Recognition Time for Symbols in Peripheral Vision

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• OF ALL the sensory capabilities exhibited by the driver, the sense of vision is almost wholly responsible for the processing of information in the driving situation. However, little is actually known about the time that this "processing" requires. It was for the purpose of obtaining information on the visual reaction and eye movements, that this research was designed.

The purpose of the project was twofold: (a) to develop a transportable recording system that can be used in moving vehicles to record driver eye movements; and (b) to investigate human response times to signals in peripheral vision.

The importance of developing equipment for obtaining objective data on eye movements and peripheral recognition time can hardly be overemphasized. Such equipment could be used to determine placement of road signs for optimum legibility, to determine speed limits in a high "visual density" zone, and possibly even to develop a method for differentiating the characteristics of good drivers from poor ones. Data from studies on visual recognition time for peripheral signals would certainly be important in determining relationships between speed and driver safety.

The first part of the project consisted of the design and development of an amplifying and recording system which may be used in moving vehicles to record driver eye movements with a minimum of interference to driver activity. The system may be used in any conventional six-passenger automobile without modification of the vehicle. The system was designed so that it could be operated by self-contained batteries, inasmuch as the line voltage of standard automobile electrical systems varies considerably. Another important feature for such a system is compactness and portability. Figure 1 shows the complete system. On the left are the self-contained batteries and the inverter for the recorder. In the center are the preamplifier and amplifier, and on the right is the recorder.

Figure 2 shows the system in actual operation. The driver is not restricted, and the equipment is compact enough to allow one person in the rear seat to monitor the equipment.

The system appears suitable for making eye-movement recordings as larger, less easily transported bioelectric recording equipment. No observable loss in performance accrues from operating the recorder from the storage-battery power pack. The amplifying equipment exhibits stable performance and is reasonably immune to the effects of temperature changes and battery aging.

The most critical factor associated with making good eye-movement recordings is electrode preparation. Electro-depositing equipment was constructed for making chlorided silver electrodes. Some success was achieved in reducing drift by this method. However, more refined equipment should be constructed and a better technique evolved. Further work involving the use of the recording system in actual field experiments should be preceded by a period wherein the investigators evolve and practice electrode preparation procedure to achieve predictable, low drift. Otherwise, the system is suitable as a research tool for making eye-movement recordings both in the laboratory and in moving vehicles.

The second part of this project involved the investigation and determination of response times to signals in peripheral vision. The original purpose for this phase of the project was to check out the recording equipment described earlier, but as the research progressed it was felt that some of the characteristics of eye movements and the process

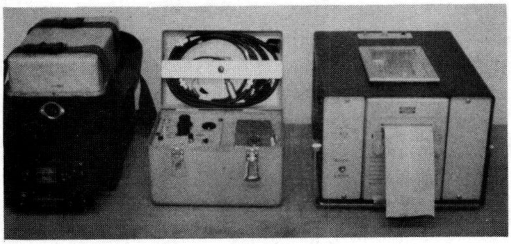

Figure 1. Display of portable equipment for the recording of eye-movement latencies. Left, battery pack and inverter; center, preamplifier and amplifier; right, pen recorder.

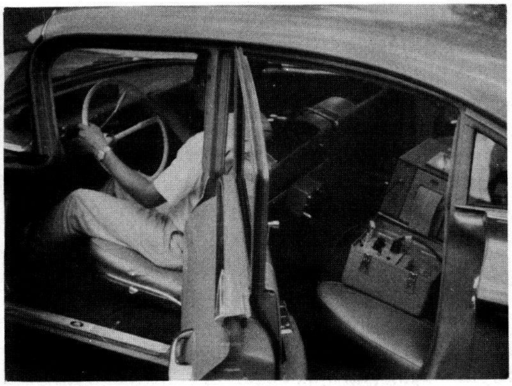

Figure 2. Portable recording equipment installed in an automobile.

of seeing should be systematically investigated. The recording equipment proved to be an invaluable tool in this investigation.

Many studies concerning the various characteristics of eye movements have been carried out since the end of the Nineteenth Century. One of these characteristics, the "speed of seeing," has been particularly important in applications in industry, the armed services, driver safety, and other related areas. It was believed that much previous research was not particularly applicable to field situations, because the type of visual reaction required of the subject did not resemble the actual field situation in terms of complexity and extent of eye movement.

Various components of the visual response were systematically investigated by Dodge and Diefendorf (1). Using photographic recording techniques, they found that the average latency was about 200 millisec. Latency is defined as the time interval between the appearance of a peripheral signal and when the eyes begin to move. They also found that the eye movement itself took from 29 millisec for a 5^0 movement to 100 millisec for a 40^0 movement. Essentially the same results were obtained by Miles (2) and Hackman (3).

These time intervals do not reflect the time involved in the process of "seeing" an object in the periphery. After the eye has fixated on the peripheral stimulus, the observer still must process the new information and make some response.

More recently other investigators have been concerned with the total response time when there is more than a simple movement involved. Hyman (4) found that the total response time increased when the task required the subject to identify the specific location of the stimulus. Words were assigned to various lights and the response time was measured by a voice key set off when the subject pronounced the correct word for the stimulus location. This increase in response time occurred even though the subject was not specifically instructed to move his eyes because Hyman's stimulus lights were so close together.

This type of response time is more closely related to the problem of seeing, inasmuch as the total visual reaction must include an identification of what is seen. As was expected, Hyman found this identification type of response time to be longer—the lengthening being a function of the statistical probability that a stimulus would appear in the specific location identified. Hyman's vocal response times varied from 300 to 750 millisec. However, this complex response still does not represent accurately the process of "seeing" an object in the periphery. To see an object in the periphery the individual must not only identify the location and swing his eyes it, but also interpret the stimulus.

This part of the project was designed for two purposes. Experiment I involved the investigation and determination of response times associated with the interpretation of peripheral stimuli. As a framework for the analysis the following hypotheses were investigated: (a) response times will be longer than the simple movement responses reported by Dodge, Miles, and Hackman; (b) response times will increase as a function

of angular displacement from the line of direct vision; and (c) response times will increase as a function of the number of stimuli to which the subject must pay attention.

Experiment II was designed to isolate and measure the various components of the total response time. By using the electrical method for recording eye movements, it was possible to isolate the latency, the travel time of the eye, and the response time for interpreting the stimulus.

The subjects for both experiments were volunteer undergraduates, and were free from pertinent visual defects as measured by an orthorater. All were highly trained prior to the experimental sessions.

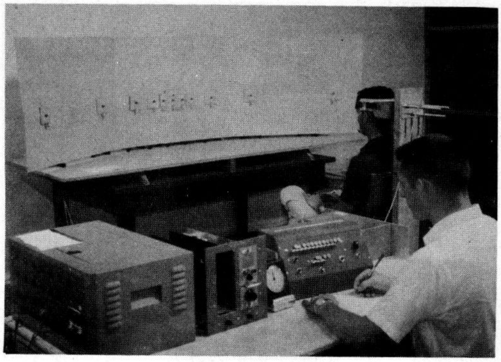

Figure 3. Laboratory layout of apparatus used in standardizing test procedures.

The apparatus for Experiment I consisted of the peripheral stimuli, tracking task, electronic voice key, timer, and appropriate experimenter's controls. The peripheral stimuli were eleven Nixie Numerical Indicator tubes, placed 6 ft on the horizontal plane from the subject at 40^0, 20^0, 10^0, 5^0, and 2.5^0 right and left. There was also one tube at center (0^0). The subject, with head held rigid by means of a headrest, performed continuous monitoring on the tracking task at the center of the array of lights. At random intervals one of the peripheral signals came on and the subject moved his eyes to the stimulus and verbalized the numeral presented into a microphone that stopped the timer.

The experimental trials were run for twelve days and were initiated on the day following the training sessions. To test the hypothesis that reaction time increases as a function of the number of possible stimuli, it was necessary to divide Experiment I in two parts—Sequence A and Sequence B. The stimuli in Sequence A consisted of four indicator lights at the 20^0 and 10^0 right and left positions. Each session consisted of 144 trials and was presented on days 1, 2, 11, and 12.

The stimuli in Sequence B consisted of the indicator lights in all eleven positions. Each session included 144 trials and was presented on days 3 through 10. The data for both sequences were analyzed by means of a four-factor analysis of variance.

In Experiment II the same apparatus was used for presenting the stimuli. To record the eye movements necessary for measuring the components of the total response, electrodes were placed behind the external canthi of the subject's eyes. The output from the electrodes was fed to the preamplifier and this terminated at an oscilloscope. The upper trace of this dual-channel oscilloscope was a record of the subject's eye movements. For the lower trace the input was from the first stage of amplification of the electronic voice key. The sweep was triggered when an indicator light came on. A Dumont oscilloscope camera was used to photograph the tracings. In Experiment II each subject made a total of 32 recorded responses each day for four days. Figure 3 shows the layout of the apparatus with the subject in position. Figure 4 shows a close-up of one of the stimuli and the tracking task. Figure

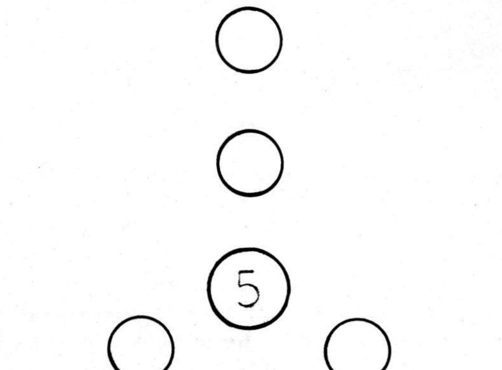

Figure 4. Schematic diagram of one stimulus used in tracking task in laboratory studies.

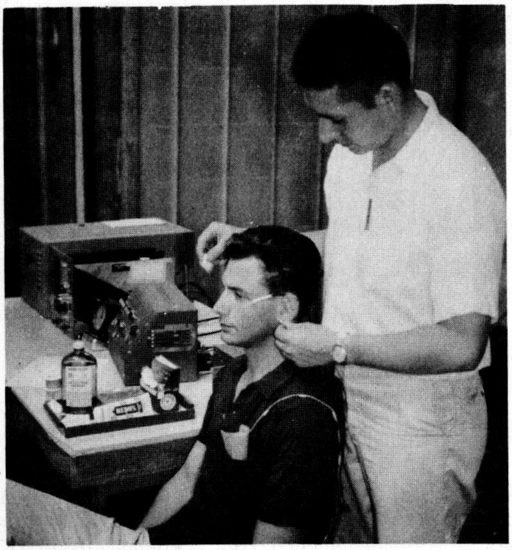

Figure 5. Electrodes being fixed on subject prior to laboratory experimental session.

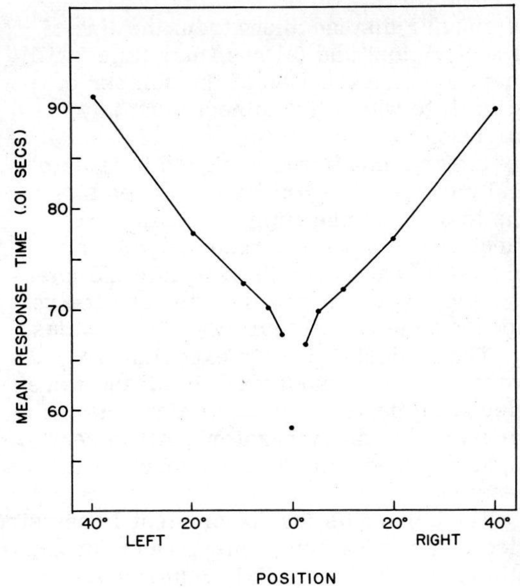

Figure 6. Relationship between lateral location of signal and response time as developed from experimental laboratory sessions.

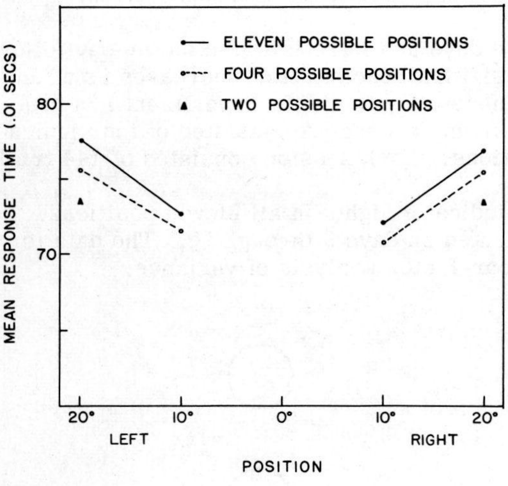

Figure 7. Mean response time as a function of number of possible stimuli.

5 shows the electrodes being fixed on the subject prior to an experimental session.

Results of Experiment I showed that response time increased as the angle from the centerline of direct vision increased. Figure 6 shows the relationship of response time to peripheral angle. There was no significant difference between mean response times to the right and left sides.

It was also found that response time increased as the number of possible signals increased. Figure 7 shows response time as a function of number of possible stimuli. Response time was slowest when the subject had to respond to one of eleven signals, as against one of four, or one of two (training trials).

The results of Experiment II showed that the time required for each of the three components of the response increased as the angle away from direct line of vision increased. Figure 8 shows the portion of the total response made up of each component. It was expected that the latency (the time before the eyes began moving) and the actual eye movement increase as a function of angle. However, the vocalization component (the time required for the subject to make his vocal response after his eyes had reached the signal) also increased with angle. Even though the subject's eyes were at the stimulus, it took longer for him to "recognize" the numeral presented and verbalize the response when the stimulus was at a greater angle in the periphery. Figure 9 shows this vocalization time as a function of angle. The bars represent the mean plus and minus one standard error. It was believed that this was due to changes in either accommodation or the hunting of the eye for an exact fixation.

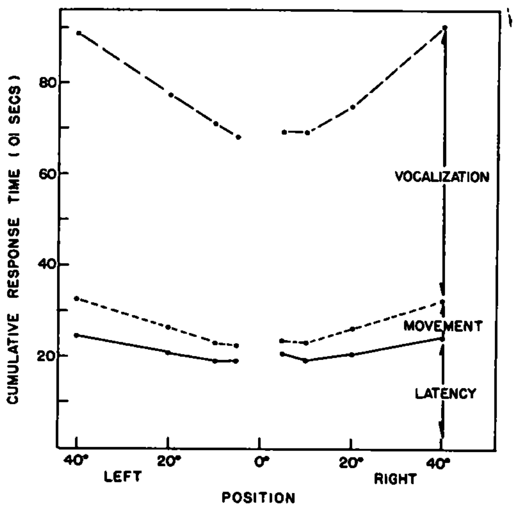

Figure 8. Eye-movement latency and movement, and vocalization as portions of the total response time.

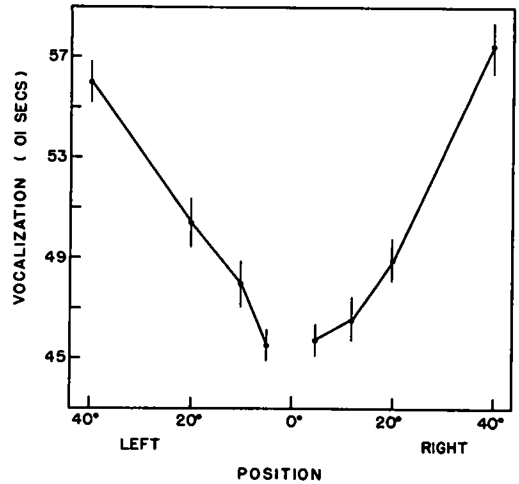

Figure 9. Relationship between vocalization time and lateral position of signal.

It was concluded that the results of the present research indicated that response times are unusually long in a complex visual situation. Further research is contemplated that would yield a mathematical relationship between response time and number of possible stimuli, and results that would explain the vocalization pheonmenon and its relation to angle away from direct line of vision.

ACKNOWLEDGMENTS

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