Use of Stress in Part-Task Driving Simulators—A Preliminary Study

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To evaluate the feasibility of using stress in driving simulator research, drivers were subjected to continuous glare while performing a series of tasks in an instrumented vehicle on a specially designed test track. The tasks included keeping within a 7-ft lane at 20 mph, maintaining a constant headway and estimating time to coincidence with an approaching or overtaking vehicle. Methodological problems in driver research were examined.

•THE IMPORTANCE of simulation in highway research is well accepted. There has been considerable recent interest in both full-scale and part-task simulators. A goal of the full-scale approach is complete fidelity in representing the visual, auditory, and kinesthetic stimuli to which the driver is exposed. This is a research and engineering feat of great magnitude, and successful full-scale simulators are still in the future. The part-task approach promises more immediate and economically feasible research on highway problems. Individual elements of the driving task, such as steering, accelerating, road following, or passing, are simulated. Only those visual, auditory, and kinesthetic stimuli necessary for the performance of the part-task are provided. This paper examines the methodological problems involved in defining the requirements for such part-task simulators.

A part-task research simulator will have as its function the determination of the effects of contemplated highway, vehicle, or driver alterations on safe, efficient transportation. It will be developed to simulate particular parts of the driving task which might be affected by such changes or experimental variables. Many meaningful variables, however, will have no effect in simulation studies, due to the ability of the driver to perform adequately under a wide range of conditions.

One method for magnifying the effect of an experimental highway or vehicular variable on a driving part-task is subjecting the driver to one or more psychological or physiological stressors. If the effects of various stressors on the part-task have previously been determined and these effects do not interact with the experimental variable, it should be possible to select a stressor that will degrade performance on the part-task of interest to a point where the effect of the experimental variable is more apparent.

Many studies may be found in the psychological and ergonomic literature dealing with the effects of stress on driving and related types of performance. Typical results of such studies are briefly summarized:

1. Carbon monoxide.—Prolonged exposure to carbon monoxide concentrations of 45 percent or greater have been found to impair performance on psychomotor tasks (1). Increasing concentrations of carbon monoxide have been found to decrease sensitivity to brightness differences under low illumination (2).

2. Fatigue and wakefulness.—Many studies have found performance decrements attributable to fatigue and wakefulness (3, 4, 5, 6). In a study of the effects of rest

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pauses on driving efficiency, Lauer and Suhr (7) found reaction time, experimenter evaluation of driving, side-to-side sway, and lateral placement of the automobile to be adversely affected by lack of rest pauses.

3. Glare.—Glare has been found to increase errors in a tracking task (8), raise the threshold for detection of a target in the vicinity of the glare source (9), and cause difficulty in fixation (10). The effects of glare are difficult to interpret in most studies, as glare may act both as a distracting stimulus, preventing the subject from devoting sufficient attention to his task, and as a veiling luminance, directly interfering with the visual portion of the task.

4. Information overload.—The information-handling ability of the driver was studied by Brown and Poulton (11) and Christner (12) by requiring the driver to perform a supplementary task: detecting the digit that was changed in successive auditory series of digits. Brown and Poulton found an increase in errors as vehicular and pedestrian traffic increased. Christner did not find the digit scan task to be a sensitive indicator of driver information-handling load.

5. Noise.—Noise has generally been studied as a distracting stimulus and has been found to impair performance in psychomotor tasks (13, 14), visual vigilance (15), decision making (16), and time estimation (17). Impairment generally occurs at noise levels above 90 db and is most serious at the higher frequencies. Noise tends to increase performance time and estimations of time intervals.

6. Heat and cold.—Heat has been found to cause decrements in a wide range of tasks, including manual dexterity, tracking and vigilance (18). Bursill (19) found a funneling of attention toward the center of the visual field with increased heat. Cold has less effect on performance in general, although it has been found to impair kinesthetic sensitivity (18).

7. Vibration.—Vibration has been found to cause decrements in ability to maintain a constant foot pressure and in compensatory tracking (20). Other effects are found for specific combinations of frequency and amplitude.

Although these studies suggest possible effects of each of the stressors examined on driving part-tasks, specific quantitative relationships between the intensity of each stress and decrements in performance on each part-task are lacking. This lack could be filled by direct experimental investigations. The feasibility of performing such studies, using an actual vehicle and a special test course, is investigated in the following experiment.

This study is concerned with the effects of glare on the performance of four driving part-tasks: road following, vehicle following, judgment of time to coincidence with an approaching vehicle, and judgment of time to coincidence with an overtaking vehicle. Because it is entirely a methodological exploration, conclusions about the effects of glare on driving would be inappropriate.

APPARATUS

A test course consisting of two white lines 7 ft apart was painted on unused airport ramps (Fig. 1). The course is 0.8 mi long and consists of four straight sections, two 100-ft radius curves, three 170-ft radius curves, one more gradual curve and one very tight curve (the U-turn). The total driving distance from the beginning of the course, around the U-turn and back to the starting point, is 1.6 mi.

A 1955 Buick was used as the test vehicle. Lights were installed on the front of the vehicle to serve as a target for photographic measurement of intervehicular distance (Fig. 2). The rear tires were illuminated to facilitate observation of road-following performance. Controls were provided to enable the experimenter, seated at the right in the front seat, to apply the brakes or prevent use of the accelerator.

A spotlight was mounted on the hood of the test vehicle, directly in front of the driver and at a distance of 84 in. from his eyes. The spotlight intensities used were 3.0, 4.5, and 5.8 v, producing glare levels of 0.09, 0.37 and 9.0 ft-candles at the eye, with the eye in the center of the beam. The light was left off for a fourth, no-glare condition. The spotlight was powered by a 12-v storage battery. Voltage to the spotlight was controlled by a rheostat and monitored with a voltmeter.

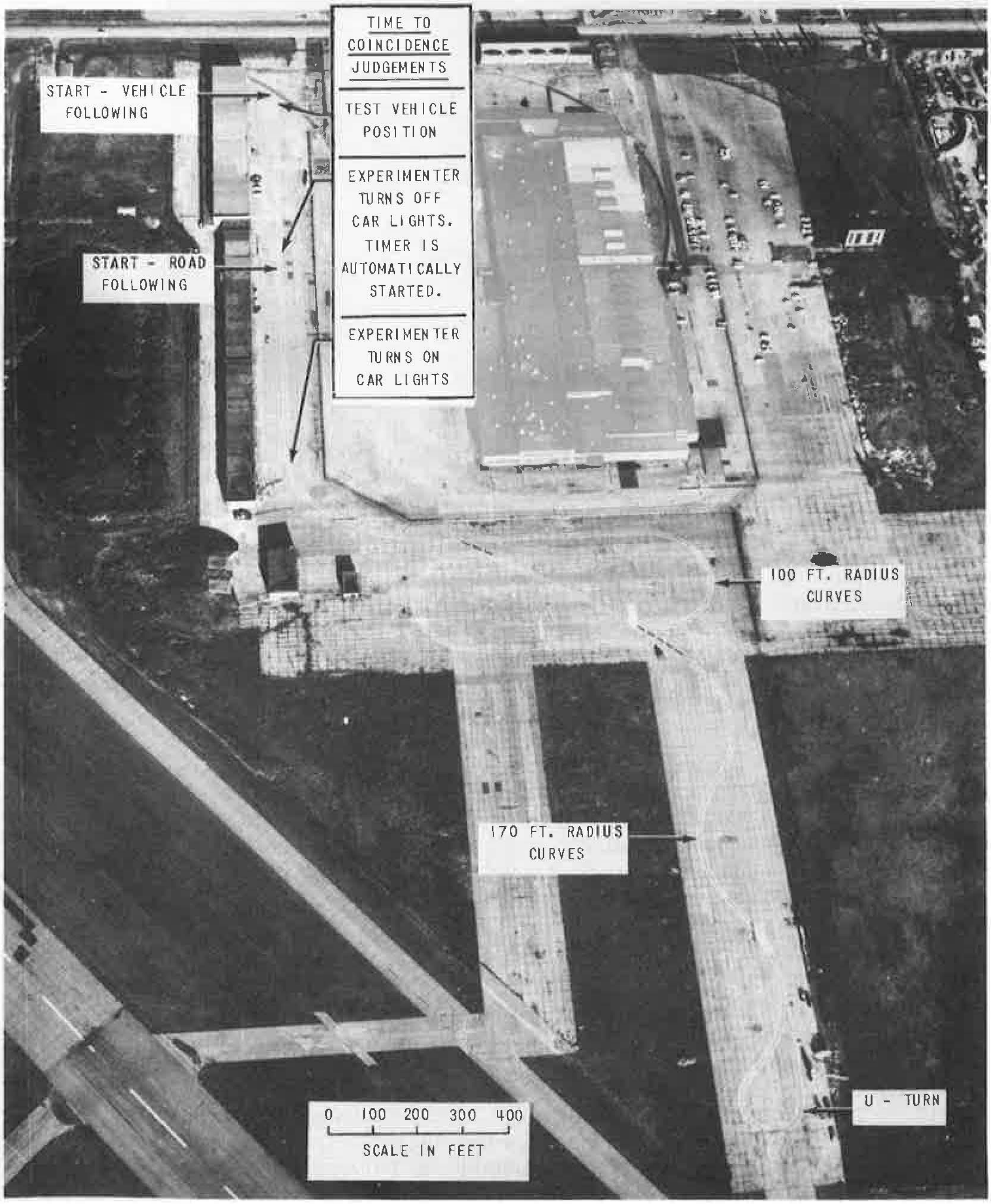

Figure 1. Driver research course.

A second vehicle was used to precede, follow, or drive toward the test vehicle for the various performance measures. For road following, an experimenter in the second vehicle used a two-way radio to record the positions of the test vehicle. For the vehicle-following runs, a motion picture camera was operated from a rear-facing seat in the preceding vehicle, a station wagon. For the time-to-coincidence runs, a standard electric timer was started by the pressure of the tires of the experimenter's vehicle on a hose laid across the test track, and stopped by a button in the test vehicle.

Figure 2. Test vehicle.

PROCEDURE

All experimental runs were made after dark. The subjects, four volunteer Laboratory employees, were run on successive nights. The subject reported about an hour before dark, practiced driving around the course six times, and then rested until the experimental runs were begun. The orders in which the four part-tasks were run and in which the four glare levels were presented were counterbalanced across subjects. The glare levels are designated 1 (no spotlight), 2 (3.0 v), 3 (4.5 v), and 4 (5.8 v).

Vehicle Following

The subject's car was positioned 64 ft behind the experimenter's car at the beginning of the test track. The subject was instructed to follow the experimenter's car, maintaining a constant distance. A shorter route across the track which eliminated the 100-ft radius curves was used, as shown by the dashed lines in Figure 1. The vehicles drove to the end of the course, turned, and returned to the starting point for each run. The distance maintained by the test vehicle was recorded by the photographic method described.

Road Following

The test vehicle started 272 ft from the beginning of the course. The subject was instructed to drive around the course, keeping between the two white lines. If he touched or crossed over one of the white lines, or returned to the correct position, an experimenter in a vehicle following the test vehicle recorded the word "on," "over," or "off." The spacing between these words, as later displayed on an oscillograph, was used to measure the time during which the subject's tires were between the lines, a tire was touching a line, or a tire was outside the painted lane.

Time to Coincidence—Approaching Vehicle

The subject's car was parked at the beginning of the test track, facing the track, but just outside the two white lines. The lines were at the subject's left. The experimenter's vehicle proceeded along the track from a point just beyond the first curve with its lights off. When it reached the straightaway, the experimenter driving the car turned his headlights on and drove 420 ft, crossing a hose which was laid across the track 272 ft from the subject's car. The pressure of his tires on the hose rang a bell which signaled him to extinguish his lights. The pressure on the hose also started the timer. The subject, who wore ear defenders, was instructed to close his eyes when the headlights of the approaching vehicle were extinguished. He was then to imagine the vehicle

TABLE 1

EFFECTS OF GLARE ON PART-TASK PERFORMANCE

Part Task	Glare Level			
	1	2	3	4
Road following[1] (%)	31	27	36	41
Vehicle following[2] (ft)	14	16	16	18
Coincidence[3] (sec):				
Approaching	1.0	1.0	1.6	0.9
Overtaking	1.1	2.1	1.2	1.4

[1] Time at least one tire was not within painted lane.
[2] Standard deviation of intervehicular separation.
[3] RMS error.

continuing to approach (it actually turned off) and press a button when he thought it would reach him. This button stopped the timer, and the time elapsed was recorded.

This part-task was begun with four practice runs, two at 25 mph and two at 35 mph. The subject was given immediate knowledge of his deviation in seconds from the correct time. At each glare level two runs were made at 25 mph and two at 35 mph in varying orders.

Time to Coincidence—Overtaking Vehicle

The procedure was the same as that used for the approaching vehicle runs, except for the position of the test vehicle. The test vehicle was between the two white lines, facing away from the approaching experimenter's vehicle. The subject observed the experimenter's vehicle through his rear-view mirror.

RESULTS

In general, there was little observable effect of the glare source used on performance on the four driving part-tasks. The results are presented to illustrate the type of data that can be collected in such studies.

Table 1 gives the performance scores obtained on the four part-tasks. Although the differences obtained were quite small, it appears that glare produced the greatest effect on road following, a lesser effect on vehicle following, and no discernible effect on time-to-coincidence judgments. If these results were obtained in a study employing a larger number of subjects and higher glare levels, or perhaps intermittent glare, it would be possible to classify the four part-tasks studied according to their relative resistance to the effects of glare.

ANALYSIS

The preceding sections illustrate the type of study that would be performed to develop a taxonomy of stressors and their effects on driving part-tasks. In the experiment performed, the effects of the stressor employed were not as striking as would be desired for actual research in this area. The study does bring out a number of methodological considerations which may be applied to further research on the effects of stress on driving part-tasks:

1. A program of extensive pretesting and apparatus modification should be carried out to insure that the intensities of the stressors used in the final study are appropriate for breaking down the driving part-tasks of interest.
2. The subject should be thoroughly trained in performing each part-task under stress, before the final measurements of his performance are taken. Learning to per-

form a specific part-task and adaptation to a given stress follows various patterns for different subjects. It is, consequently, not reasonable to counterbalance learning and adaptation effects across subjects. The effects must be eliminated before the start of the experiment proper.

3. Due to these large individual differences, it is essential that a sufficient sample of drivers be studied. Ten would be a minimum.

4. Intra-individual differences are also large in studies of this kind. It is recommended that each subject/condition combination be replicated at least once.

If these considerations are given sufficient attention, experimental determinations of the effects of stress on driving part-tasks should be a feasible and fruitful approach. Data collected by this method could be used to select the part-tasks to be simulated and the types and levels of stress to be included in each part-task simulator.

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