63-3-1

TECHNICAL RESEARCH NOTE 118

FIELD STUDY OF VIGILANCE UNDER HIGHWAY DRIVING CONDITIONS

APRO

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AD Div 23/1, 28/3, 28/4

US Army Personnel Research Office, OCRD
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by D. A. Dobbins, J. G. Tiedemann, and D. M. Skordahl.
October 1961. Rept on Error-Free Performance c-02 Proj. --
46 pp. incl. illus., tables, 15 Ref (APRO Technical Research Note, No. 118)
(DA Project 2195-60-001) Unclassified Report

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Error-Free Performance c-02

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December 1961

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PREFACE

The present publication reports on a portion of Subtask c, Study of Army Drivers Performing on the AASHO Road Test, of the ERROR-FREE PERFORMANCE Task, FY 62 Work Program. The entire research task furthers the U. S. Army Military Personnel Management (DCSPER) objective of developing and making available for operational use research products to optimize the selection, classification, assignment, and utilization of Army personnel. Problem areas of interest to the Army Security Agency are also being studied under the ERROR FREE PERFORMANCE Task.

Advancements in military technology require a high degree of dependability in the various man-machine complexes. Human performance is generally more variable than the machine components of the system. Hence, human performance in the more critical jobs represents a significant determinant of the overall reliability of any weapons or communications system. Decrement in or errors of performance occur as a result of various internal factors such as fatigue, boredom, poor morale, and anxiety. Decrement in or errors of performance also occur as a result of various external factors such as emergency pressures, isolation, weather extremes, methods of supervision, and other working conditions.

The primary objective of the ERROR-FREE PERFORMANCE Task is to minimize the incidence of human error in critical assignments and to develop means of inhibiting decline in critical performance. The research is designed to lead to improved selection and assignment of personnel in jobs of which the sustained ability to detect and respond to critical signals is an important component, and to improved utilization of personnel in those jobs through identification of the psychological factors involved and through optimum work methods.

Other reports and papers dealing with vigilance research are listed at the conclusion of the present report.

BRIEF

FIELD STUDY OF VIGILANCE UNDER HIGHWAY DRIVING CONDITIONS

Requirement:

A natural laboratory for a preliminary study of vigilance was provided by a road test sponsored by the American Association of State Highway Officials (AASHO) and the Highway Research Board of the National Academy of Sciences. The Army Personnel Research Office (formerly the Human Factors Research Branch) arranged to study the signal detection performance of drivers under road test conditions.

Procedure:

From November 1958 to November 1960, Army drivers drove trucks over experimental highways under conditions conducive to boredom and fatigue, conditions characteristic of many Army monitoring jobs. Signal detection performance of 42 AASHO drivers was measured by means of the Transportation Corps Vigilance Tester to 1) determine the nature and extent of any decrement in vigilance over a 7-hour driving shift and 2) to examine the range and stability of individual differences in signal detection scores.

Findings:

Overall level of signal detection was consistently high and stayed at a high level in spite of such inhibitory factors as noise, vibration, long hours, boredom and fatigue. These factors did make their influence felt, however, in increasing the variability of vigilance performance among drivers. Findings in the present study suggest that the low monitoring proficiency often found in the passive monitoring of laboratory displays may be of limited generality.

The TC Vigilance Tester, designed and produced for the AASHO experimentation by AASHO Instrumentation Laboratory and APRO scientists, proved capable of providing psychometric scores sufficiently consistent to justify its research use.

Utilization of Findings:

Investigators seeking a basis for recommending monitor schedules for military or industrial personnel should employ simulation of work environment in which as many of the operational work procedures as possible are represented. Experimental situations in which relevant aspects of the signal environment and of the monitoring task are omitted may result in a serious underestimation of human capabilities for many monitoring tasks.

FIELD STUDY OF VIGILANCE UNDER HIGHWAY DRIVING CONDITIONS

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FIELD STUDY OF VIGILANCE UNDER HIGHWAY DRIVING CONDITIONS

Modern military technology requires a high degree of reliability and dependability in the various man-machine complexes. But human performance is generally more variable than the machine components of the system. Hence, human performance in the more critical jobs represents a significant determinant of the overall reliability of any weapons or communications system.

The Army has many jobs in weapons and communications systems requiring an operator or attendant to pay close or sustained attention and to respond to infrequent and irregularly spaced visual signals. Errors and declines in performance may be critical whether job content is fairly simple but requires a high degree of operator vigilance, or whether job content is complex and characterized by the continuing simulation of operations whose missions may rarely or never occur.

The US Army Personnel Research Office[1/] in July 1959 initiated a research task to identify and study behavior requiring a high degree of dependability. What are the critical Army jobs in which human errors or performance decrement might lead to costly or serious consequences? Having identified such jobs, how can the Army reduce the occurrence of critical errors or inhibit the decline in critical performance? It is believed that experimental research leading to improved personnel selection techniques and work methods will provide some useful answers.

In laboratory studies, individuals have been observed to detect and react to a progressively smaller proportion of such signals with the passage of time. The classical decrement in vigilance is rapid during the first thirty minutes and then stabilizes at a low detection plateau (McGrath, Harabedian, and Buckner, 1959). The opportunity for studying vigilance performance under controlled and at the same time moderately realistic working conditions was afforded by the American Association of State Highway Officials (AASHO) and the Highway Research Board of the National Academy of Sciences (AASHO Road Test, 1961). From November 1958 to November 1960, Army drivers drove trucks over experimental highways under conditions conducive to boredom and fatigue. The AASHO Road Test provided a natural laboratory for the study of vigilance. The obvious monotony of continuous driving in a restricted environment, the sleepiness, boredom, and even hallucinations reported by drivers toward the end of a driving shift confirmed the feasibility of a study of vigilance in the Road Test framework. The present APRO experiment, a study of the general problems of declines in detection of critical signals as a function of time spent in monitoring, was conducted during the second year of the AASHO Road Test. The APRO study did not attempt to relate vigilance performance to driving safety.

1/ The Human Factors Research Branch, TAG R and D Command, became the US Army Personnel Research Office under the Chief of Research and Development on 3 December, 1961.

SPECIFIC OBJECTIVES

The research described in the present Research Note was specifically designed to (1) examine the general level of signal detection performance of AASHO drivers and to determine the nature and extent of any decrement in vigilance over a driving shift, and (2) to examine the range and stability of individual differences in signal detection and to estimate the reliability of the vigilance test scores. Additionally, the study permitted evaluation of the usefulness of specially constructed apparatus to measure signal detection performance.

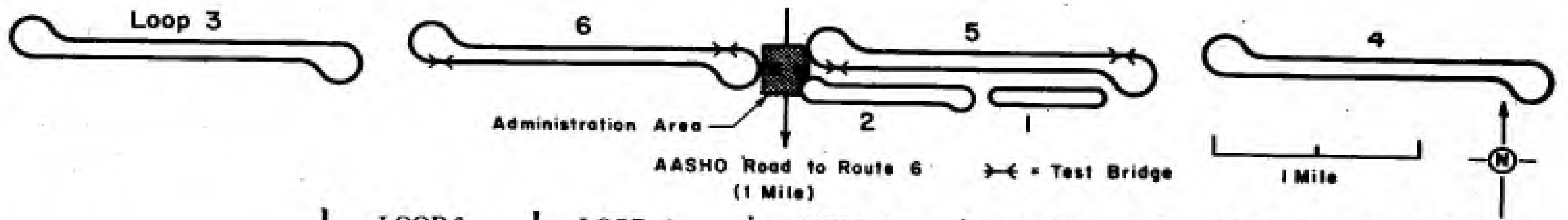
METHOD

AASHO Road Test

The primary purpose of the Road Test, which provided the framework for the present study, was to observe the effects of varying traffic loads, continuously applied, on different types of highway surface. The setting--near Ottawa, Illinois, 89 miles southwest of Chicago--was considered representative of many parts of the United States in terms of soil and climate. Traffic consisted of commercial trucks loaded with concrete blocks to near maximum axle loads. Driving was conducted on five two-lane loops (a sixth loop served as control against which traffic effects would be measured) laid out as shown in Figure 1. There were 20 trucks to each loop, 10 to each traffic lane.

The United States Army Transportation Corps had transferred a complement of 300 enlisted men and officers to the Road Test site as drivers. Twenty trucks were assigned to each of five driving loops. In order to have traffic coverage over all hours of day and night, three driving schedules were formed, with two driving shifts to each schedule. Each shift lasted approximately nine hours, seven and one-half of which were driving time. Schedules were changed every two weeks so as to equalize day and night duty for each driver. Table 1 shows the three schedules, the hours of each shift, and driving period.

Each driving shift was made up of seven driving periods and six rest breaks--five 15-minute rest breaks and one 40-minute meal break. During the 15-minute breaks, traffic was stopped and drivers went into the crew shacks for refreshments and smoking. During the meal break, hot meals were delivered to the crew shacks. During the driving periods, men drove continuously around the assigned loop. Driving periods became progressively shorter toward the latter part of the shift, being sequenced in intervals of 90, 90, 90, 60, 45 and 30 minutes. Speed of driving was rigidly controlled. Special equipment on the lead trucks kept driving speed down to 35 miles per hour on the tangents and from 15 to 25 miles per hour on the loop turn-arounds. Stringent safety precautions were enforced.



Test axle loadings:	LOOP 3	LOOP 6	LOOP 5	LOOP 2	LOOP 1	LOOP 4
	12,000-lb. single	30,000-lb. single	22,400-lb. single	2,000-lb. single	No traffic	18,000-lb. single
	24,000-lb. tandem	48,000-lb. tandem	40,000-lb. tandem	6,000-lb single	Strain test traffic	32,000-lb. tandem

Figure 1. Physical Layout of the AASHO Road Test Project Driving Loops. (Source: <u>AASHO Road Test Highway Research Board Pamphlet</u>, Sept., 1958.)

Table 1

DRIVING SCHEDULE FOR AASHO HIGHWAY ROAD TEST
(Source: AASHO Road Test Project Bulletin)

SCHEDULE "A" 1000-0505			SCHEDULE "B" 1530-1035			SCHEDULE "C" 2030-1535		
1st Shift	Hour	Minutes	1st Shift	Hour	Minutes	1st Shift	Hour	Minutes
Drive	1000-1130	90	Drive	1530-1700	90	Drive	2030-2200	90
Break	1130-1145			1700-1740	Meal	Break	2200-2215	
Drive	1145-1315	90	Drive	1740-1910	90	Drive	2215-2345	90
	1315-1355	Meal	Break	1910-1925			2345-0025	Meal
Drive	1355-1525	90	Drive	1925-2055	90	Drive	0025-0155	90
Break	1525-1540		Break	2055-2110		Break	0155-0210	
Drive	1540-1640	60	Drive	2110-2210	60	Drive	0210-0310	60
Break	1640-1655		Break	2210-2225		Break	0310-0325	
Drive	1655-1740	45	Drive	2225-2310	45	Drive	0325-0410	45
Break	1740-1755		Break	2310-2325		Break	0410-0425	
Drive	1755-1840	45	Drive	2325-0010	45	Drive	0425-0510	45
Break	1840-1855		Break	0010-0025		Break	0510-0525	
Drive	1855-1925	30	Drive	0025-0055	30	Drive	0525-0555	30
		450			450			450
2nd Shift			2nd Shift			2nd Shift		
Drive	1940-2110	90	Drive	0110-0240	90	Drive	0610-0740	90
Break	2110-2125		Break	0240-0255		Break	0740-0755	
Drive	2125-2255	90	Drive	0255-0425	90	Drive	0755-0925	90
Break	2255-2310		Break	0425-0440		Break	0925-0940	
Drive	2310-0040	90	Drive	0440-0610	90	Drive	0940-1110	90
	0040-0120	Meal		0610-0650	Meal	Break	1110-1125	
Drive	0120-0220	60	Drive	0650-0750	60	Drive	1125-1225	60
Break	0220-0235		Break	0750-0805			1225-1305	Meal
Drive	0235-0320	45	Drive	0805-0850	45	Drive	1305-1350	45
Break	0320-0335		Break	0850-0905		Break	1350-1405	
Drive	0335-0420	45	Drive	0905-0950	45	Drive	1405-1450	45
Break	0420-0435		Break	0950-1005		Break	1450-1505	
Drive	0435-0505	30	Drive	1005-1035	30	Drive	1505-1535	30
		450			450			450

Vigilance Testing Apparatus

APRO investigators had to develop an experimental task which would yield measures of signal detection without interfering with driving safety. The vigilance measurement concept finally incorporated in the Transportation Corps Vigilance Tester involved the detection of visual light signals emitted from a display mounted in the cab of the truck. To increase the difficulty of the task, a discrimination problem was added. Two types of light signals were presented, one requiring a response (the critical signal), and the other requiring no response (noncritical signal). The task of responding was made as simple as possible, requiring only the depression of a foot pedal.

The apparatus[2/] consists of a signal display unit (Figure 2), a response mechanism (a foot pedal connected to appropriate counters), and a programming mechanism by which the sequencing of light signals and intervals between signals was controlled. The instrument panel (Figure 3) located on the face of the programming unit, and mounted on the truck bed, allowed the experimenter to control intensity of signal, duration of signal, and display illumination by setting appropriate knobs and switches. Specifications for the Vigilance Tester and details of its operation are presented in Appendix A.

For the APRO experiment, a basic one-hour program was developed, with a total of 121 signals. Critical signals appeared at the rate of 30 per hour, noncritical signals at the rate of 91 per hour. The relatively high noncritical signal rate was established with the intention of making the vigilance task more difficult. The order in which a signal appeared in a given light position was randomized. Intersignal intervals of 5 to 75 seconds were interspersed at random. Each signal lasted 1.0 second, a rather long duration in comparison with that used in laboratory studies, but considered necessary in view of the attention required by the concomitant task of driving. Eight-hour tapes were assembled by systematically randomizing and reversing the order of 30-minute blocks of the original program.

Maximum signal brightness, necessary during the day because of the high illumination level of both display and surround, was constant during daytime driving. Signal brightness was lowered somewhat for night driving in an attempt to reduce contrast between display and surround and thus to equalize probability of detection during day and night driving. The attempt was not successful, however, and the difference in contrast between display and surround probably was the main factor contributing to observed significant differences in day versus night performance.

2/ Mr. H. C. Huckins, Chief Instrumentation Engineer of the Road Test Project, designed the mobile apparatus in its entirety and built and tested a prototype apparatus, performed acceptance tests on the 14 instruments assembled by a contractor, and maintained and modified the apparatus during actual testing. The instruments were built with funds furnished by the U. S. Army Transportation Corps.

Figure 2. Mounted signal display unit of the Transportation Corps Vigilance Tester.

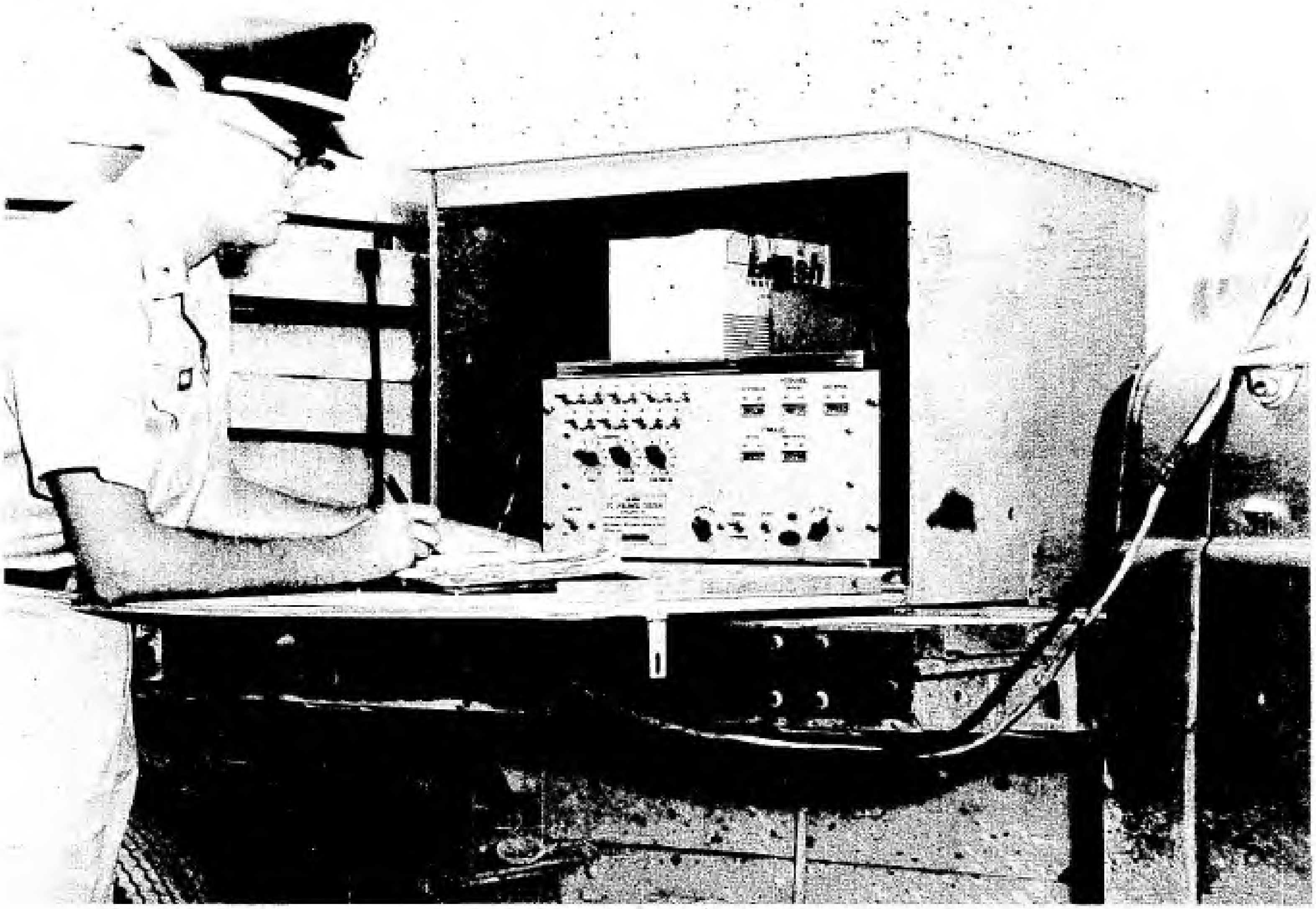


Figure 3. Programming Mechanism of the Transportation Corps Vigilance Tester mounted on truck bed.

After the appearance of a light signal, the driver had five seconds in which to make a response before the circuit closed. The counters cumulatively registered responses made during a driving shift. No within-period measures could be taken.

The relevant signal parameters may be summarized as follows (a more comprehensive description is presented in Appendix A):

<u>Signal Rate</u>: Critical - 30 per hour
Noncritical - 91 per hour

<u>Intersignal Intervals</u>: 5, 10, 15, 20, 30, 50, and 75 seconds

<u>Signal Duration</u>: 1.0 seconds

<u>Signal Intensity</u>: 150 milliamp incandescent light bulbs

<u>Response Lockout Interval</u>: 5 seconds

Performance Measures

Two vigilance performance measures were computed from data obtained from the Vigilance Tester counters:

<u>Percent detection score</u>. The percentage of critical signals detected.

$$\frac{\text{No. of critical responses}}{\text{No. of critical signals}} (100)$$

<u>False detection score</u>. A score representing errors of commission, that is, responses to noncritical signals and responses when no signals appeared. The measure included responses made 5 seconds or more following either a critical or a noncritical signal inasmuch as the lockout device prevented registry of late responses as signal detections.

$$\frac{\text{No. of false responses, including responses to imaginary signals}}{\text{No. of noncritical signals}} (100)$$

Scores on the two measures were free to vary independently because each score was derived from different signal occurrences. A driver who responded indiscriminately to all signals which appeared would have a perfect percent detection score and a high false detection score as well. A false detection score was therefore a necessary adjunct to the psychometrically deficient percent detection score.

Data analysis showed that the two types of errors of commission--responses to noncritical signals and responses to "imaginary" signals, that is, responses made when no signals appeared--occurred in approximately equal number and varied to approximately the same degree among subjects. Each type thus contributed about the same amount of total false detection score variance. The inclusion of "imaginary" errors in the numerator of the fraction was questionable mathematically, but was considered justifiable in that the two terms seemed logically equivalent.

One additional point on measurement--"No Signal" responses included late responses. However, extensive observations of drivers during pilct testing showed that late responses were rarely made, the five-second lockout interval being more than adequate.

Sample for APRO Vigilance Study

The sample analyzed in the present study consisted of 42 drivers. Of these, 19 were tested during daytime driving, 23 during night driving. Beyond the selection incurred in assignment to the AASHO Road Test, the only stipulation for selecting drivers for the vigilance test was that they must have been assigned to a particular driving loop at least one month prior to testing. Drivers were included in the analysis sample only if vigilance test response records were complete for six consecutive driving periods. The difficulties encountered in testing one driver uninterruptedly over one complete driving shift proved formidable. Numerous individual response records were invalidated by vehicle breakdowns, highway maintenance breaks, and mechanical difficulties with the vigilance testers. These fortuitous circumstances, rather than any known selection bias, determined whether a driver completed six full driving periods without interruption and was therefore included in the sample.

The limited number of complete data cases and their distribution over the five driving loops did not permit a comprehensive analysis covering all five loops under all three schedules. Loops 3 and 4 were selected as most representative, since trucks in the two loops were similar in having neither the largest nor the smallest axle load among those trucks in the Road Test (Figure 1). The total sample was augmented by 10 drivers from other loops.

Drivers were tested only during Schedules A and C. The two schedules each provided a distinct day shift and a distinct night shift, whereas each shift of Schedule B spanned both day and night intervals (Table 1). The number of drivers tested is shown by schedule, shift, and loop in Table 2.

Table 2

COMPOSITION OF VIGILANCE STUDY SAMPLE BY SCHEDULE, SHIFT, AND LOOP

	Schedule A		Schedule C		
Loop	Day	Night	Day	Night	Total
2	0	1	0	0	1
3	0	0	5	6	11
4	0	7	8	6	21
5	1	0	0	0	1
6	4	3	1	0	8
Totals	5	11	14	12	42

Testing Procedures

Vigilance testing was conducted from August through November 1960 by one project officer and three enlisted men--the latter acting as data recorders. The testing sequence for each driving shift was as follows: Prior to the driving shift, the vigilance testers were mounted on the trucks and checked to be sure they were in good operating condition. When drivers arrived for the usual pre-shift briefing, the project officer gave them the standard instructions (Appendix B). The drivers were told they were participating in a human factors experiment and were urged to do their best within the limits of driving safety. Data recorders entered the name of each driver, his truck number, and other identifying information on standard data forms. Each driver responded to a few practice signals to make sure he fully understood the procedure. The position of the foot pedal was adjusted so as to be most comfortable for the individual.

Drivers were instructed to turn on the vigilance tester as they entered loop traffic, and to turn it off at the end of the driving period as they turned into the parking area. During rest breaks, and at the end of the driving shift, data recorders read from the instrument panel the cumulative record of signals and responses and recorded the information on the data forms. In case of malfunction of the vigilance tester, an auxiliary tester was mounted on the truck if time permitted. Too frequently, however, replacement was not possible, a condition which accounts in part for the relatively small number of cases meeting requirements for analysis.

Statistical Procedures

Treatment of the data. Data from different schedules and loops were merged for analysis, t-tests having revealed no significant differences between mean detection levels of drivers of the two schedules or the two loops selected for analysis (Appendix C).

Inability to equalize display-surround contrast for day and night testing precluded a precise test of day-night performance differences. However, day and night distinctions were maintained in data analysis, inasmuch as F tests yielded significant differences in mean detection levels under the two conditions.

Frequency distributions of detection scores and false response scores showed marked skew (Appendixes D and E). Correlation between means and standard deviations was also in evidence. To reduce the observed irregularities and make the data amenable to parametric analysis, each driver's scores were transformed to arcsin scores ($X = \arcsin \sqrt{P}$) where, in this study, P is the percentage detections or percentage false detections.

Analysis of detection levels and trends. For each of the two vigilance performance measures, arcsin means, standard deviations, and ranges of scores were computed for each driving period, separately for day and night drivers, and for the total group.

Analysis of variance was performed on the transformed data to test for differences between day and night drivers, for differences among the vigilance score means over the six driving periods, and for interactions (Edwards, 1960). Analysis of variance was supplemented by tests for significant trends among the means over the driving periods and for differences in slope between day period means and night period means (Edwards, 1960).

Changes in inter-subject variability from first to sixth driving period were also tested for significance by means of t-tests (McNemar, 1955). Correlation coefficients between scores on period one and period six were computed. The reliability of individual difference scores was estimated by internal consistency analysis.

RESULTS

Overall Detection Level

The overall level of signal detection was high. For all six driving periods combined, drivers detected, on the average, 83 percent of the critical signals. The average number of false detections for all drivers was 4.0 percent.

Night drivers detected a significantly higher percentage of critical signals than did day drivers (90% vs 74%). However, no significant difference in mean percentage of false detections was found between the two groups. Mean false detection score for night drivers was 4.2%, for day drivers, 3.8%. Tables 3 and 4 show mean percent detection scores and false detection scores for each driving period, separately for day and night drivers, and for the total group. Percent detection score means are plotted by driving period in Figure 4, false detection means in Figure 5.

Performance Trends Over Six Driving Periods

Vigilance performance remained at a high level throughout the six driving periods, in spite of monitoring conditions conducive to boredom and fatigue (Tables 3 and 4). Percent detection score means for all 42 drivers failed to show the hypothesized decrement as driving time progressed. Quite the contrary, a steady improvement in total group performance was demonstrated. Improvement was pronounced in the case of night drivers, whereas day drivers maintained a relatively constant performance level (Figure 4).

In errors of commission, denoted by false detection scores, the total group demonstrated a steady decrease in error rate over the six-period driving shift, a result also contrary to expectations. Night drivers showed definite improvement whereas day drivers showed irregular variations in error scores (Figure 5).

A summary of analysis of variance for the two performance measures is shown in Table 5. F ratios associated with driving period main effect for both detection level and false detection score, when results for day and night drivers were combined, failed to reach the .05 point of statistical significance. More precise tests for the presence and significance of linear and curvilinear (quadratic) trends revealed significant trends in the period means (Table 6). The trend in percent detection level means was linear and upward; in false detection means, the trend was linear and downward.

When tests for trends were made separately for day and night period means, significant trends in both performance measures were found for night drivers but not for day drivers. Thus, significant trends found for overall period means were due to even more significant trends during night driving.

Tests for quadratic trends, summarized in Table 6, revealed no significant curvature in the means of either performance measure. When the variation in period means associated with both linear and quadratic components was removed, a residual with 3 degrees of freedom remained. Contained in this residual was variance associated with cubic or higher trends. F ratios, testing for the presence of higher trends, yielded no significant residuals associated with day, night, or total period means. The significant trends established were considered well accounted for by linear increases or decreases.

Table 3

PERCENTAGE OF CRITICAL SIGNALS DETECTED BY ROAD TEST DRIVERS IN EACH OF SIX DRIVING PERIODS (ARCSIN SCORES)

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Periods 1-6, Inclusive
Day Driving (N = 19)							
Mean	61.2	60.3	60.1	61.7	61.8	59.8	60.8
Std. Dev.	9.7	12.3	11.5	10.5	13.4	17.6	10.4
Range	39.2/75.9	40.5/90.0	36.1/80.2	45.6/77.3	43.7/90.0	27.1/90.0	27.1/90.0
Night Driving (N = 23)							
Mean	72.2	73.9	75.0	73.1	77.6	78.3	75.0
Std. Dev.	11.0	10.2	13.3	10.9	11.4	12.3	9.4
Range	49.4/90.0	54.3/90.0	36.2/90.0	51.5/90.0	52.9/90.0	53.7/90.0	36.2/90.0
Total (N = 42)							
Mean	67.2	67.7	68.3	67.9	70.4	69.9	68.6
Std. Dev.	11.7	13.1	14.5	12.1	14.6	17.5	12.2
Range	39.2/90.0	40.5/90.0	36.1/90.0	45.6/90.0	43.7/90.0	27.1/90.0	27.1/90.0

Table 4

SCORES ON FALSE DETECTION MEASURE FOR ROAD TEST DRIVERS IN EACH OF SIX DRIVING PERIODS
(ARCSIN SCORES)

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Periods 1-6, Inclusive
Day Driving (N = 19)							
Mean	8.4	10.8	7.3	9.8	9.1	4.9	8.4
Std. Dev.	5.8	9.3	5.6	14.5	11.7	5.0	5.7
Range	0/20.4	0/36.7	0/19.2	0/66.3	0/43.9	0/14.5	0/66.3
Night Driving (N = 23)							
Mean	10.4	9.6	8.9	7.0	6.0	6.5	8.1
Std. Dev.	9.3	11.6	8.0	6.2	6.5	5.9	6.0
Range	0.0/42.4	0.0/40.6	0.0/31.2	0.0/15.9	0.0/18.3	0.0/17.0	0.0/42.4
Total (N = 14)							
Mean	9.5	10.1	8.2	8.2	7.4	5.8	8.2
Std. Dev.	7.9	10.7	7.1	10.8	9.3	5.6	5.9
Range	0/42.4	0/40.6	0/31.2	0/66.3	0/43.9	0/17.0	0.0/66.3

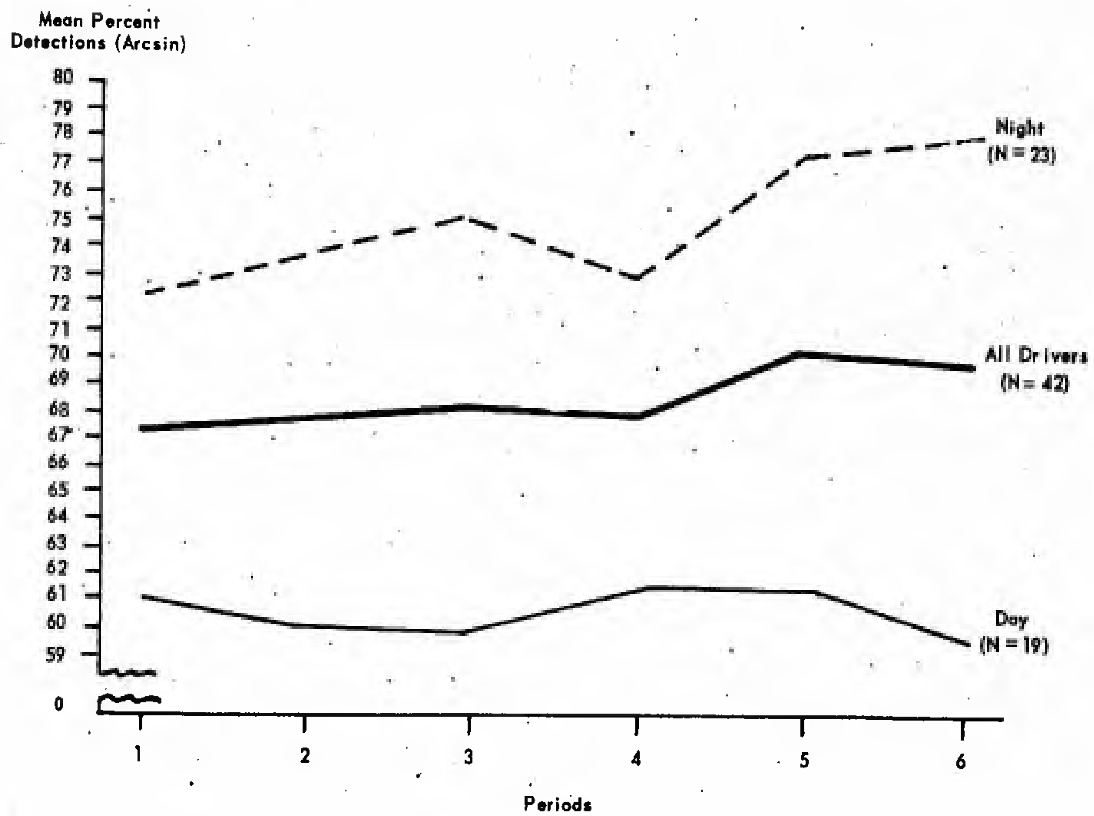


Figure 4. Mean Percent Detection Scores by Driving Period

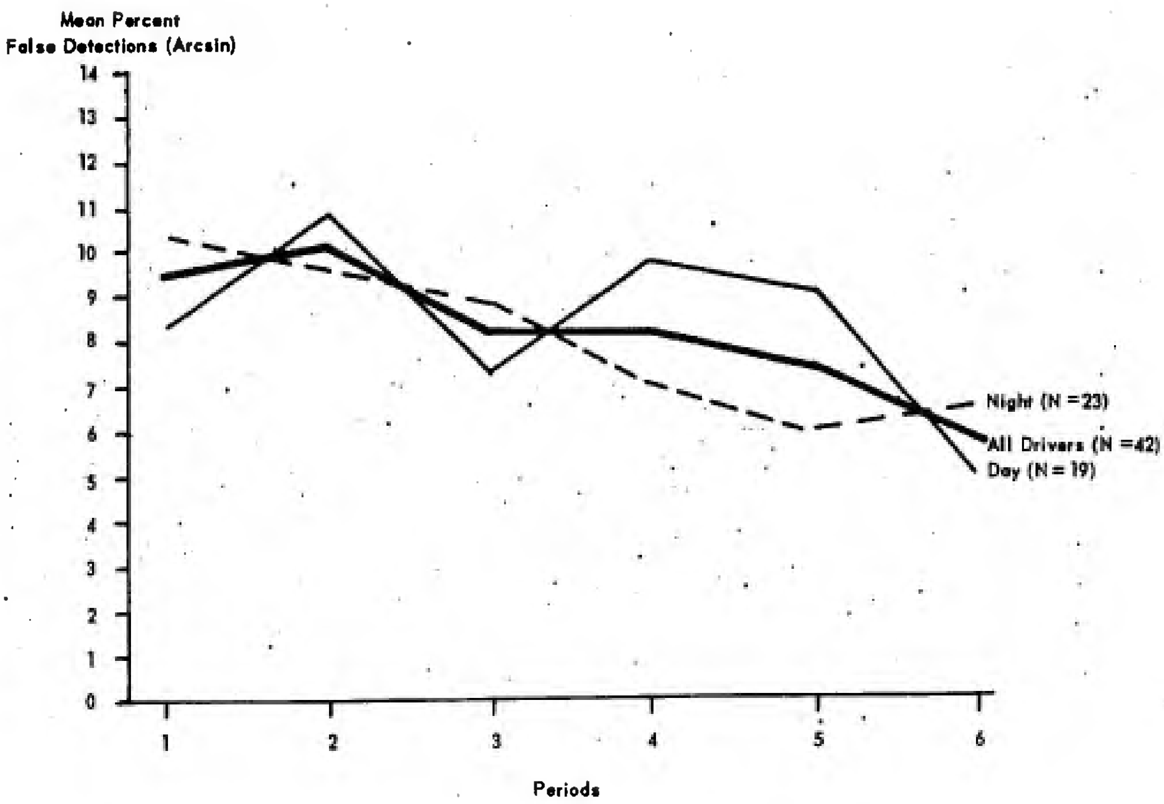


Figure 5. Mean False Detection Scores by Driving Period

Table 5

SUMMARY OF F-RATIOS (ARCSIN SCORES) FROM ANALYSIS OF VARIANCE
(N = 42)

	Sources of Variance		
Performance Measures	Day vs Night	Periods	Periods X Day/Night
Percent Detections	20.4*	1.2	1.3
Percent False Detections	0.3	1.8	1.0
df	1/40	5/200	5/200

*Significant beyond 1% point.

Table 6

SUMMARY OF F-RATIOS FROM TREND ANALYSIS
OF PERIOD MEANS OF VIGILANCE MEASURES
(ARCSIN SCORES)

	Trend		
Performance Measures	Linear	Quadratic	Residual
Percent Detections			
Day Periods Only	0.0	0.0	0.4
Night Periods Only	8.4**	0.3	0.8
Total Periods	4.4*	0.1	0.5
Day/Night X Period	4.8*	0.3	0.4
Percent False Detections			
Day Periods Only	2.0	2.0	1.1
Night Periods Only	6.1*	0.1	0.2
Total Periods	7.7**	0.5	0.3
Day/Night X Period	0.8	1.5	0.9
df	1/200	1/200	3/200

*Trend significant beyond 5% point.
**Trend significant beyond 1% point.

The periods by day-night interaction terms of the regular analysis of variance (Table 5) failed to reach the .05 point of significance for either dependent measure. This interaction tested the hypothesis that day and night period means differed in general conformation. Trend tests, performed as a more specific test of the hypothesis that different slopes were present in day and night period means, demonstrated a significant difference in slopes for day and night drivers, on the percent detection measure but not for the false detection measure. The differential trend is readily seen in Figure 4. No significant difference was found between the quadratic components of day and night period means.

Table 7

SIGNIFICANCE TESTS OF DIFFERENCES IN VIGILANCE TEST SCORE VARIANCE BETWEEN DRIVING PERIOD 1 AND DRIVING PERIOD 6 (ARCSIN SCORES)

Performance Measures	Variance Period 1	Variance Period 6	$S_6^2 - S_1^2$ Diff.	p[a]
Percent Detections				
Day	94.09	309.76	+215.67	.01
Night	121.00	151.29	+ 30.29	N.S.
Overall	139.24	306.25	+167.01	.01
Percent False Detections				
Day	33.64	25.00	- 8.64	N.S.
Night	86.49	34.81	- 51.68	.05
Overall	62.41	31.36	- 31.05	.05

df: day = 18; night = 22; overall = 41

[a]Based on two-tailed t-tests.

Extent and Stability of Individual Differences in Vigilance Performance

Wide individual differences in both vigilance measures were present during the first driving period. Percent detection scores during driving period one ranged from 40.0% to 100.00% and false detection scores from 0.0% to 45.5% (Tables 3 and 4). Percent detection scores showed an increased range for period six (20.8% to 100.0%), and the range of false detection scores had narrowed (0.0% to 8.5%). The standard deviations for both measures are plotted by driving period in Figures 6 and 7.

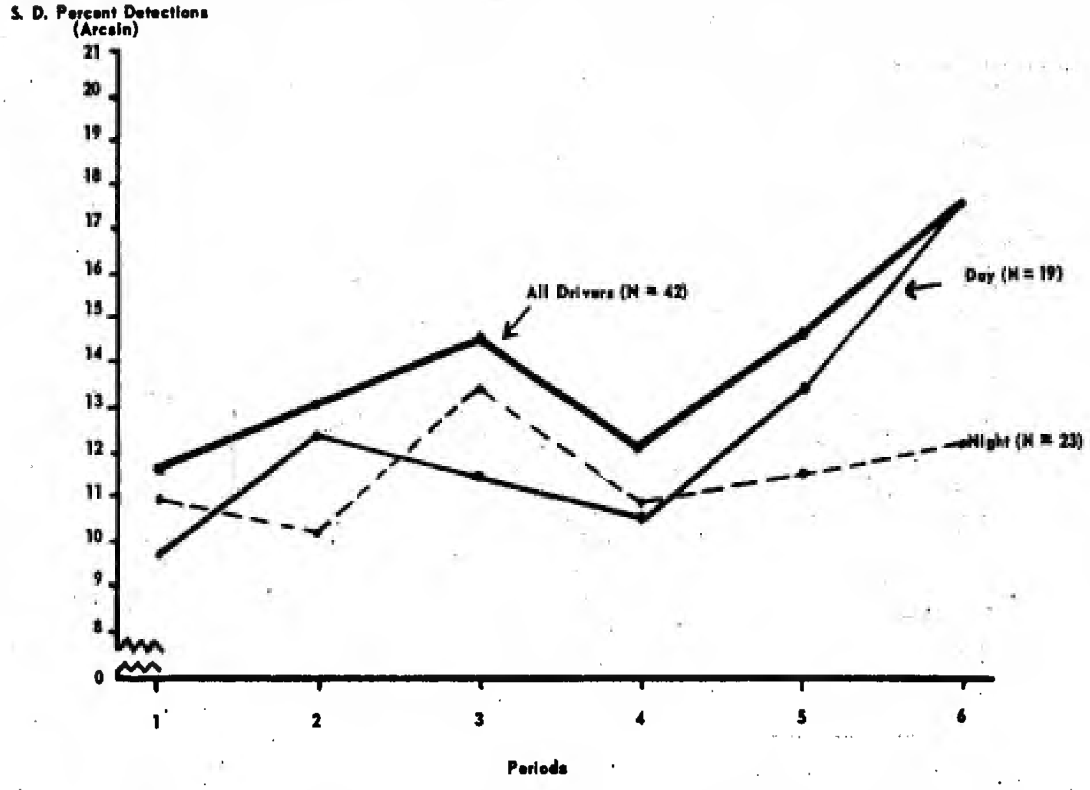


Figure 6. Standard Deviations of Percent Detection Scores by Driving Period

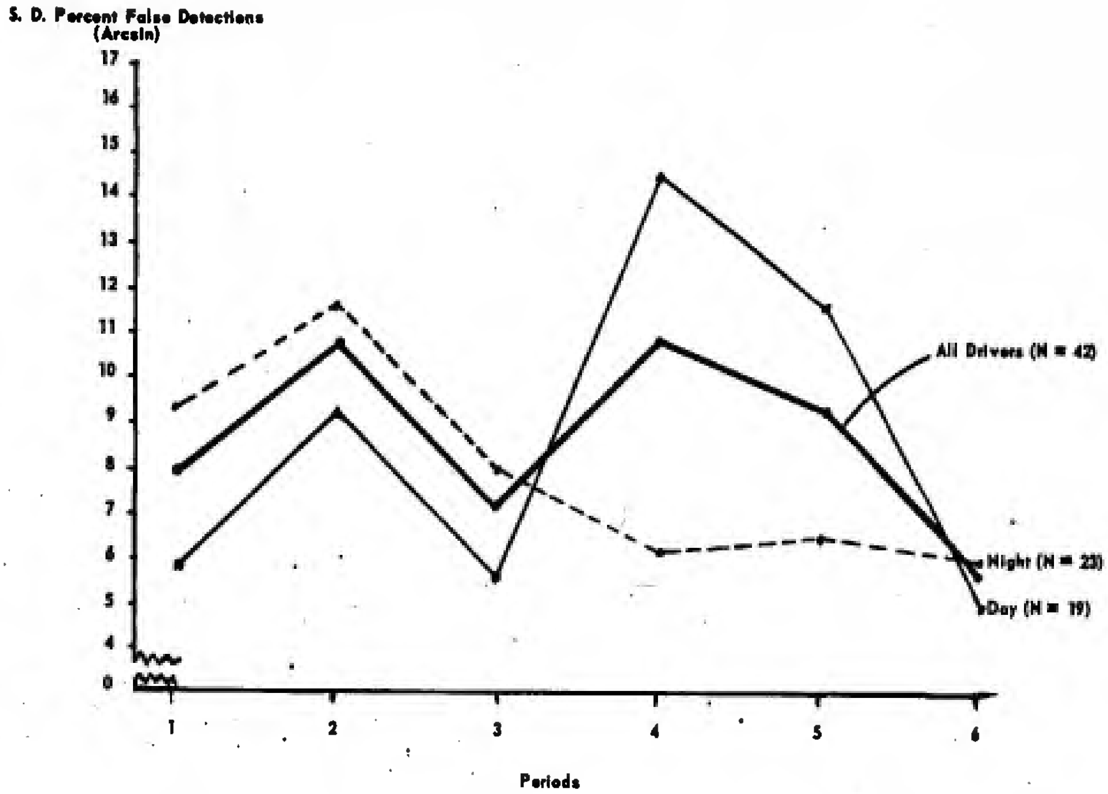


Figure 7. Standard Deviations of False Detection Scores by Driving Period

Differences among individuals in the detection of critical signals increased significantly between driving periods one and six (Table 7). Individual differences in percent false detections decreased significantly during this interval. Changes in variance were not parallel for day and night drivers. Percent detection score variability increased significantly for day drivers, and also increased--but not significantly--for night drivers. False detection score variability, on the other hand, decreased slightly and non-significantly from period one to six for day drivers, significantly for night drivers.

Moderate stability of initial differences among drivers in percent detection scores was indicated by a coefficient of .67 between scores for period one and period six, after five and one-half hours of driving. Correlation was higher for night than for day drivers (.64 vs .52). Relatively low stability (r = .23) was found for the false detection measure (Table 8). Individual differences for false detection measures were much more stable for day drivers than for night drivers (.50 vs .09).

Table 8

RELIABILITY COEFFICIENTS FOR VIGILANCE PERFORMANCE MEASURES (ARCSIN SCORES)

	Day Driving	Night Driving	Total
Odd-Driving Periods Versus Even-Driving Periods			
Percent Detections	.94[a]	.88[a]	.93[a]
Percent False Detections	.87[a]	.91[a]	.88[a]
First-Driving Period Versus Sixth-Driving Period			
Percent Detections	.52	.64	.67
Percent False Detections	.50	.09	.23

[a]Augmented by Spearman-Brown Formula.

Reliability of the Measures

Reliability coefficients, computed between scores on odd-numbered and even-numbered driving periods and augmented by the Spearman-Brown formula, were .93 and .88 for the percent detection and false detection scores, respectively (Table 8).

MAJOR FINDINGS

Four major findings of the present investigation require comment: (1) the unusually high average percentage of critical signals detected and the low percentage of error in the form of false detections; (2) the lack of decrement in vigilance performance as a function of time spent in monitoring; (3) the high reliability of individual differences in vigilance; and (4) the increased variability in percent detections as a function of time spent in monitoring.

High Level of Performance

Considering the length of the driving shift and the conditions under which monitoring was performed, detection of critical signals across all six driving periods was unusually high. Approximately 83 percent of all critical signals were correctly detected. Rates of false detection were also considered low, averaging only 4.0 percent for all drivers across the six periods.

The significant differences in performance found between night and day drivers are believed to be an artifact of the testing conditions rather than true night-day differences in alertness. There was much greater contrast between display and surround during day than during night driving. During the day the surround--the windshield of the truck--included colors, movements, and glare not present to nearly the same degree during night driving. Even though signal intensity was reduced at night and the display face illuminated to help equalize detection probability, the display-surround contrast could not be controlled. Contrast differences are believed to account also for the night performance trends. The surround of the signal display units became increasingly more homogeneous during the early morning hours of the night shift as lights from traffic on adjacent highways, farmhouses, and villages were less in evidence. The progressive increase in display-surround contrast may have made critical signals increasingly easier to detect for night drivers.

Learning was rejected as a potential explanation for the trends toward improved performance primarily because there is little reason to believe that learning would result in a linear improvement over a seven-hour period for night drivers but not for day drivers.

Sustained Level of Performance

The major purpose of the present study was to measure expected decrement in vigilance performance as a function of periods spent driving. No performance decrement was observed in the detection of critical signals, nor was an increment in false detections noted.

Factors present in the driving situation which were expected to depress the average percentage of critical signals detected included truck noise and vibration. These two factors have a demonstrated effect on monitoring behavior (Loeb and Jeantheau, 1958; Jerison and Wing, 1957). Fatigue and boredom were also expected to depress detection levels. The sheer physical fatigue caused by driving large, heavily loaded trucks for seven hours was reported as considerable by drivers. Add to this the energy required to discriminate among nearly 850 total signals in order to respond to approximately 210 critical signals, and the average detection level attained is rather surprising. Boredom induced by repeated circling of the driving loops was also expected to depress rates of critical signal detections. Since less-than-perfect detection performance was found for the group as a whole, all of the factors mentioned may have exerted some influence. In the light of the high detection levels, it must be concluded that the influence on monitoring was minimal. There is a possibility that some performance decrement did occur within driving periods. However, the overall high detection levels left little freedom for within-period variance.

Recent findings from research by other investigators allow more enlightened speculation as to some possible reasons the expected performance decline did not occur. These speculations may be discussed under three categories: Characteristics of the signal environment, characteristics of the task, and characteristics of the subjects.

<u>Characteristics of the signal environment</u>. One type of study, in particular, which has recently appeared in the vigilance literature may bear on the results of the present study. At least two studies have dealt with the deliberate programming of "artificial" or "irrelevant" signals into the monitoring task (Garvey, Taylor and Newlin, 1959; McGrath and Hatcher, 1961). These studies have shown that artificial signals, under certain conditions, enhance the detection of the real signals. This effect is marked when the artificial signals are perceptually similar to the real signals. In the present study, critical and noncritical signals were identical in all aspects except for the fact that critical signals appeared in red panels and noncritical signals in white panels. A high rate of noncritical signals was planned in the <u>a priori</u> belief that this procedure would make the appearance of critical signals less predictable and the total task consequently more difficult. In view of the observed effects of artificial signals in the studies cited, however, the end result of the high noncritical signal rate in the present study may have been to increase detection levels of critical signals and reduce the likelihood of a performance decrement.

Another possible explanatory factor was the high complexity of the signal environment caused by the "divided attention" aspect of the study. Studies of "complex" vigilance, i.e., tasks requiring subjects to monitor multiple signal sources (Jerison and Wallis, 1957; Jerison and Wing, 1957) do not report the typical decline in vigilance. Rather, these studies report a constant detection level over a period of monitoring. The divided attention feature of the present study makes it conceptually somewhat more similar to a complex than a simple study of vigilance.

The difference between these studies and the present one is that the absolute signal detection levels reported are much lower than those of the present study. However, the amount of environmental stimulation received from non-experimental signals in the present study may have enhanced alertness on the experimental task.

As mentioned earlier in the report, a psychometric question which concerned researchers was the feasibility of measuring directly a behavioral phenomenon which was in fact divided between two tasks--an experimental vigilance task in which responses were measured, and the actual task of driving, also requiring vigilance, in which responses were not measured. The overall high percentage detection level indicated that drivers were able to devote an adequate amount of time to the experimental task. That drivers were able to cope adequately with both tasks is also confirmed by observation and driver self-reports. No driving accidents occurred as a result of using the testers. No doubt the highly routine driving sequence under highly predictable conditions reduced considerably the amount of attention required by the actual driving task.

Other characteristics of the present experiment which were different from the usual laboratory experiments and which also may have helped prevent the appearance of a performance decrement were the relatively long one-second signal duration, and the relatively restricted range of intersignal intervals.

Characteristics of the task. Another important difference between the vigilance task of the present study and those generally used in laboratory studies is the degree of activity required by the monitor. As has been mentioned, drivers performed their normal driving tasks which included the monitoring of and responding to truck instruments and other loop traffic. While the absolute amount of perceptual-motor behavior required in driving was not extensive for the experienced drivers, it was relatively greater than that required of laboratory subjects passively monitoring experimental displays. Ray, Martin and Alluisi (1960) have pointed to conflicting results between active and passive vigilance tasks and have suggested the degree of active participation required by the subject may make a critical difference in the appearance of performance decrement.

Two other aspects of the Road Test research design probably helped maintain high detection levels. These were the diminishing length of driving periods as a shift progressed, and the interpolated rest pauses. Interpolated rest pauses generally have restricted the vigilance performance decrement in laboratory studies (McGrath, Harabedian, and Buckner, 1959), and might be expected to have the same effect in the present study--even though spaced relatively far apart.

Characteristics of subjects. Investigators suspect that driver motivation may have played a key role in the maintenance of high detection levels. Most drivers seemed interested in the task. Many who were not tested requested the opportunity to take the test. It is suspected that the sources of motivation were extrinsic to the experimental task itself and could be attributed to relief from driving boredom. Also, many drivers may have had lingering suspicions that their performance might somehow be entered in their official records, in spite of instructions to the contrary. This suspicion probably served as a negative motivator.

The role of motivation in vigilance has not been systematically studied. However, Adams and Chiles (1961) found that highly motivated subjects were able to perform complex monitoring and cognitive tasks under fatiguing work schedules for as long as 15 days without serious performance decrement. Their results suggest that future vigilance research should devote more attention to the subjects' attitude toward the experimental task. Adams and Chiles used a realistic space mock-up apparatus in their experiment. Their task appears to have much more face validity than many others such as clock monitoring used in laboratory studies. Plans are now under way by the Army Personnel Research Office to develop a realistic vigilance apparatus (Dobbins, 1961).

Range and Stability of Individual Differences in Vigilance Performance

In view of the wide initial individual differences in vigilance levels and the relative stability of these differences during a complete driving shift, the vigilance phenomenon may be classed among the relatively enduring aspects of the individual. High score reliability, if found for acceptable retest intervals, will qualify the vigilance phenomenon as a profitable subject area for psychologists interested in the prediction of individual differences. Only recently have attempts been made to conceptualize vigilance as an attribute of the individual. In a continuation of the present study, APRO human factor scientists have undertaken the evaluation of a number of hypothesized predictors of individual differences in vigilance performance (Dobbins, et al., 1961).

The observed increase in variability in percentage detections from period 1 to period 6 for day-shift drivers was not unexpected in the light of previous findings. Buckner, Harabedian, and McGrath (1960) have presented evidence that detection variability increases not only in percentage measures but also in measures of threshold sensitivity and response latency. The suggested explanation is that initial individual differences in vigilance increase along with increasing motivational differences among subjects as boredom and monotony come into play toward the end of the monitoring period.

Day-night differences in detection score variability may be, at least to some extent, a statistical artifact. As the average percentage of signals detected by night drivers systematically increased toward morning, score variation was restricted by the 100 percent upper score limit. Day drivers, on the other hand, did not show this increasing trend in average scores. Their scores were consequently more free to vary during period 6. The visibility artifact is also presumed to account for the significant decrease in percentage false detection variability from period 1 to period 6 found for night-shift drivers but not for day-shift drivers.

THE TC VIGILANCE TESTER

The TC Vigilance Tester, a mobile apparatus specifically designed to administer an experimental vigilance task to operators of moving vehicles, proved capable of generating internally consistent scores sufficiently reliable from a psychometric viewpoint to justify future use. The scores generated also showed adequate sensitivity to individual differences.

The apparatus reliability of the testers used in the present study was fairly low in terms of frequency of breakdowns. Experience gained during the course of the study, however, suggested that modifications of certain components would lead to a highly satisfactory instrument.

CONCLUSIONS

In the present study, signal detection performance began at a high level, and stayed at a high level in spite of inhibitory factors present in the monitoring conditions--noise, vibration, long hours, boredom, and fatigue. Evidently compensatory factors also present combined to sustain a high level of performance. The influence of inhibitory factors was apparent in increased variability of performance rather than in level of performance.

Together with findings of other research on active and complex monitoring tasks, the present findings support the contention that the rapid, severe decrement found in the passive monitoring of laboratory displays may be of limited generality. The results of laboratory experiments do not seem to represent adequately the human monitoring proficienc, when the monitoring task is meaningful and when monitors are physically active. The classical decrement curve may represent a basic and significant perceptual phenomenon under conditions of low general stimulation. However, when investigators are seeking a basis for recommending monitoring schedules for military or industrial personnel, research should be based on more realistic simulation of representative signal environments and work methods. Otherwise there is danger of seriously underestimating human capabilities for many monitoring tasks.

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APPENDIXES

APPENDIX A

THE TRANSPORTATION CORPS VIGILANCE TESTER--STRUCTURAL COMPONENTS AND TEST METHODOLOGY

The TC Vigilance Tester, as finally assembled, had three components: the signal display unit, the response mechanism, and the programming mechanism. The programming mechanism was made up of a teletype transmitter unit, a relay complex, and an instrument panel.

SIGNAL DISPLAY UNIT

Display units were mounted (by means of angle irons) in the center of the dashboards facing the driver, and slightly to the right of the driver's line of sight (Figure 2). The display consisted of 15 clear light bulbs equally spaced in a circle four inches in diameter. The cardboard face of each display was arbitrarily marked off into six "critical" panels, painted red, and nine "noncritical" panels which were white. Investigators felt that at least four critical panels were necessary to force attention to all quadrants of the circle. Two additional critical panels were then added to reduce symmetry.

RESPONSE MECHANISM

The response unit consisted of a foot pedal attached to a heavy cast-iron plate, and placed on the floorboard near the driver's left foot. A response was simply a depression of the foot pedal. Prior to testing, the driver was allowed to place the foot pedal in the position most appropriate and comfortable for his particular body build. Once positioned, the cast-iron base plate kept the unit from shifting.

PROGRAMMING MECHANISM

The programming mechanism, mounted on the truck bed and connected to the display and response unit by cables, consisted of three separate parts: a teletype tape transmitter unit, a complex of electrical relays and vacuum tube, and an instrument panel. Programming units were mounted within specially built 21" x 27" x 21" wooden housings attached to the truck beds by angle irons. The power source for the units was the 12-volt truck batteries. The current was transformed into 110 AC by a power converter, which was placed in the front seat beside the driver. The teletype transmitter unit utilized a five-level punched-tape program to transmit commands to the relay complex. The punched tape controlled the sequencing of light signals and the time intervals between signals. Certain relays were opened at the command of the tape to allow signals to appear at specified times in different positions on the display face. Different relays opened and closed to permit signals and responses to register in the appropriate counters. The instrument panel, shown in Figure 3, allowed the experimenter to control signal intensity, signal duration, and display illumination by setting appropriate knobs and switches. Signal and response counters also appeared on the instrument panel.

VARYING CHARACTERISTICS OF THE SIGNAL

Certain characteristics of the signal could be systematically varied or held constant at the discretion of the experimenters.

Signal Rate. Critical signals were programmed to appear at the rate of 30 per hour. The rate was representative of rates typically used in laboratory experimentation. Noncritical signals were programmed to appear at the rate of 91 per hour. A relatively high noncritical signal rate was established with the intention of increasing the difficulty of the task. However, other research studies, cited in the discussion section, suggested that the high noncritical rate actually decreased the difficulty of the task. A basic one-hour program was developed, consisting of 121 total signals. Signals appeared in each panel an equal number of times per hour--5 per hour in each of the six critical panels--9 to 12 per hour in each of the nine noncritical panels. The order in which a signal appeared in the light positions was randomized. From the basic one-hour program, eight-hour tapes were punched to cover one seven-hour driving shift plus a one-hour buffer in case of tape difficulties. The eight-hour tape programs were assembled by systematically randomizing and reversing the order of 30-minute blocks of the original program.

Intersignal Interval. Seven intersignal intervals were available to the experimenter: 5, 10, 15, 20, 30, 50, and 75 seconds. The basic one-hour program was drawn from an approximately rectangular distribution of intervals. A rectangular distribution was used to decrease signal regularity and make the task more difficult. Each intersignal interval occurred approximately the same number of times during a one-hour interval--16 to 18 times each, per hour. The order in which a given intersignal interval occurred was randomized; the pairing of a signal in a given position on the display face with the intersignal interval which followed was random. Frequency of signal appearance is summarized in Table A-1, frequency of intervals of varying length in Table A-2.

Signal Duration. The TC Vigilance Tester has a signal duration range from 0.1 to 1.0 seconds. In the present study, signal duration was kept constant at 1.0 seconds throughout the course of testing. The relatively long signal duration was used in an attempt to prevent drivers from missing critical signals because their attention was momentarily taken up by the driving task.

Table A-1

NUMBER OF TIMES LIGHTS APPEARED IN EACH OF 15 POSITIONS IN ONE HOUR

Light Position	N
1[a b]	5
2	10
3	10
4[a]	5
5	10
6[a]	5
7	9
8	12
9[a]	5
10	11
11[a]	5
12	10
13[a]	5
14	10
15	9

[a]Critical positions.

[b]Light Position "1" was 12 o'clock on the display face; the remaining numbers followed in clockwise sequence.

Table A-2

NUMBER OF TIMES EACH OF SEVEN INTERSIGNAL INTERVALS OCCURRED IN ONE HOUR

Intersignal Interval	N
5 Sec	18
10 Sec	17
15 Sec	16
20 Sec	17
30 Sec	17
50 Sec	18
75 Sec	18

Signal Intensity. The light signals were 150-milliamp incandescent bulbs which could be varied from below to well above threshold strength. Although no physical measure of light intensities used was available, maximum signal brightness was constant for all drivers during daytime driving. The maximum signal brightness, necessary during day driving because of the high illumination of both display and surround, was relatively brighter during night driving because of lower illumination levels. Signal brightness at night was accordingly reduced in an attempt to equalize probability of detection for both day and night.

In the center of the display, another bulb, installed behind a circular disc of clear plastic, was constantly 'on' during night driving. The disc was painted black to eliminate direct glare, but light filtered through the unpainted circumference and adequately illuminated the display face. Investigators felt that the relative degrees of signal brightness and level of illumination on the display face was roughly comparable over day and night driving. One deficiency, impossible to control, however, was the relative amount of contrast between the signal display unit and its surround. The surround of the display was the windshield of the truck. Much more movement, color, and glare were visible through the windshields during the day than at night.

Response Lockout Interval. After the appearance of a light signal, the driver had five seconds in which to make a response. This feature was included to give drivers the opportunity to respond to a detected signal even though momentarily diverted by the driving task. The circuit was open for five seconds after the appearance of both critical and noncritical signals. If the driver responded after the five-second interval, the response was recorded in a separate counter described below. Once a response had been made, the lockout interval was automatically terminated, making it impossible for a driver to record more than one correct response to a signal.

RECORDING INSTRUMENTATION

Five counters on the face of the instrument panel recorded the following signal and response information:

Critical Signals. This counter cumulatively recorded the number of critical signals, i. e., signals appearing in red panels.

Noncritical Signals. This counter cumulatively recorded the number of noncritical signals, i. e., signals appearing in white panels.

Critical Responses. This counter cumulatively recorded the number of responses made within five seconds to critical signals. These were "correct" responses.

Noncritical Responses. This counter cumulatively recorded the number of responses made within five seconds to signals designated as noncritical. These were "incorrect" responses.

No-Signal Responses. This counter had two purposes. First, it recorded responses to "imaginary" signals, i. e., those made when no signal appeared. Second, it recorded responses made to either a critical or noncritical signal when the response was made five seconds or more after the occurrence of the previous signal. These responses were also "incorrect."

APPENDIX B

TC VIGILANCE TESTER--INSTRUCTIONS TO DRIVERS

Prior to testing, the project officer read the following instructions to drivers assembled in crew shacks:

> "During this driving shift you will be taking a test on the Transportation Corps Vigilance Tester, which was specifically developed for driver research at the AASHO Road Test.
>
> In the cab of the truck you are assigned to, there are three pieces of equipment: a light-box mounted on the dash, a foot pedal near the clutch, and a converter with an on-off switch on the seat next to you.
>
> When you enter the cab to begin driving, the tester will not be working. First, be sure that you can see the face of the light box. Second, locate the foot pedal and move it to a position which is comfortable for your left foot. Third, try out the foot pedal to get the feel of it.
>
> As each driving period begins, immediately after you cross the first bridge, reach over and turn the tester on by pushing the converter on-off switch to the 'on' position. Do not do this unless you have your truck completely under control. Throughout this testing you are to bear in mind that your driving is the most important consideration. If there is a conflict between driving safety and performance on the tester, where the safety of your vehicle or of any other vehicle is in question, your first duty is to your driving.
>
> Soon after you turn the converter on, you will see lights appearing in some of the holes in the face of the light box. You will not be able to predict when or where a light will appear.
>
> The face of the light box is broken down into red and white zones. When you notice a light coming on in a red zone of the light box, push the foot pedal once and only once, as soon after the light comes on as is consistent with safe driving. Do <u>not</u> push the foot pedal when a light

comes on in a white zone because this will count as an error. Be careful not to push the foot pedal accidentally, because this will also count as an error.

If you don't see any lights for one complete lap, flip the on-off converter switch off and on again. If, after one more lap, you again see no lights, flip the switch off and on again. If there are still no lights, leave the switch alone but tell the recorder about the trouble during the break.

At the end of each driving period, as you start to pull your truck up for the break, flip the converter on-off switch to the 'off' position.

Do not attempt to get your scores from the recorder. He has been instructed not to give any man his score because it would interfere with the successful accomplishment of this research.

Any Questions? . . . .

This is an important program, so you are to do the best you can. I want to remind you once more, however, that the routines and regulations that pertain to driving are not in any way changed or modified by your taking part in this study. As always, you are responsible for the behavior of your truck. Your primary job is to drive your truck safely and in exactly the manner that you have been instructed by your crew chief and by your orders. Do not let the test interfere with your good safety record. Keep that record clean, and do as well as you can on this test at the same time.

You will not be identified, except by number. We will know, however, if any man willfully destroys any part of this machine. This is U. S. Army property.

Remember to turn your converter on after crossing the bridge, push the foot pedal once for each red zone light only, and turn the converter off as you prepare to stop for your break."

APPENDIX C

T-TESTS FOR VIGILANCE PERFORMANCE MEASURES COMPARING SCHEDULE AND LOOP MEANS (Untransformed Data)

	Percent Detections				Percent False Detections			
	n	X̄	S.D.	t*	n	X̄	S.D.	t*
Day								
Schedule A	5	68.6	16.4	0.9	5	5.2	6.6	0.5
vs								
Schedule C	14	75.7	12.3		14	3.8	4.0	
Night								
Schedule A	11	87.3	10.8	1.0	11	2.3	1.9	1.0
vs								
Schedule C	12	91.6	8.1		12	6.1	7.2	
Day								
Loop 3	5	80.4	12.2	1.0	5	4.1	4.5	0.4
vs								
Loop 4	7	73.3	10.5		7	3.1	3.6	
Night								
Loop 3	6	93.7	3.7	0.8	6	7.9	8.1	1.5
vs								
Loop 4	13	91.5	8.6		13	2.7	4.2	

*No differences significant at the 5% level.

APPENDIX D

PERCENT DETECTIONS BY DRIVING PERIODS
(Untransformed Data)

Day Driving (N = 19)	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Mean	75.5	72.9	73.3	75.8	74.4	70.1
Std. Dev.	14.6	16.3	16.8	15.2	16.7	23.6
Range	40.0/94.1	42.2/100.0	34.7/97.1	51.2/95.2	47.8/100.0	20.8/100.0
Night Driving (N = 23)						
Mean	87.8	89.7	89.5	88.7	92.0	91.9
Std. Dev.	11.7	9.8	15.2	10.5	10.1	10.7
Range	57.7/100.0	66.0/100.0	34.9/100.0	61.3/100.0	63.6/100.0	65.0/100.0
Total (N = 42)						
Mean	82.2	82.1	82.1	82.8	84.1	82.1
Std. Dev.	14.5	15.6	17.8	14.4	16.1	20.8
Range	40.0/100.0	42.2/100.0	34.7/100.0	51.2/100.0	47.8/100.0	20.8/100.0

APPENDIX E

PERCENT FALSE DETECTIONS BY DRIVING PERIODS
(Untransformed Data)

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Day Driving (N = 19)						
Mean	3.1	5.7	2.6	6.5	5.9	1.5
Std. Dev.	3.3	9.5	2.9	18.4	12.0	1.9
Range	0.0/12.1	0.0/35.7	0.0/10.8	0.0/83.8	0.0/48.1	0.0/6.3
Night Driving (N = 23)						
Mean	5.4	6.3	3.9	2.5	2.3	2.3
Std. Dev.	9.4	11.0	6.4	2.5	3.0	2.7
Range	0.0/45.5	0.0/42.3	0.0/26.8	0.0/7.5	0.0/9.3	0.0/8.5
Total (N = 42)						
Mean	4.3	6.0	3.3	4.3	3.9	1.9
Std. Dev.	7.4	10.3	5.2	12.7	8.6	2.4
Range	0/45.5	0/42.3	0/26.8	0/83.8	0/48.1	0/8.5

AD Div 23/1, 28/3, 28/4

US Army Personnel Research Office, OCRD
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October 1961. Rept on Error-Free Performance c-02 Proj. -- 46 pp. incl. illus., tables, 15 Ref (APRO Technical Research Note, No. 118)
(DA Project 2195-60-001) Unclassified Report

UNCLASSIFIED
Human Resources Research
--Personnel Utilization

Opportunity for an initial study of vigilance was afforded by a road test sponsored by the American Association of State Highway Officials and administered by the Highway Research Board of the National Academy of Sciences. Army drivers operated trucks over experimental highways (Nov 1958 to Nov 1960) under conditions of monotony and in a restricted environment characteristic of many Army monitoring jobs. The APRO study, conducted during the second year of the road test, was designed (1) to examine the general level of signal detection of 42 drivers and determine the nature and extent of any decrement in vigilance over a 7-hour driving shift, and (2) to examine the range and stability of individual differences in signal detection scores. In spite of such inhibitory factors as noise, vibration, long hours, boredom, and fatigue, overall level of signal detection was high and remained high throughout the driving periods (83% of all critical signals were detected). The high level of performance maintained across all driving periods was contrary to the hypothesized decrement in detection as driving time progressed. Increased variability in vigilance performance among individual drivers was observed in the later driving periods. The specially constructed Vigilance Tester used proved capable of providing psychometric scores sufficiently consistent to justify research use.

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