t B_c/B_b agrees with $B_c \cdot B_b^{\frac{1}{2}}$.

B_c can never decrease below a limiting value dependent on B_b.

B_c/B_b tends to be constant for large values of d and t.

B_c = contrast

B_b = background brightness

14. Bowman, M. A. and Van der Veldan, H. A. "The Two-Quanta Explanation of the Dependence of the Threshold Values and Visual Acuity on the Visual Angle and Time of Observation." Journal of the American Optometric Association. Vol. 37. (1947). pp. 908-919.

Check the two-quanta explanation.

Eye of the observer was completely darkened, a flash of light was transmitted.

Flash of light was received on a spot of the retina about 7° nasal from the fovea. A rod reacts on the impulse of one quantum and sends an impulse to its nerve connection. A light impression will be given when impulses are given by two rods lying in an area corresponding to a visual angle of 10 minutes and following each other within the time of .02 seconds.

15. Broadbent, D. E. "S-R Compatibility and the Processing of Information." (Cambridge University.) (Paper to Symposium XXXVIII (Information Processing and Performance) at 17th International Congress of Psychology, August, 1963; abstr. in Acta Psych., 1964, 23, 325-326).

Recent studies have shown that when men are sufficiently practiced at a particular kind of task, they can do it just as fast with a large number of alternative signals as with a small one. Although some results can be explained by various special features which might have been involved in the task, they have tended to increase popularity of theories which make time taken for choice reaction dependent upon some process of statistical decision with the nervous system. These results also make it plausible that the relationship between choice time and probability of any particular event will be influenced by the degree of uncertainty which exists concerning correct response when any particular stimulus is presented. A study is here reported in which the same task is performed under compatible and incompatible conditions, and the effects of various other factors are noted upon both versions of the task. Stimuli were always vibrations applied to finger tips; responses were pressing of keys by fingers. In compatible conditions, response was given with finger that had been stimulated, while in incompatible conditions, response was made with corresponding finger of opposite hand. Either two or four alternative stimuli were presented. Incompatible version of task not merely gave slower performance when there were two alternative signals, but also gave larger difference between two alternative and four alternative conditions. The incompatible version also showed more interference with simultaneous auditory task, and was also more seriously affected when time of arrival of the reaction stimulus became uncertain. It showed larger effects when one stimulus was more probable than the others, with the improbable stimuli giving very long reaction times under incompatible conditions (condensed abstract).

16. Chaney, R. B. "Information and Complex-signal Perception." (Paper U10 to 67th Meeting, Acoustical Society of America, May, 1964).

Information processing with certain multidimensional auditory signals was investigated as a function of observer's previous experience in identification of those signals. Physically similar signals representing speech sounds and sonar signals were presented for identification of four to six dimensions, including source, content, localization, and variations of duration and frequency. Two groups of listeners were selected, both with similar linguistic background, but one with extensive training in sonar-signal perception, while the other was essentially naive in this respect. These groups attempted to identify under pressure of time the dimensions of each test signal as it was presented simultaneously with an irrelevant signal. Information-transmission rates were determined for each dimension of each signal type (speech sonar). Results are discussed in terms of a hypothesized perceptual hierarchy of response that depends not so much on physical properties of signal per se, but rather on listener's familiarity or experience with them.

17. Crinigan, Richard P., Jr. "A Survey of Motorists' Vision Requirements." Traffic Safety. Vol. 57, No. 3. (September, 1960). pp. 29-32.

Determine passing vision standards.

Survey of 40 states' requirements was made by questionnaire. Questionnaires were sent to 49 states of which 40 answered.

All states make a test for visual acuity. Passing standard average is 20/40 ranging from 20/25 to 20/70. Eighteen states test color perception. Three states test for fusion. Retest, nine states test vision at renewal time for operator license; eleven states test older people more often; twenty-five states require accident repeaters to be retested. Keep upgrading vision tests; set national vision standards; and start testing eyes under night conditions.

18. Dobbins, D. A., Tiedmann, J. G., and Skordahl, D. M. "Vigilance Under Highway Driving Conditions." Perceptual and Motor Skills. (1963). pp. 16-38.

Study the effect of prolonged driving on the vigilance of Army truck drivers.

Forty-two Army truck drivers drove heavily loaded trucks in nine hour shifts over experimental driving loops. They monitored a visual display of fifteen lights on which 30 critical signals appeared each hour.

Critical signal detection averaged 83% over all driving periods. Individual differences in critical detection scores ranged from 21% to 100%.

19. "Drivers Get a Lift From Raised Lane Markers." The American City. Vol. 81. (May, 1966). pp. 147.

Raised reflective lane markers add an extra margin of safety to Nimitz Freeway near Oakland, California.

Catadots measure 5.8 inches high and four inches in diameter and appear as a series of lane markers in the day and a line of reflectors at night. They are good for fog and cause a rumble when they are run over.

After ten years of experimentation, "dots" were adopted rather than pointed lines. They are used with painted lines. State officials report that plain lines are best in daytime, and "dots" are best at night. "Dots" diffuse and dissipate light in daytime appearing gray and dull. They show as white to oncoming traffic and red to the opposite direction.

20. Elliott, Frank R. and Louttit, C. M. "Auto Braking Reaction Times to Visual vs. Auditory Warning Signals." Indiana University. Before Indiana Academy of Science on November 5, 1937.

Do auto drivers react faster to sight than sound? How do women compare to men? How do occupational groups compare? What correlations are there between speed and age, speed and experience?

Experiment ran at Indiana State Fair. Ford Coupe was stationary. Subject held acceleration one-half way in until signaled to shift to the brake Bergstrom Chronoscope at driver's eye level measured reaction time. Three trials of sight and three trials of sound were run per subject. Seven hundred subjects were used.

It took 1/100 of a second less time to brake stimulated by sound than by light. A person who reacts rapidly to one method also reacts well to another. Women require 4/100 of a second more time to react than men. People with more education and higher on the Barr scale have faster reaction times. Age tends to slow reaction time.

21. Fitts, P. M. "Cognitive Factors in Information-processing." (Paper to Symposium XXXVIII (Information-processing and Performance) at 17th International Congress of Psychology, August, 1963, abstr, in Acta Psych., 1964, 23, 327-328).

This paper considers some of the implications of viewing human information-processing as if it were under the control of a learned programme. It is assumed that human subjects (a) learn information-processing programmes relatively slowly, (b) shift from one programme to another once they are learned, and (c) may sometimes continue to use relatively inefficient programmes for long periods. In the studies described, some subjects were trained in a three-alternative and others in a fifteen-alternative perceptual-motor task. Improvement in speed continued steadily for 10,000 trials, and choice reaction time remained consistently faster throughout learning trials for a smaller number of alternatives. However, when subjects were shifted to opposite task at the end of 10,000 trials, their response times changed almost immediately to a level approximating that reached by subjects who had received extensive training on the other task (generalized transfer). Two conclusions are drawn: (1) subjects can learn both specific and general information-processing skills of programmes, but some skill learning is quite slow in adult subjects, and certain general skills, such as capacities for adapting to changes in payoff for speed vs. accuracy, or changes in relative frequencies within a sequence, are already possessed by adult subjects; and (2) cognitive aspects of information-processing, as reflected in generalized skills, can readily be accommodated by assuming learning of efficient decision-type programmes. (Condensed abstract)

22. Fletcher, Edwin D. "Visual Acuity and Safe Driving." Journal of the American Optometric Association. (February, 1949). pp. 439-442.

General discussion of visual acuity and safe driving.

Since accident-proneness cannot be defined with any degree of certainty, it cannot be measured by tests.

Although some people can drive safely with 20/200 vision, not all people with 20/200 vision can drive safely.

Road signs must be seen and understood, or driving becomes hazardous. A person needs more visual acuity for night driving. There seems to be no difference in the number of people who have visual acuity trouble in accident vs. non-accident groups. Unsafe vision that is compensated for (by glasses or care in driving) becomes safe vision.

23. Goldberg, S. and Roby, T. B. "Information Acquisition in a Pattern Identification Problem." (Bedford, Mass.: Air Force Systems Command, Electronic Systems Division, 1963, Rep. ESD-TDR-63-141, 23 pp.)

Information acquisition is an important factor in decision making. Two experiments are reported which investigate information-seeking behavior conditions: (a) Information storage--the means of "storing" (keeping track of) information; e.g., memory, pencil and paper, visual display. (b) Information density--how much information was given and how it was distributed in time and/or operations. (c) Information cost--the extent to which subject expected gain was a function of information seeking.

24. Gordon, Donald A. "Experimental Isolation of the Driver's Visual Input." Human Factors. Vol. 8, No. 2. (April, 1966). pp. 129-137.

Present the operator's visual input. Determine what the main point of vision is and if there is a set pattern of viewing the roadway.

Decrease the visual field so essential information is obtained in separate visual fixations. Continuous film record is made of the center of visual aim. Using this method, positional data were obtained for ten drivers on a two-lane low traffic density road.

Essential information for driving are road's edge and centerline. Driver does not have a fixed point of forward reference. There is not a common pattern of viewing. Movements from road edge to centerline may be caused by contrary requirements of perceptual anticipation and vehicular alignment.

25. Gordon, Donald A. "Perceptual Basis of Vehicular Guidance." Public Roads: A Journal of Highway Research. Vol. 34, No. 3. (August, 1966). pp. 53-68.

Covers vehicular guidance as related to the driver's visual environment.

Covers:
1) Generalized equations of the driver's moving visual environment
2) Static and dynamic visual fields in vehicular guidance
3) Motion parallax and perceptual hypothesis testing
4) Perceptual mechanisms in vehicular guidance

Covers the ideas and equations rather well.

26. Gordon, D. A. and Michaels, R. M. "Static and Dynamic Visual Fields in Vehicular Guidance." Highway Research Record No. 84. (1965). pp. 1-15.

Determine the visual input. Mathematical description of the moving ground plane from the driver's eye. Use made by the driver of the positional velocity and acceleration fields.

Derivation of equations of position and motion, assumptions made and ideas drawn from other works.

Scaling of visual angle, features of visual environment, velocity field. Roadway boundaries and lane markings in aligning, angular acceleration as square of vehicular speed, angular acceleration is not directly sensed.

27. Gould, J. D. and Schaffer, A. "Eye-movement Patterns in Scanning Numeric Displays." (Perceptual Motor Skills, April, 1965, 20, 521-535).

Eye movements of three subjects during visual scanning of 15° 21' on 6x6 numeric matrices were studied, using a modification of the Mackworth eye-marker apparatus, as a function of frequency of target numeral (0 to 7), digit scanned for, and learning (176 trials). Results indicated that time to scan varied significantly with both frequency and target digit, and these time differences were reflected by significant departures from the overall average number of fixations (18), while average duration of fixations (0.31 sec) remained relatively constant. The average durations of fixations on target numbers (0.32 sec) and non-target numbers (0.30 sec) were not statistically significantly different. Average center-to-center distance between the closest fixation and a target number was 2° 29' and this differed among digits, being 2° 42' for the most quickly recognized and 1° 36' for the most difficult to recognize. The results indicated the possible role of eye movements in information-processing.

28. Haber, H. "Safety Hazard of Tinted Automobile Windshields at Night." Journal of the American Optometric Association. Vol. 45. (1955). pp. 413-419.

Theoretical analysis of the effects of tinted windshields on visibility distance at night.

Replaced with plain windshields and figured the percent loss.

Loss is dependent on isofootcandle profile of headlamps, angular size and reflectance of the target and distance from the target. Loss ranges from 9 to 15% at distances between 1000 and 2000 feet. Loss is greatest where target matches the background (loss may be 30 to 45%). Recommend reconsideration of the minimum 70% transmittance law.

29. Hattwick, R. G. "Dark Adaptation to Intermediate Levels and to Complete Darkness." Journal of the American Optometric Association. Vol. 44. (1954). pp. 223-228.

Determine adaptation characteristics.

The course of change of the visual threshold was measured during adaptation from high-luminance levels to various low-luminance levels and to darkness. Measurements were foveal and parafoveal.

It would be incorrect to use the time necessary to adapt from a given light-adapted level to darkness to determine the time required to adapt to an intermediate level.

30. Heath, W. and Finch, D. M. "Determination of Windshield Levels Requisite for Driving Visibility." Highway Research Board Bull. 68. (1953). pp. 1-15.

Tinting to reduce heat also reduces light transmission. Determine if there is any difference in nighttime visibility with untinted or tinted windshields.

On road tests, visibility distances measured by a recorder in the auto, a button pressed when the object was first seen, marked on a drum connected to speedometer.

Tinted glass causes a reduction in visibility distances. Recommend that 70% luminous transmittance be required.

31. Hill, A. B. and Large, C. Q. "The Effects of Time Stress and the Elimination of Cue Information of the Display-control Relationships of Moving Scale Instruments." (Army Operational Research Establishment). (Journal Applied Psychology, August, 1964, 48, 255-258).

The reading of four rotary-moving scale assemblies of different display-control relationships was investigated using sixteen subjects, eight soldiers and eight scientists, in a Latin-square design. Performance times, initial movement errors, and final settings on each assembly were noted. Initial movement errors indicated that an assembly employing compatible movement, scale numbers increasing from left to right, and a "turn anticlockwise to increase" condition was optimum. Performance times tended to reflect the number of errors committed. No final setting errors were made, this being attributed to the nongraduated type of scale used. The absence of cue information provided by the visibility of two or more scale values was found to be detrimental to performance.

32. Johansson, G. and Rumar, K. "Drivers and Road Signs: A Preliminary Investigation of the Capacity of Car Drivers to get Information from Road Signs." Ergonomics. Vol. 9, No. 1. (January, 1966). pp. 57-62.

Purpose of the investigation was two-fold:
1) To find the maximum level of performance in recording (seeing and taking in the information contained) road signs.
2) To find to what degree road signs, which are supposed to act as signals, fulfill their function in imparting information to drivers.

It was found that the mean percentage of drivers recording a road sign was 47 percent of those who passed it. (This is based on five different signs and approximately 1000 drivers.) Variation between signs was concluded to be due to urgency of information contained in the sign; the greater the urgency, the higher the percentage recorded.

33. Kuzokov, M. M., et.al. "Fluorescent Road Signs." (In Russian). (Avtom. Dorogi, 1963, 26(9), 5-6; Road Abstr., January, 1964, 31, 17).

Fluorescent enamels three to four times brighter than ordinary enamels have been used on experimental road signs in the U.S.S.R.; they are visible at 1000 m in daylight and 300 m at night and legible at 300 m and 200 m, respectively. The enamel is prepared from organic materials (resin pigment with fluorescent coloring matters and a colorless binder). Absorbed violet, blue and green light can be converted into red and orange and radiated with the reflected rays; colors obtained are yellow, red, and blue. Signs of this type were tested by Soyuzdorny in 1962; no deterioration has been noted after 14 months' service on the Moscow-Gorke road and on a site in Moscow. A comparative table of costs and performances for various types of signs shows that the initial higher cost of fluorescent signs is justified by their long life and performance.

34. Lee, R. E. "Driver Eye Height." (Austr. Rd. Res., May, 1964, 31, 108).

Vertical curve design in Australia is based on driver eye height of 4 ft. above road. This paper describes investigations carried out on both urban and rural roads in Victoria to determine whether this value is realistic. Some 2000 photographs were taken of passing cars at three urban and four rural sites. Almost 800 of these were rejected urban and four rural sites. Almost 800 of these were rejected for various reasons, but the remainder was examined, and horizontal and vertical co-ordinates establishing driver's eye height were recorded on punched cards. Examination of results shows that newer cars give lower eye heights than older models, and about 50% of eye heights were less than 4 ft. It is suggested that 3 ft. 6 in. would be a more realistic value for use in curve design.

35. Marimont, R. B. "Model for Visual Response to Contrast." Journal of the American Optometric Association. Vol. 52. (1962). pp. 800-806.

Presents a model that explains the phenomenon of subjective brightness; high illuminance greatly increases the apparent contrast of a scene.

Model makes both reference level and gain of the system depend on average illumination. Model uses only one correction factor.

Model needs improvement but is a step in the right direction.

36. Martin, Harrison P. "Night Vision." Motor Boating. Vol. 114. (July, 1964). pp. 119.

Discussion of night vision.

It takes time for the eye to adjust to darkness. A person can look at red light and go into the dark not needing time to adjust, RAF 1943. Use of red goggles by the Army during WW II proved beneficial. Try to avoid the need to change light intensity rapidly.

37. Matanzo, F., Jr. and Rockwell, T. H. "Driving Performance Under Nighttime Conditions of Visual Degradation." Human Factors. Vol. 9, No. 5. October, 1967. pp. 427-432.

Nighttime driving performance was studied in relation to four different driving tasks and four levels of visual degradation. Four matched but task-differentiated groups of four subjects each drove an instrumented vehicle at night on a superhighway. The four levels of visual degradation presented the roadway to the driver at overall luminance levels of 5.288 mL.

The visual degradation caused the subjects to slow down and to position the vehicle slightly farther away from the shoulder. It was found that a driver also is capable of driving at a constant speed and of maintaining a constant lane position at very high degrees of visual degradation.

38. Michaels, Richard M. and Burton, W. Stephens. "Methods of Human Engineering." Society of Automotive Engineers, Farm Construction and Industrial Machinery Meeting, Milwaukee, Wisconsin, (September 11-14, 1967).

What are the stimuli used by man to estimate velocity?

I. Angular velocity of elements in the environment. From a line along the center of the visual field, angular velocity increases rapidly but proportionally from zero back toward the driver's position in the vehicle. There is no one-to-one correspondence between what the driver sees and what his speedometer reads.

II. Sensitivity of the eye to motion decreases from the fovea to the periphery; however, angular velocity increases from the center out. Most velocity judgments are made on moving in the periphery.

Closure on a car

I. Man detects changes in closure and closure rate relative to vehicle being overtaken.

II. Visual angle subtended by the car ahead in man's measure of distance. There is no simple relation between distance and visual angle. Distance information is of marginal use to the driver.

Humans must process information while controlling the car, must take time from steering and speed control to explore the environment, and must measure information load and time sharing capabilities. Tests have shown that tracking and searching are hurt in the presence of each other. Need information on displays in vehicle to minimize time sharing.

39. Mortimer, R. G. "The Effects of Glare in Simulated Night Driving." (Purdue University, 1963, L. C. Mic. 64-5752, 206 pp., $2.75; Dissertation Abstract, June, 1964, 24, 5575).

Using a night driving simulator, studies were made of the effects of low illumination and headlamp glare on night driving. In all six studies, tracking (steering) accuracy was a dependent variable. Experiments I and Ia investigated interactions between roadway illumination, glare illumination, glare duration, and glare frequency. Results showed that reduction in roadway illumination from low daylight to night driving levels, and presence of glare in night driving caused large decrements in tracking performance. Experiment II showed that tracking accuracy could be increased when mean angle between fixation point and glare source was 21°; Experiment III showed that closing the left eye when meeting glare from simulated headlamps and in a no-glare (control) treatment, led to a decrement in tracking performance. Experiment IV confirmed the harmful effect of sunglasses worn in night driving under both glare and glare-free conditions. Experiment V determined the influence of low concentrations of alcohol in the blood upon performance in a simulated driving task under daylight and night driving conditions. In four visual tests only static visual acuity was significantly impaired by alcohol. It is suggested that the legal limit defining alcohol influence is too high, and that dual standards for day and night driving may be warranted. (Condensed abstract)

40. Mourant, R. R. and Rockwell, T. H. "Dynamic Visual Search in Driving." 1968 Annual Convention of the Human Factors Society, Chicago. (1968).

A study of the driver's eye movement.

Variables - route familiarity, driving conditions (open road vs. following a car). Eye movements were filmed while traveling at 50 mph.

As driver became familiar with road, center of vision became more compact shifting down and to the left. Following a car induced greater visual workload (increased rate of sampling lane markers, greater visual travel distance to examine signs and other traffic). Peripheral area of eye is used for monitoring lane position, other vehicles, and road signs so fovea may be used when needed.

41. Murdock, B. B. and Oldham, E. C. "Size of Code Alphabet and Decoding." (Burlington: Vermont University, 1 August, 1964, Contract Nonr-3219-02x, AD-605, 665, 8 pp.).

To determine effect of size of code alphabet on decoding, and original message consisting of first thirteen letters of the alphabet was generated by zero-memory source with (first-order) redundancy of approximately 14%. This message was encoded with either binary, ternary, quarternary, or septenary code. There was a different group of subjects for each code, and their task was to decode back into original thirteen letters as rapidly and as accurately as possible. Results showed that, over four sessions of testing, performance (i.e., decoding) was most rapid with septenary code and was progressively slower as size of code alphabet decreases. Since information load per symbol increases but number of symbols per code word decreases as size of coding alphabet increases, it would appear that the latter was a critical variable. In general, results confirm that for optimum information-processing one needs to maximize number of bits per chunk; thus, within limits of present experiment, the larger the size of code alphabet the better the performance.

42. Paluszkiewicz, L. "Investigation of the Application of Information Theory to Assessment of the Readability of Dial-indicating Apparatus." (In Polish: English Summary). (Ochr. Pracy, Nov., 1964, 19, 21-24).

Results of psychological investigations on interdependence between entropy of indicating apparatus and speed of perception of information are presented. Investigations have been made on five different groups of tests including 100 pictures of round scale with hand. It is established that entropy cannot be considered as precision-comparability criteria for readability of different types of indicating apparatus, but only for apparatus of same type with varying probability of appearance of separate signals.

43. Peckham, R. H. and Hart, W. M. "A Hypereffective Visual Signal for Night Driving Naming Device." Highway Research Record No. 25. (1963). pp. 84-85.

Study of the effects of slow rate flicker, concerned with interactive stimulation with low frequencies.

Contrasted brightness and dimness, two parameters luminance and time, rates 2.5, 5, and 10/sec., brightness contrast varied near threshold, sound buzzer if saw flash.

Slower rate of flashes raises the threshold, can create visual stimulus in excess by altering rate and brightness. Several fast flashes noticed better than a solid light.

44. Popescu-Neveanu, Josif, G., and Ene, P. "Certain Questions Connected with the Informational Elements of Control." (In Rumanian; French summary). (Rev. Physiol., 1963, 9(2), 249-272; Theor. Cyber. Abstr., 1964, (2), 73).

The authors investigate mnemonic diagrams on equipment by means of a graphical unit termed by them "descriptive diagram." After a survey of the specialized literature devoted to the psychological questions of control panel design, the authors analyze material accumulated in ten design institutes and twenty-five plants, concerning the forms of descriptive diagrams of various equipment.

45. Raper, V. J. "Nighttime Seeing Through Heat-absorbing Windshields." Highway Research Board Bull. 68. (1953). pp. 16-30.

Does the 18% loss of light transmitted through a heat absorbing windshield hamper night driving?

Test an airstrip with two identical cars. Regular and heat absorbing windshields were introduced into the cars. Speed of 40 mph, against glare and with clear road was used.

Heat absorbing windshields reduce vision by about 6% with no approaching car and 2% with an approaching car.

46. Raper, V. J. "Relation of Visual Acuity and Contrast Sensitivity Under Nighttime Driving Conditions." Highway Research Board Bull. 336. (1962). pp. 114.

Determine if visual acuity and ability to detect low contrast have the same bearing on night driving.

Compare thirty subjects against standard AMA test chart and Luckiesh-Moss low contrast chart.

There is no correlation between visual acuity and the ability to detect low contrast differences at night. Low contrast is synonymous with ability to see distances at night in a moving car.

47. Richards, O. W. "Vision at Levels of Night Road Illumination." Highway Research Board Bull. 56. (1952). pp. 36-65.

Discusses and summarizes some of the information pertinent to night driving, explained what levels are best for signs, etc. Covers (1)illumination range of night driving, (2) dark adaptation, (3) colored glasses and vision, (4) acuity and contrast, (5) specific factors - the eye, (6) night myopia, (7) aniseikonia, (8) general systematic factors, (9) glare, and (10) special conditions of night driving vision.

48. Salvatore, S. "Estimation of Vehicular Velocity Under Time Limitation and Restricted Conditions of Observation." Highway Research Record No. 195. (1967). pp. 66-74.

Ability of subjects to estimate the velocity of the vehicle in which they are riding. Developed to control the focus of visual stimulation.

Vehicle speed was a parameter, stimulation time held constant, four subjects (three females and one male), 120 observations, timed exposures to seeing the road.

Peripheral visual stimulation results in more accurate estimation of speed. Low speed underestimated - high speed overestimated.

49. Salvatore, Santo. "Vehicle Speed Estimation from Visual Stimuli." Public Roads: A Journal of Highway Research. Vol. 34, No. 6 (February, 1967). pp. 128-131.

Determine how the operator obtains speed information from visual stimuli in the field.

Three females and one male with uncorrected vision were used.

Speed estimation is more accurate in the periphery than in the fovea. Increased acceleration increases all absolute and relative error, thus reducing sensitivity of the visual mode. Absolute error is directly proportional to speed of the central stimulation only when acceleration is minimized. Deceleration is more effectively sensed than acceleration.

50. Schoppert, W. W. K., Moskowitz, S. F., Hulbert, and Burg, A. "Some Principles of Freeway Directional Signing Bases on Motorists' Experiences." Highway Research Board. Bull. 224. (1960). pp. 30-87.

Determine the signing and marking aids sought by motorists in the use of freeways, particularly in urban areas.

Determine how well existing standards and practices provide these aids and what changes could reasonably be made in existing practices to provide the aids sought by motorists. (What to say on signs.)

Analyzing signing locations, interviewing drivers about experiences (roadsize interviews, off the road interviews).

(1) Long trips--people use route numbers to identify path and place names to identify control points. (2) Metropolitan driving--paths identified by freeway names and place names, and place names assume less importance. (3) Urban driving (short trips in a city)--control points almost invariably identified by intersections, not by place names; identify streets by name, not route number.

51. Senders, J. W., Elking, J. I., Grignetti, M. C., and Smallwood, R. "An Investigation of the Visual Sampling Behavior of Human Observers." NASA Contractor. Report No. NASA CR-434. (April, 1966).

Determine an average person's method for visually sampling information from his environment.

In laboratory set-up, various subjects were given information from different sources at varying rates. They were expected to act on this information in some manner.

(1) It was concluded that people tend to increase the number of samples taken from an information source as the amount of information being generated by the source increases. (2) Man can extract between

1 and 1.5 bits of information per sample. (3) Man apparently decides to sample an information source when his uncertainty about the current state of that source reaches a constant threshold value.

52. Senders, J. W., et. al. "An Investigation of Automobile Driving Information-processing: Final Report." (Cambridge, Mass.: Bolt, Beranek, and Newmann Inc., 26 April 1966, Rep. 1335-0497, Contract CPR-11-0958, PB-170, 879, 164 pp.).

The report is concerned with the development of a method of measuring the driver's attention demand. A visor-shutter device was constructed, the light-dark ratio at which could be controlled and varied. Under mild traffic conditions, the driver would be expected to tolerate a relatively long dark interval; under heavy traffic, he would tolerate no interruption of his view of the road. The device was validated by determining the longest dark intercal which would be tolerated, when the car traveled at various speeds on a straight section of Interstate, and on a curved track. A formula was developed to explain the factors influencing attentional demand.

53. Senders, J. W., Kristofferson, A. B., Levision, W. H., Dietrick, C. W., and Ward, J. L. "The Attentional Demand of Automobile Driving." Highway Research Record. No. 195. (1967). pp. 15-32.

Emperical investigation of the relationship between the amount of interruption of vision and driving speed. Determine various parameters of a math model. Time between information.

Driver allowed to see the road for various lengths of time while driving a 1965 Dodge car, student subjects.

Less frequent the observation, or shorter the period of observation, slower will be the speed that driver can maintain.

54. Sergeyev, G. A. and Romanenko, A. F. "Statistical Methods for Investigating the Channel Capacity of the Human Operator." (In Russian). (Coll. Abstr. of papers for the Second Meeting of the Society of Psychologists, No. 3, Moscow, Akad. ped. Nauk RSFSR, 1963, 89-94; Theor. Cyber. Abstr., 1964, (4), 69).

The possibilities of using the so-called transfer function, which represents the system of differential equations relating input signal of automatic control system to output signals, are discussed. In cases where transfer function is inadequate, it is proposed to introduce the system of statistical and informational characteristics reflecting dynamic indices of human operator's errors and his informational properties. The basic indices of this system are to be found experimentally, and a number of concrete requirements of the experiments are stated.

55. Siegel, A. I., Miehle, W., and Schultz, D. G. "Information Transfer in Display-control Systems." "Exponent Determination and First Applications of Display Evaluative Index: Second Quarterly Progress Report, for 16 September - 15 December, 1961." (Villanova, Pa.: Applied Psychological Services, 15 December 1961, Contract DA-039-SC-87230, Project 3A99-01-001, AD-272, 068, 76 pp.).

Exponents (weightings) for bases (factors) in a display evaluative index are determined. Display evaluative technique is then applied to several Signal Corps' equipments and to hypothetical variations of these equipments. Indices and judges' ratings of ability of displays on these equipments and their variations to transfer information required for a relevant operation action appear to be in reasonable concordance.

56. Stiles, W. S. "The Effect of Glare on the Brightness Difference Threshold." Proceedings of the Royal Society of London Series B. Vol. Civ (May, 1929) pp. 322-351.

Determine the brightness-difference threshold in presence of a point-source of glare.

Presentation of a method for doing this.

Percentage of probable error of a single observation of the threshold is about seven percent. Threshold is subject to fluctuation during an extended series of reading. The threshold in the presence of the glare source is best expressed in terms of the equivalent background brightness.

57. Teichner, W. H. "Information Processing Under Task Stress: Final Report (Amherst: Massachusetts University, November, 1963, Pep. ESD-TDR-63-657, Contract AF19-628-290, Project 7682, Task 768201, AD-430, 412, 54 pp.).

Report of studies of human information-processing related to variables present in high-speed systems operations. Reviews earlier reported data pertinent to the effects of informational input rates and related factors. Presents experiments concerned with two other aspects of the problem: (1) interaction of short-and long-term memories in human data handling, and (2) effects of presented information rates on subjective information, i.e., amount of information, in the operator's estimate, of what is presented by the display.

58. "Traffic: Signs of Color." Time. Vol. 90. (November 24, 1967) pp. 84.

Report on the use of color for traffic signs.

National Joint Committee on Uniform Traffic Control Devices suggests using color on signs because hard-to-read signs cause drivers to panic. It is not good to surprise a driver at 70 mph. The first thing a

driver sees about a sign is color. The basic color spectrum used needs to be broadened. Results in Washington, D. C., and Denver have been favorable.

More use of uniform symbols is needed. More break-away signs are needed as the sign population grows.

59. Walker, J. "The Perception of Road Direction Signs." Ergonomics, Proceedings of Second International Congress on Ergonomics, Dortmund. (1964). p. 271.

Six layouts of advance road direction signs, including designs displayed in Britain, Europe, and the U.S.A. were used on drivers approaching a road junction. Time and error scores served as criteria for statistical treatment of the data. The results suggest that not only may the symbols be changed to aid discrimination, but the form of the layout may reduce conceptual work.

60. Whalen, J. T., Rockwell, T. H., and Mourant, R. R. "A Pilot Study of Driver's Eye Movements." Ohio State University Engineering Experiment Station. Report No. EES 277-1. (April, 1968).

To determine general information about driver's eye fixations and develop experimental procedures using the eye-mark camera.

Sample drivers were fitted with the eye-mark camera and told to read all road signs as they drove along a Columbus, Ohio, roadway at 50 mph. Studies were made of eye fixation positions, time of fixations, and corresponding traffic conditions.

Results: (1) Under routine driving conditions, drivers tend to concentrate most of their visual activity at a point approximately 200 feet ahead and to the upper right of the roadway. (2) When information available becomes greater and traffic conditions become more critical (as at intersections, passing, etc.), information sampling (fixations) is taken from each source more frequently, and time spent on each fixation is reduced. (3) The eye-mark camera was concluded to be accurate within ± degree of visual angle.

61. Williams, Charles M. "Legibility of Numbers as a Function of Contrast and Illumination." Human Factors. Vol. 9, No. 5. (October, 1967). pp. 455-460.

While contrast is recognized as an important variable affecting legibility, scant information of what happens in the mid-ranges is available. Thus, nine levels of contrast consisting of black lettering on white and gray backgrounds were compared under three levels of illumination - 0.06, 0.60, and 6.0 footcandles. Eighteen subjects were asked to search a stimulus array for a particular stimulus and then to indicate its relative position among the stimuli. Reaction time and errors were recorded.

Illumination proved to be the single most important factor. Significant differences in performance were observed between the contrast conditions under poor illumination, remains above 0.60 footcandles. Black-on-white and white-on-black did not differ significantly and were associated with shortest reaction times and fewest errors at all levels of illumination.

62. Wolf, E., McFarland, R. A., and Zigler, M. "Influence of Tinted Windshield Glass on Five Visual Functions." Highway Research Board Bull. 225. (1960) pp. 30-45.

Assumes 30% reduction in light transmission. Study effects of tinted glass at various luminances: (1) dark adaptation, (2) recovery from shock of a blinding light, (3) visual acuity, (4) depth perception, (5) effects of glare.

Laboratory tests were run.

(1) Rise in threshold corresponded to brightness loss due to tinted glass in dark adaptation test. (2) Recovery from light shock was not enhanced by tinted glass. (3) Visual acuity reduced slightly by tinted glass. (4) Tinted glass caused 25% to 35% loss of depth perception. (5) Glare was not reduced by tinted glass.

6.2 HUMAN INFORMATION PROCESSING CAPABILITY IN COMPLEX TASK

63. Bartlett, N. R. and Hudson, G. E. "Theory of the Effects of Light Intensity and Duration in Determining Visual Responses." National Academy of Sciences of the United States of America. Vol. 28, No. 7. (July, 1942). pp. 289-292.

Presents applications to the phenomena of brightness discrimination and absolute threshold measurements of a theory based on the familiar differential equation proposed by Hecht to account for some of the phenomena of the sensory process

Derivation of equations for: absolute threshold, brightness and darkness discrimination; "Inverse" Absolute Threshold.

64. Beitel, Robert J., Jr. "Inhibition of Threshold Excitation in the Human Eye." Journal of General Psychology. Vol. 14. (1936). pp. 31-61.

Check summation of the eyes.

When inducing patch and test patch have same order of magnitude and are presented alone within 17.2 minutes of separation, summation of excitation is demonstrated.

When the test patch was viewed in foveal vision with one eye and the inducing patch with the other eye, the threshold intensity of the test patch was found unaltered.

When intensity of the inducing patch is of the same order of magnitude as the threshold intensity of the test patch when presented alone, spatial summation of excitation is demonstrated within the limits of 130 minutes of separation.

65. Bekesy, G. Van. "Neural Inhibitory Units of the Eye and Skin. Quantitative Description of Contrast Phenomena." Journal of the American Optometric Association. Vol. 50. (1960). pp. 1060-1070.

Show how the numerical values for the neural unit can be determined for the eye and skin and how they can be used in description of Mach bands.

Neural unit - an area of sensation surrounded by a refractory area of inhibition. Rather than drawing the bands, it is possible to use a formula to calculate and to draw in the bands.

66. Brown, I. D. "A Comparison of Two Subsidiary Tasks Used to Measure Fatigue in Car Drivers." Ergonomics. Vol. 8, No. 4. (October, 1965). p. 467.

Car driving has been studied by combining it with subsidiary task performance which is negatively correlated with the perceptual load imposed by changing conditions of traffic. The present experiment compares a subsidiary task which required almost continuous attention to an auditory display, and which involved memory spans of only three seconds, with an alternative task which did not require continuous attention, but which involved memory spans of up to 55 seconds. The former was found to have some advantages. This comparison was combined with a study of men engaged in eight-hour spells of car driving. Some explanations are offered for the finding that performance on the subsidiary tasks was better at the top of the work-spell than at the beginning.

67. Brown, I. D. "Effects of a Car Radio on Driving in Traffic." Ergonomics Vol. 8. No. 4. (October, 1965). p. 475.

Eight drivers were tested in light and heavy traffic while listening to recorded programs of music and speech. The effects of these auditory distractions on the use of the car controls and time taken over a standard test circuit of 2.2 miles were measured by comparison with scores obtained in a quiet condition of normal driving. In light traffic, music significantly reduced the frequency with which the accelerator and brake pedals were used, and in heavy traffic it increased the time taken per circuit. These changes were interpreted as being beneficial. Speech had an insignificant effect on all scores, whether listening was motivated simply by interest in the program, or by the need to remember its content.

68. Brown, R. L., Galloway, N. D., and San Guliana, R. A. "Effects of Time-sharing and Body Positional Demands on Cutaneous Information-processing." Perceptual and Motor Skills. Vol. 20. (1965). pp. 1021-1026.

Check ability to interpret coded electrocutaneous pulses while engaged in visual discrimination task in four positions (standing, sitting, kneeling, and prone).

Time-sharing demand significantly impairs performance. Variation in body position has negligible effect on performance.

69. Bruner, Jerome and Potter, Mary C. "Interference in Visual Recognition." Science. Vol. 144. (April 24, 1964). pp. 424.

Determine if initial sight of an object out of focus had any bearing on recognition time.

Pictures of common objects were slowly brought into focus for adult observers.

Recognition was delayed when the object was first seen out of focus. Greater and longer the blur, the longer the recognition time was. This may be due to partly the difficulty in rejecting incorrect hypothesis based on substandard cases.

70. Cartirette, Edward C. and Jones, Margaret Hubbard. "Visual and Auditory Information-processing in Children and Adults." Science. Vol. 156. (May 19, 1967). pp. 986-988.

To determine the relation of visual and auditory processing, depending upon age of the subject and each other.

Children of three ages compared with adults in a recognition experiment requiring continuous processing of information.

Children - growth in precision for visually presented words is steeper than for auditorially presented words. Visual and auditory performance are related. Adults - visual processing at least as good as auditory.

71. Dowling, John E. "The Site of Visual Adaptation." Science. Vol. 155. (January 20, 1967). pp. 273-279.

Article supporting the theory that the main site of visual adaptation is in the bi-polar cell layer of the retina. Tries to show that the mechanism in the eye that decreases sensitivity (or gain) in the visual system is not in the receptor cells, but at the locus.

Discusses results of recent experiments.

The b-wave is the first of the known responses in the visual system to show typical adaptation properties; site of visual adaptation may be in the bi-polar cell layer, the locus of b-wave generation.

72. Johnston, Dorothy M. "Search Performance as a Function of Peripheral Acuity." Human Factors. Vol. 7, No. 6. (December, 1965). pp. 527-535.

This study was made to investigate the relationship between the size of visual fields of observers and the time required to locate targets on static displays. The findings indicate that people with large visual fields can find targets more rapidly than observers with small fields. These findings have practical application in selection and training of persons who must perform visual tasks. In addition, equations which may be used to determine search time (as a function of visual field size and area to be searched) are presented.

73. Johnston, Dorothy M. "The Relationship of Near-vision Peripheral Acuity and Far-vision Search Performance." Human Factors. Vol. 9, No. 4. (1967). pp. 301-393.

Determine if there is a relationship between near-vision, peripheral acuity, and far-vision search.

Twenty-five subjects with uncorrected vision of 20/30 foveal acuity; they were given: (1) a near-vision peripheral acuity test, (2) a far-vision search test.

Low correlation between near-vision, peripheral acuity, and far-vision search performance was shown. The relation was shown to be negligible.

74. McKinney, John Paul. "Disappearance of Luminous Designs." Science. Vol. 140. (April 26, 1963). pp. 403-404.

Determine if the human eye denoted images better when it is fixed or allowed to move.

Contact lenses over the eye to assure that image hits the same retinal spot. Six designs were used. Some work for luminous point on black background.

When lumination is low and the eye fixes on a luminous design, parts of the figure disappear and reappear rapidly. Fixed-vision will cause disappearance of the subject. Slow movement of the eyes tends to lessen the fading of images.

75. Montague, W. W., Webber, C. E., and Adams, J. A. "The Effects of Signal and Response Complexity on Eighteen Hours of Visual Monitoring." Human Factors. Vol. 7, No. 2. (April, 1965). pp. 163-172.

Four groups of 15 subjects receiving different combinations of signal rate and complexity monitored a display composed of three rows of four digital display boxes each containing a constant reference number. A change in a number lasting six seconds was the signal to be detected. There were two levels of rate, either 16 or 64 signals per hour, and complexity of response was varied by having some subjects merely report the change, while others evaluated the size of the change.

Neither rate nor response complexity influenced performance. Although all groups showed significant vigilance decrement during the session, the magnitude was relatively trivial and in line with other similar studies. In complex tasks, man seems to be an adequate monitor over rather extended time periods.

76. Mowbray, G. H. "Simultaneous Vision and Audition: The Detection of Elements Missing From Overlearned Sequences." Cambridge University.

Test the relative efficiency of vision and audition under conditions of simultaneous stimulation.

Read an alphabet or number sequence through and write down letters missing; they listened in the auditory portion.

Non-simultaneous operation - more errors made with alphabet than with numbers; more auditory errors than visual errors on number sequence (errors of omission).

Four to five times as many errors made on auditory compared to visual (omission).

Simultaneous - more errors than non-simultaneous, increase in omission errors for visual was greater than auditory.

77. Rutschmann, Ruth. "Perception of Temporal Order and Relative Visual Latency." Science. Vol. 152. (May 20, 1966). pp. 1099-1101.

Look at the ability to use peripheral vision as compared to foveal; investigate the temporal order on location of flashes on the retina. Stimuli were pairs of light flashes generated by Sylvania R1131C glow modulator tubes, one flash stimulated the fovea, the other 30° to left (temporal retina).

Peripheral reaction times are longer than foveal at 30°. Latency functions are dependent on specific retinal location of stimuli.

Uncertainty of temporal order results when the onset of foveal flash is delayed. Relative latencies vary as a function of peripheral locus is stimulated.

78. Sheridan, T. B., Fabis, B. F., and Roland, R. D. "Preview Control Behavior and Optimal Control Norms." Second Annual NASA - University Conference on Manual Control. NASA SP-128. (1966).

Investigate man's ability to process and utilize preview information in the control process.

Subjects were given varying amounts of preview information at varying lead times, and a standard control procedure was carried out in each case. (This was a laboratory exercise.)

Man apparently attempts to take in a relatively constant amount of information about his environment. When driving task is routine on relatively straight roadway, etc., the driver will tend to look farther ahead and increase the amount of preview information. But when in heavy traffic, making passing maneuver, on winding road, etc., the driver will shorten his preview distance in order to handle the same amount of information.

6.3 REFERENCES OF GENERAL INTEREST TO PROJECT RF 606

79. Bierley, R. L. "Investigation of an Intervehicle Spacing Display." Highway Research Record, 1963, (25), 58-75; Road Abstr., April, 1964, pp. 31, 91.

Experiments to test the effects of two types of information display were carried out by General Motors Corporation, U.S.A. The one showed a driver the distance between his car and the one ahead. The other showed this distance and the relative velocity of the two cars. The instrumentation is described, as well as the experimental method, and results are presented. The more informative method resulted in less variable spacing between cars.

80. Daniel, J. "Measurement of Fatigue in Engine Drivers by Means of Psycho-physiological Methods." (In Slovak). Psych. Stud., Praha, 1960, 2, 66-97; Psych. Abstr., August, 1964, 38, 5490550.

Ninety-seven electric and steam engine drivers were tested before and after working shifts lasting 13-21 hr. Results of simple tapping, simple reaction time, steadiness of hand, and illusion of weight tests decreased significantly. Disjunctive reaction time and complicated tapping were better after work; fatigue does not seem to influence complicated tasks. Electric engine driver's fatigue seems to be of neurophysical origin, steam engine driver's fatigue of muscular origin.

81. Davis, E. P. and Fitzpatrick, J. T. "Sign Placement to Reduce Dirt Accumulation." Highway Research Board. Bull. 89. (1954) pp. 7-13.

At placement four feet above and eight feet to right of roadway for light striking purposes, signs get very dirty and hard to read, where they are placed.

Several sign positions tested for dirt accumulation.

Place signs at least six feet above and ten feet to the right; rain keeps them clean and they are more easily read. Also less danger to cars.

82. Annon. "Devices for Reducing Road Hazards." (Engineering, Lond., 3 October, 1964, 198, 442).

Many new developments have been demonstrated recently at the Road Research Laboratory, which will lead to increased safety on the road. Among these new techniques are: (1) new method of measuring the skidding resistance of the road surface by means of fifth wheel mounted inside the wheelbase of a test vehicle, (2) lamp posts of lightweight metal construction with a special base mounting designed to collapse under relatively light impact, with very slight damage to the vehicle, compared with that normally suffered in such accidents. Statistics show that hundreds of people a year are killed on the roads in Britain

due to vehicles crashing into lamp posts, (3) to prevent the most disastrous crashes which occur when a vehicle crosses the central reservation of a dual carriageway and collides head-on with oncoming traffic, the laboratory has carried out experiments to find suitable barriers which will prevent this, without severely damaging vehicles crashing into it, (4) the laboratory has now developed a successful system which is fitted to the front wheel of a motorcycle. A demonstration of the modified machine on a wet surface showed that not only did it remain upright when the rider braked hard with the front wheel only, but it actually stopped in a shorter distance compared with an unmodified machine.

83. Farber, E. and Silver, C. A. "Knowledge of Oncoming Car Speed as Determiner of Driver's Passing Behavior." Highway Research Record. No. 195 (1967) pp. 52-65.

Study the effect of increased information about oncoming car speed on the driver judgment in accelerative passing. Considers sight distance, legal passing zone, oncoming traffic.

Cars equipped with distance and speed recording devices; subjects were college students with at least four years experience driving, presented with a passing situation and told to pass at the last safe moment.

Can judge distance well of oncoming car, do not respond to oncoming car speed normally, drivers make good use of verbal knowledge of oncoming car's speed.

84. Greenshields, B. D. "Driving Behavior and Related Problems." Highway Research Record, 1963, (25), 14-31; Road Abstr., March, 1964, 31, 68.

In experiments along a 15-mile road route, selected to give a range of driving conditions (town center, residential, dual-carriageway road and two-lane rural road)
corder were used to determine reversals of steering wheel, operation of acceleration and brake pedals, accumulated amount of steering wheel turn, changes of speed and direction, traffic events such as parked vehicles, overtaking and being passed, and highway events such as intersections, or roadside features. Drivers taking part were selected from six categories, namely, young drivers who had completed a school driver-training course, driver education teachers, men who earned their living as drivers, drivers who frequently broke traffic regulations, high-accident drivers, and a control group of average drivers. Results were subjected to discriminatory analysis, which is discussed. There is evidence that drivers in different categories of driving experience have different driving patterns. Sample tested was small; further research on testing drivers with the drivometer is being undertaken.

85. Hulbert, S. and Wojcik, C. "Driving Simulator Devices and Applications." (Paper to Society of Automotive Engineers, Automotive Engineering Congress, January, 1964, 68 pp.; MIRA mon. Summ. Auto. Engr. Lit., June, 1964, 29-30).

Part I describes and discusses devices which have been built, mainly in America and in Britain, to produce in a driver the illusion of driving a motor vehicle and are intended either for training, testing, or solely for research. Devices producing no motion or only vibration are termed "fixed-base," and those producing actual motion "moving-base." Travel sickness occurs more often on simulators than on actual driving. Part II describes a fixed-base, driving simulation laboratory at the University of California which has been fitted out to measure performance of road-transport systems. A car is driven on the steel rollers of a standard chassis dynamometer; driver views: (1) road scene projected onto a curved screen of 8.5 ft. radius and (2) road scene behind him, a rear-view mirror showing a moving picture projected on a screen placed beyond rear window. A special single-lens projection process, dimension 150, nearly duplicates the human binocular field of vision. Also described is a moving-base simulator comprising a car cab (containing controls, dashboard, seat, etc.) mounted on a steel structure permitting roll, pitch, and yaw to simulate inertia forces as experienced during car travel. Driver observes a moving picture projected on a cylindrically curved screen of four-ft. radius; this screen being also mounted on the steel structure, moving-picture scene, cab and driver can tilt as a unit (condensed abstract).

86. "Human Engineering Analysis Aid to Safe Driving Solutions." SAE Journal. Vol. 76, No. 6. (June, 1968). pp. 56-57.

General discussion of safe driving.

Driver must reduce his speed to bring the angular velocity of the visual field into the range needed for steering control.

The perceived speed is nonlinearly related to ground speed. Sensitivity of the human eye to motion decreases from the fovea to the periphery. Angular velocity of the moving field increases from the center outward. Most velocity judgments are made near the periphery. Speed judgment is likely to be less stable when the peripheral field is degraded by darkness.

87. Jackman, W. T. "Driver Obedience to Stop and Slow Signs." Highway Research Board Bull. 161. (1957). pp. 9-17.

Determine the effect of standard yellow and black "STOP" and "SLOW" signs of the driver.

"SLOW" sign used a radar meter, equal locations and road conditions, heights of two ft. and five ft. were studied; five types of signs were used.

No position or combination of "SLOW" and "STOP" signs was more effective than the others under given conditions. Drivers were influenced by road factors and not the sign. Red "STOP" sign and yellow "STOP" sign position for best results is different.

88. Jones, H. V. and Meimstra, N. W. "Ability of Drivers to Make Critical Passing Judgments." (J. Engr. Psych., October, 1964, 117-122).

This study was designed to determine how accurately drivers can estimate what has been termed clearance time. Subjects viewed an approaching vehicle and were instructed to designate the last possible moment when they felt they could safely pass a lead car. They did not actually pass the lead vehicles. On the basis of timings taken by the experimenter, it was possible to determine whether the driver could actually have passed the lead car safely (overestimate) or whether he would not have had adequate time to complete the pass (underestimate). It was concluded that drivers are not able to make this type of judgment accurately.

89. Kobyaski, M. and Matsunaga, T. "Development of the Kaken Driving Simulator." Highway Research Record No. 55. pp. 29-35.

How the simulator was designed and what considerations were made. Feedback mechanism, visual environment 16 mm films. Considering vision, car speed controls film speed.

Visual 16 mm Bell and Howell 707, 40 km/H = 32 frames/sec. 60 km/H = 48 frames/sec.

OK for building a simulator or considering driving conditions.

90. "Mercuries Outshine Fluorescents for Sign Lighting." The American City. Vol. 82. (December, 1967). pp. 122.

Report on the qualities of mercury lighting.

Mercury lamps have longer life and reduced maintenance cost. They can light signs eighteen feet up by having their main beam angle changed. The lamp unit gives off more uniform light. The cost is about $4.00 per square foot compared to $5.00 for fluorescent lighting.

91. Michaut, G., et. al. "Psychological Study of Car Driving." (In French; English summary). (Travail Hum., July/December, 1964, 27, 193-219).

The first part of the article consists of a bibliographical survey of the reciprocal effects of the driver and the vehicle. In the second part the authors describe a specially-equipped vehicle and in the third part, results obtained when driving on a specially prepared closed circuit are graphically shown. During the tests, the following points were investigated: (1) heart and respiration rates of the driver, (2) steering-wheel movements, (3) accelerator pedal movements, (4) vehicle speed, and (5) responses to an auditory detection task. A total of 23 subjects was used, 15 of them twice. The parameters obtained can be used for a study in real life situation of driving. The authors believe that the results provide a basis for further research under different experimental conditions.

92. Nathan, J., Henry, G. H., and Cole, B. L. "Recognition of Road Traffic Signals by Persons with Normal and Defective Color Vision." (Austr. Rd. Res., September, 1963, 1(7), 30-38; Engr. Index, 1963, 953).

Investigation to establish extent and nature of difficulty experienced by group of color defectives in recognition of 3-color signal light system equivalent to road traffic signals in relevant dimensions; 13 filters were chosen with chromaticities near boundaries of green, yellow, and red limits; filters were presented in random orders, each 16 times, under 2 levels of surrounding luminance, one mesopic and other photopic; analysis of reaction times is presented.

93. Pancia, M. A. "Signs That Sell Traffic Safety." The American City. Vol. 81. (November, 1966). pp. 122.

Facts about signs presented.

As population expands, so does the need for signs. The average sign lasts three years. Of the signs that are lost early, 10% are accident victims, and 65% are targets of vandals.

94. Polter, M. "Driver Reaction Time." (In Russian). Atom. Transp., 1963, 41 (11), 47-50; Road Abstr., January, 1964, 31, 20.

Research is described on the possible effect on driver reaction time of individual characteristics, age, alcohol, fatigue, length of training and place of work. Measurements were made of the reactions to various signals and situations, in a driver trainer and on the road, of 2525 experienced and learned drivers, including some who had been involved in road accidents. Performance in all tests improved after a three-day training program of 20 to 30 minutes per day. It is considered that insufficient attention is given in driver training to the necessity for improving a driver's reaction to emergency situations. Drivers who had been involved in accidents had the longest reaction times. A graph of reaction time according to age shows a sharp increase at 50 years. Fatigue was found to have no significant effect, but tests made up to an hour after the consumption of a small quantity of alcohol indicated a 30 to 40% increase in reaction time. The importance of individual characteristics was shown by the fact that reaction times for drivers of similar age and driving experience varied from 0.32 to 0.66. Shortest reaction times were observed in tests on rural roads when drivers were free from the tension associated with driving in urban traffic. The same reaction times were obtained with the driver trainers as on the road.

95. Raper, V. J. "Arriving for Better Headlighting." Highway Research Board. Bull. 191. (1958) pp. 49-52.

Comparison of the 1940 sealed beam, 1955, sealed beam and dual-unit sealed beam determine which has the best seeing distance.

Car equipped with recorder and signal system for when the object was noticed.

Shows new sealed beam and dual headlights are better when properly aimed. If public wanted a better aiming, more improvement could be made. Dual-unit has the greatest seeing distance under all conditions.

96. "Sign Uniformity Still Lagging." The American City. Vol. 79. December, 1964 pp. 104.

Report on sign uniformity.

U.S. Bureau of Public Roads, of January, 1967, saw little hope of sign uniformity. States do not want to give up old ways or spend money necessary to make the change. Some states' standards differ from the Bureau of Public Roads standards by 30 or more respects. The federal government has no legal control over most highways. Reflectorized license plates reduce nighttime collisions.

97. Solomon, D. "Accidents on Main Rural Highways Related to Speed, Driver, and Vehicle." (Washington: Department of Commerce, Bureau of Public Roads, 1964, 44 pp., 3s. 2d.; Road Abstr., September, 1964, 31, 206).

Study was confined to two- and four-lane major roads of the non-motorway type. It is believed that material presented is the first based on comprehensive national survey from which valid information can be obtained on relationship between accidents and speed, driver and vehicle. Research was conducted with cooperation of States of Arizona, California, Connecticut, Iowa, Minnesota, Missouri, Montana, New Jersey, North Carolina, Oregon, and Virginia.

98. Smith, W. M. "Visual Recognition: Facilitation of Seeing by Hearing." (Psychonom, Science, 1965, 2(6), 157-158).

A previous finding of enhanced visual recognition through vocalization by subject is confirmed and extended by the present experiment which shows that similar effects on visual recognition occur when a voice other than subject's is employed. Such facilitation of visual recognition is the result of perceptual interaction, not kinesthetic or auditory feedback, as such, nor factors of expectancy and set.

99. Snider, J. N. "Capability of Automobile Drivers to Sense Vehicle Velocity." Highway Research Record. No. 159. (1967) pp. 25-35.

Concerns velocity estimation and acceleration estimation. How does feedback or speed aid one in estimation, can one remember speed?

Allowed to see speedometer and drive car before test to get feel.

May need to know driver's sensory capacity and how to augment it.

100. Toth, William J. "Watch Those Road Signs." American Home. Vol. 70, No. 9. November, 1967. pp. 42-43.

What is wrong with road signs?

Survey of American motorists.

Signs don't tell the driver how to get where he is going. Signs are not properly located and may be in very poor condition. Use five basic sign shapes: diamond - warning of something ahead, octagonal - stop, rectangular - directional information, round - railroad crossing, triangle - yield.

101. Verbeck, J. W. "Optics Operate Signals in Emergencies." American City. Vol. 82, (March, 1967). pp. 1254.

A discussion of transmitters mounted on fire cars to send an optical energy signal to receivers mounted on traffic lights, provide fire cars a green light.

102. Von Klebelsberg, D. "Results of an Analysis of Driving Behavior." (In German). (Z. exp. angew. Psych., 1963, 10(4), 197-603; Psych. Abstr. October, 1964, 38, 1029).

Two observers evaluated the driving behavior of ninety-one drivers during a 40-km trip. A table containing sixty categories and a nine-step scale of every category served as guide for evaluation. Factor-analysis revealed seven factors which are called: (1) readiness to react; (2) hesitating behavior; (3) hard driving without consideration of consequences for car; (4) patient, flexible behavior; (5) goal-directed, systematic driving; (6) temperament; and (7) tendency to push ahead.