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Bulletin 212

Characteristics of Vehicle Operators

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Characteristics of Vehicle Operators

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Driver Characteristics and Speed Performance Related to the Facility

DONALD E. CLEVELAND, Research Associate, Bureau of Highway Traffic, Yale University

●THIS PAPER reports on the results of an investigation of driver characterictics conducted at the Bureau of Highway Traffic, Yale University. Information used in the investigation was gathered with the cooperation of the state highway, police, and motor vehicle agencies of the states of Connecticut and Virginia.

Despite continuing improvements in motor vehicle accident rates it is generally agreed that the accident toll can be significantly reduced. Research on the driver-vehicle-highway relationship can provide information useful to agencies concerned with enforcement, engineering, education, and driver licensing in their endeavors to improve highway operations.

If it can be shown that a small group of operators is consistently responsible for a disproportionately large percentage of accidents and dangerous actions, elimination or improvement of these operators can be expected to reduce accidents if they can be identified at the earliest possible time. A possible approach to the identification problem involves relating driving record to some combination of personal characteristics of the operator. Another approach is to evaluate performance characteristics of the operator-vehicle combination under varying road environments and to relate this performance to the driving record. Inasmuch as most passenger cars and light trucks are capable of operating at the complete range of speed usually observed on the highway and relatively small changes in speed can be easily recorded, the freely chosen speed of operation should make an excellent performance characteristic to observe.

The object of this study was to gather facts on the relationship between free-speed performance of passenger cars and light trucks and the moving-violation and accident-responsible records of the operators under different road-way environment conditions. Personal and trip characteristics surmised to affect the speed of operation were taken into consideration.

PREVIOUS STUDIES

Similar investigations were conducted prior to World War II by Tilden (1) and De Silva (2); and in 1950 by Lefeve (3). Tilden (1), at a rural Connecticut location, found that among vehicle owners operating at speeds in excess of 50 mph a significantly larger percentage had been involved in accidents and had more accidents than owners of vehicles traveling at speeds between 35 and 45 mph. De Silva (2), at six rural tangent locations in Connecticut, found that men owners operating at higher speeds were more likely to have accident and violation experience than their counterparts operating at moderate speeds. Lefeve (3), at two rural locations in New York, found that in the afternoon faster drivers had more accident experience than slower drivers.

This study differs from the previously reported studies in several significant ways. It was conducted in two states at 11 locations, providing greater opportunity for observed speeds to vary and including locations with more restrictive environments. Accident experiences where the operator was judged to have no responsibility were eliminated from consideration. Moving violations were considered in addition to accidents. Special attention was given to those operators whose driving record consisted solely of speeding violations. The population studied was restricted to light vehicles during week-day non-peak hours.

DESCRIPTION OF FIELD STUDIES

Field observations were conducted on a city street in Connecticut, two-lane highways in both Connecticut and Virginia, a three-lane highway in Virginia, a four-lane undivided highway in Virginia, and a four-lane freeway in Connecticut.

It was desired that each highway selected for study provide two different environments affecting speed within a distance of a few miles. A first speed-measuring station was selected at a rural location where the operator was faced with no specific regulation or traffic or unusual roadway condition which would cause him to drive at other than a desired rural speed. A second speed-measuring station was selected where some condition of roadway, roadside development, or traffic regulation would make it prudent for the careful operator to drive at a lower speed than at the first station. It was also desired that the distance between these two points be approximately two miles, a distance over which free speed would generally be possible, yet long enough for variations in over-all speed to become apparent, and thus a third value of speed could be obtained. Satisfactory radio communication, camouflage of men and equipment, and convenient locations for conducting roadside interviews were other considerations in the selection of sites.

Figure 1. First speed-measuring station, study 6; US 460, Virginia.

Locations meeting the foregoing requirements were found at four of the study sites. Only one speed-measuring station was used in the Connecticut city street survey and because of the similar environment, the second speed-measuring station on the Connecticut Freeway was not substantially different from the first station. Figures 1 and 2 show the aspects facing the driver at the two speed-measuring stations at the 4-lane Virginia study site.

The mission of the observers at the first speed-measuring location was to select free-moving vehicles registered in the state in which the study was being conducted, determine by radar the speed of these vehicles at this location, broadcast a description of the vehicles and registration numbers to the other stations, broadcast a signal at the time of arrival of the vehicles at the point, and obtain speed distributions and classify native and out-of-state vehicles.

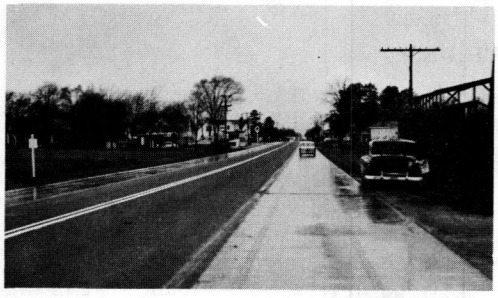

Figure 2. Second speed-measuring station, study 6; US 460, Virginia.

The men at the second speed-measuring point had the mission of determining the elapsed time between arrival of the studied vehicles at the first and second locations, determining the spot speed of the vehicles at that point, and developing speed distributions and classifications.

Interviews with the operators of studied vehicles were conducted at the interviewing station. The interviewers obtained the following information from the operator through direct observation, questions, or reference to the operator's permit:

1. Origin and destination of the trip.
2. Degree of familiarity with the highway.
3. Relationship to owner of vehicle.
4. Estimate of annual mileage. [1]
5. Sex.
6. Age.
7. Full name.
8. Town of residence.
9. Registration number of vehicle.
10. Time of interview.

[1] Except Study No. 1, Merritt Parkway, Connecticut.

The field studies were conducted between 9:00 a.m. and 4:00 p.m. on the dates shown in Table 1. All studies were conducted on a dry road surface with clear or overcast skies and with seasonal temperatures.

TABLE 1

FIELD STUDY DATES AND LOCATIONS

Study No.	Location	Dates	No. of Interviews	Avg. Daily Traffic
1	Merritt Pkwy., Stratford, Conn.	July 10-13, 1950	727	25,000
2	Dixwell Ave., Hamden, Conn.	Nov. 8-10, 1950	441	13,000
3	US 44, Canton, Conn.	Aug. 28-30, 1950	376	4,000
4	US 250, Short Pomp, Va.	Dec. 12, 13, 1950	414	4,700
5	US 360, Virginia	Dec. 11, 14, 1950	266	8,000
6	US 460, Disputanta, Va.	Dec. 15, 1950	231	4,500

OFFICE STUDIES

After matching and coding, the cards containing all field information were taken to the motor vehicle agencies and information was obtained on the moving violation and accident experience of the operators from 1945 to June 1957. Accident reports were studied and the following information obtained as to location, amount of property damage, number of personal injuries, and whether or not the operator being studied could be assigned any responsibility for the occurrence of that accident. This responsibility was defined as contributing to the accident through failure to operate in a reasonably prudent manner. For example, many intersectional accidents were considered as occurring because of actions of both drivers. In rear-end accidents, the operator of the rear vehicle was frequently held solely responsible.

In order to generally equalize exposure time the 1957 licensing status of the operators was determined. Only those operators who were still licensed or who had lost their license through motor vehicle violations and accidents were considered in the analysis. This group is not fully representative of the population observed on the highways in 1950, because those individuals who had moved or who were no longer licensed for other reasons were not included in the group. Separate analysis of the larger population is not included in this report.

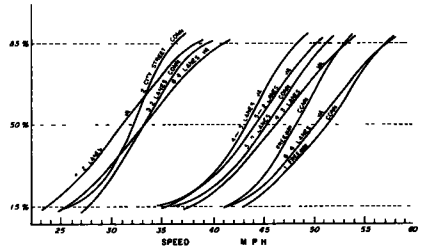

Figure 3. Cumulative speed distribution curves, 1950 speed study.

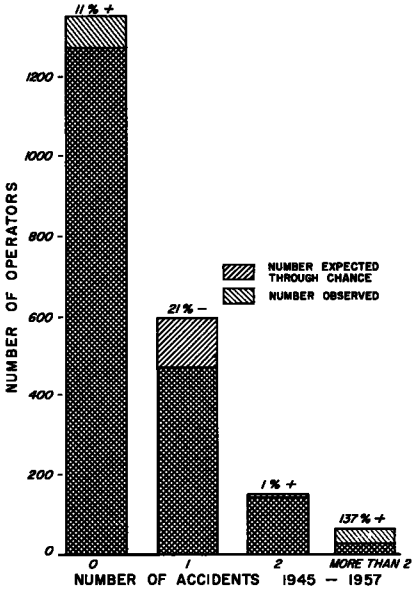

Figure 4. Comparison of observed accident experience with chance distribution.

SPEED DISTRIBUTIONS

It was found that the mean speeds of the groups studied were representative of the

free-moving speeds of native vehicles. No significant differences in means by time of day or day of week were found; accordingly, all operators for a study were grouped for analysis purposes.

Figure 3 presents cumulative speed distribution curves for the six studies. The curves fall into three classifications—restricted speed stations in the city and built-up areas that have median speeds of from 31 to 34 mph, unrestricted rural two- and three-lane highways with median speeds ranging from 43 to 46 mph, and higher-speed unrestricted four-lane highways with median spot speeds ranging from 48 to 51 mph.

TABLE 2

COMBINED ACCIDENT AND CONVICTION RECORDS, 1945-1957

(a) Connecticut Studies

No. of Accidents	Study No.	No. of Cases for the Following Convictions												
		0	1	2	3	4	5	6	7	8	9	10	11	12
	1	281	65	27	10	2	2	1	-			1		1
0	2	173	35	18	3	3	-	1	2			-		-
	3	137	19	11	8	2	-	6	-			-		-
	1	62	35	24	4	4	1	-	2	-				
1	2	47	27	8	6	5	1	2	-	1				
	3	29	19	11	1	-	1	1	-	-				
	1	9	9	2	4	2	3				1			-
2	2	14	10	4	4	2	1				-			1
	3	7	8	5	1	1	-				-			-
	1	4	6	2	1	1	3	2	-	-	-			
3	2	2	2	1	3	-	-	1	1	-	1			
	3	2	-	2	-	-	-	-	-	1	-			
	1	1	1	-	-		-						-	1
4	2	-	1	-	1		-						1	-
	3	-	-	1	-		1						-	-
	1			1	2					-				
5	2			-	-					1				
	3			-	-					-				
	1							1						
6	2							-						
	3							-						

(b) Virginia Studies

No. of Accidents	Study No.	No. of Cases for the Following Convictions												
		0	1	2	3	4	5	6	7	8	9	10	11	12
	4	201	3	4	1	-			-					
0	5	172	11	4	-	2			1					
	6	137	6	6	-	-			-					
	4	63	19	1	2		-		-					-
1	5	39	16	3	2		-		1					-
	6	18	9	3	2		1		1					1
	4	18	5	-	2	3	1							
2	5	5	5	9	-	-	-							
	6	6	1	4	-	-	-							
	4	4	2	-		1								
3	5	2	3	-		-								
	6	1	-	1		-								
	4				1								-	
4	5				-								-	
	6				-								1	

DRIVING RECORD DISTRIBUTIONS

Table 2 presents the distributions of convictions and responsible accident records. The Virginia operators were responsible for an average of 0.43 accidents compared to 0.51 for the Connecticut drivers. The average number of moving violation convictions was 0.32 for the Virginia drivers and 0.79 for the Connecticut operators.

Further analysis of Table 2 shows that from 74 to 87 percent of the operators had only one responsible accident or moving violation in the 12-year period. The operators with two or more responsible accidents and more than one moving violation ranged from 2.4 to 5.7 percent of the group studied. This small group had from 11 to 30 percent of the accidents and from 17 to 38 percent of the convictions. If the data were distributed according to chance, small percentages of the operators would be expected to have relatively large percentages of the driving records. Figure 4 shows the number of operators with varying numbers of responsible accidents observed in the studies compared with the number expected from a chance distribution. There are 11 percent more operators with no accidents than expected, 21 percent fewer with one accident, and 137 percent more than expected with more than two accidents.

If the acquisition of driving records is the result of chance variation, the operators with difficulties before 1951 should have the same probability of difficulty from 1951 to 1957 as those who had no record in the earlier period. Figures 5 and 6 present results obtained when record experience in the 1945-1950 period was used as a basis

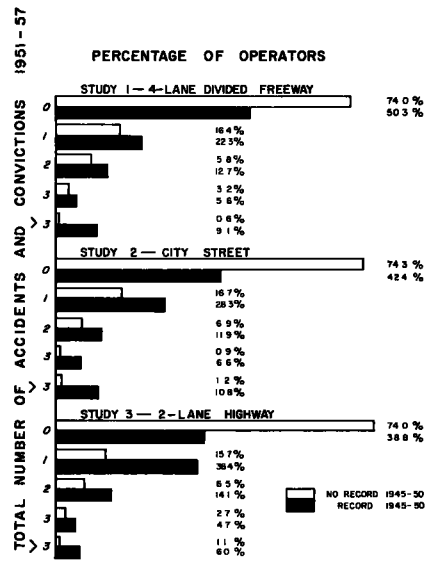

Figure 5. Experience record, 1951-1957; Connecticut studies.

for comparison of records in the 1951-1957 period. Generally, although 25 percent of the operators without trouble in the earlier period had records in the 1951-1957 period, approximately 50 percent of the operators with records from 1945 to 1950 also had accidents or violations in the later period. Operators who had records in the earlier period also had significantly more accidents and convictions in the later period.

A further investigation was made of the 1951-1957 period based on classifying the operators into groups with and without two or more responsible accidents and convictions in the 1945-1950 period. The 1951-1957 record experience is similarly classified and the results are shown in Figure 7. In all studies a larger percentage of operators with multiple accident and conviction experience in the earlier period recorded two or more record items in the 1951-1957 period than did the operators with fewer records in the early period. In the case of the Connecticut city street study, 42.6 per-

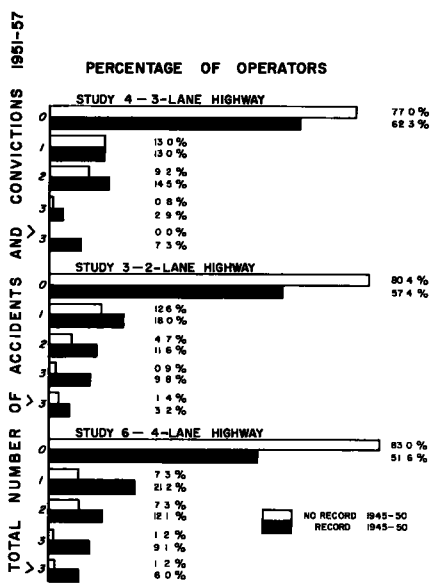

Figure 6. Experience record, 1951-1957; Virginia studies.

cent of the 1945-1950 multiple-record operators had two or more records from 1951-1957, whereas only 12.1 percent of the operators with better early records were involved in multiple-record experience in the later period.

EFFECT OF EXPOSURE

Table 3 presents the relationship between estimated annual mileage and multiple-record experience. For the operators with a maximum of one accident or conviction in the 1945-1950 period, increasing annual mileage resulted in a statistically significant (Chi-square test) increase in the percentage of operators with multiple records in the 1951-1957 period. However, for those operators with more than one accident or conviction in the early period there was no significant tendency for a larger percentage of the operators to have multiple experience from 1951 to 1957 as the estimated annual mileage increased. The Connecticut studies show a slight, but not significant increase in percentage with multiple records with increasing mileage, whereas the Virginia studies show a decrease.

TABLE 3

EFFECT OF EXPOSURE ON MULTIPLE-RECORDS EXPERIENCE

1945-1950 Record	Percentage of Operators with Multiple Records in 1951-1957					
	0-10,000 Miles Ann.		10-20,000 Miles Ann.		More than 20,000 Miles Ann.	
	Conn.	Va.	Conn.	Va.	Conn.	Va.
0.1	8.8	6.6	13.4	10.5	17.6	16.8
Multiple	31.6	37.5	33.3	28.6	37.2	20.0

In summary, these studies show that for the group studied a small percentage of operators have been consistently involved in a disproportionately large percentage of the multiple accident and conviction experience.

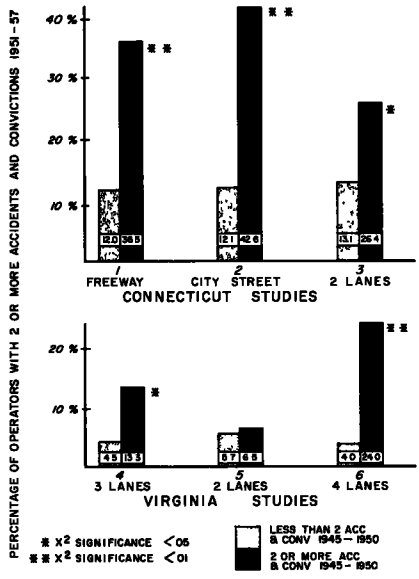

Figure 7. Multiple driving record experience, 1951-1957.

SPEED-RECORD STUDIES

The relationship between speed of operation and driving record was investigated from a number of approaches. The analysis of speed was based on the mean speed of the operators and the variance (the square of the standard deviation), a measure of "scatter" or dispersion. The speed change between stations was developed as an absolute value, as well as a change in percentile speed. Operators were classified in three groups by record experience—those without driving records from 1945 to 1957, those with one or more responsible accidents or convictions in this period, and those with two or more accidents or convictions in both the 1945-1950 and 1951-1957 period.

The speed study locations were classified as unrestricted or restricted, depending on the nature of the road environment. The results are presented in Table 4.

The mean speeds of the operators with records at all seven unrestricted speed

TABLE 4

SUMMARY OF SPEED STUDY RESULTS

Study		Record Operators			No-Record Operators			Test of Significance	
No.	Location	No.	Mean	Variance	No.	Mean	Variance	Variances	Mean
				(a) Unrestricted Speed Location					
1-1	Freeway, Conn.	295	52.00	43.77	279	51.10	40.27	-	[1]
1-2	Freeway, Conn.	248	48.00	31.50	227	47.79	31.82	-	-
3-1	2 lanes, Conn.	134	45.17	46.07	136	44.90	37.53	-	-
4-1	3 lanes, Va.	132	46.53	59.73	199	45.39	45.64	[1]	-
4-2	3 lanes, Va.	113	43.18	49.30	183	42.13	31.11	[2]	-
5-1	2 lanes, Va.	102	44.82	39.78	173	43.42	51.31	-	[1]
6-1	4 lanes, Va.	61	50.88	59.42	137	48.77	46.83	-	[1]
				(b) Restricted Speed Location					
2-1	City St., Conn.	212	31.67	24.66	173	31.24	17.97	[1]	-
3-2	2 lanes, Town, Conn.	113	34.52	26.80	116	34.21	23.66	-	-
5-2	2 lanes, Devel., Va.	98	32.11	52.19	159	32.12	39.32	[1]	-
6-2	4 lanes, Town, Va.	46	35.02	65.76	125	33.55	50.90	-	-
				(c) Over-All Speed					
1	Freeway, Conn.	272	54.07	34.93	259	53.05	36.65	-	[1]
3	2 lanes, Conn.	123	42.67	23.49	123	42.34	20.31	-	-
4	3 lanes, Va.	109	47.83	53.72	179	45.55	41.48	-	[2]
5	2 lanes, Va.	96	45.88	41.88	153	44.63	35.80	-	-
6	4 lanes, Va.	56	50.66	51.11	130	47.31	45.41	-	[2]

[1] Significant at 5 percent level.
[2] Significant at 1 percent level.

locations were higher than those of the non-record drivers. Three of these differences were statistically significant. The range in differences of means was from 0.2 to 1.4 mph. At six of the seven unrestricted locations the variance or "scatter" of the speed of the operators with records was greater than the variance of the no-record operators. These differences were significant for only two studies.

At the four restricted-speed locations, although the record operators had slightly faster mean speeds at three of the stations none of these differences were significant, ranging from 0.3 to 1.5 mph. At all four locations the variances of the record operators were greater than those of the non-record operators and the results were significant at two of the locations.

At the five study locations where over-all speeds between the two spot-speed measuring stations were obtained, the record operators also had higher mean speeds than the no-record operators. These differences were significant for three of the studies. The differences ranged from 0.3 to 2.4 mph. The variances of the record operators exceeded those of the no-record drivers in four of the five studies. None of these differences was individually significant.

TRIP AND PERSONAL CHARACTERISTICS

Similar analyses were undertaken to determine if trip length, road familiarity, ownership, sex, age, or annual mileage developed different speed-record relationships. There were 200 comparisons by individual characteristics between record and no-record

operators. Operators with records had higher mean speeds in 145 of these comparisons and their variances exceeded the no-record driver population variances in 144 cases.

The analysis of individual characteristics showed significant tendencies for several characteristics. Operators with records who were men, were born from 1899 to 1928, with annual mileages in excess of 10,000 miles, on trips of greater than 50 miles in length, or who were vehicle owners, had higher mean speeds than their no-record counterparts in more than 90 percent of the comparison. No personal or trip characteristic exhibited an unusual tendency toward variance differences between record and no-record operators.

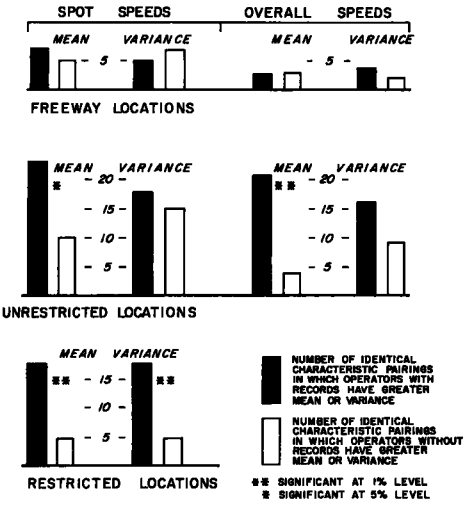

Figure 8. Effect of roadway type.

Non-owners, women, those born before 1899 and after 1929, and those with annual mileages less than 10,000 miles are the characteristics for which there was the least tendency for operators with records to have greater mean speeds than those without records.

When individual characteristics were compared by type of facility only one characteristic showed a significant difference. The record operators born before 1899 had greater variance than the no-record operators at all seven unrestricted speed stations, but had less variance at all four restricted locations.

Tests of complementary characteristics showed a tendency toward higher mean speeds by record operators for owners and relatives compared to non-owners and employees, men compared to women, those born from 1899 to 1928 compared to both older and younger operators, and those with greater annual mileages compared with less active operators.

Relatively few of the differences were large enough to be statistically significant with the samples obtained in the study. Only 34 of the 200 variance comparisons and 36 of the 200 comparisons of means were significant at the 5 percent level, generally the record operator means and variances being significantly greater than the no-record operators. The maximum significant difference in variance indicated a 15 to 85 percentile range of 21 mph for record operators compared with 10 mph for no-record drivers. The maximum difference in mean speeds was on the Merritt Parkway, where the mean speed of the youngest record drivers was 57.3 mph compared with 49.1 mph for the young operators without records.

The only characteristic group with no significant differences in mean or variance between record and no-record operators was the group of women operators. Drivers

TABLE 5

COMPARISON OF SPEEDS OF WORST, OTHER RECORD, AND NO-RECORD OPERATORS

Study No.	Location	Speed (mph)					
		Worst Operators		Other Record Operators		No-Record Operators	
		Mean	Var.	Mean	Var.	Mean	Var.
1	1	53.2	37.0	51.9	44.3	51.1	40.3
	2	49.4	25.7	47.9	31.9	47.8	31.8
	1-2	54.6	43.1	54.0	34.0	53.0	36.6
2	-	32.9	24.9	31.5	24.9	31.2	18.0

whose annual mileage exceeded 10,000 miles per year recorded no significant differences in variance between record and no-record operators. No significant differences were found in mean values between record and no-record operators for those who drove less than 10,000 miles per year.

No single characteristic produced a significant difference in means or variances between record and no-record drivers in as many as one-half of the comparisons. Characteristics which most frequently resulted in significant differences with record operators driving faster or with more dispersion than no-record operators were owners and relatives, men, those with higher annual mileages, those born from 1899 to 1928, those on short trips, and those very familiar with the highway.

Most of the significant differences by characteristic were found in the Virginia studies. Thirty of the 36 significant mean differences and 25 or the 34 significant differences in variance were recorded in Virginia. Eleven of the 16 significant means at unrestricted locations were in the Virginia studies and 15 of the 17 significant differences in means for over-all speeds were also found at the Virginia study locations. Sixteen of the 18 significant variance differences at unrestricted locations were found in the Virginia studies.

Comparisons were made of the differences of speed and variance of groups of record and no-record operators who were identical in all measured personal and trip purpose characteristics. In 65 percent of the comparisons the drivers with records had a higher mean speed than those without records. In 63 percent of the comparisons, the record operator group had greater variance than their no-record counterparts.

EFFECT OF ROADWAY ENVIRONMENT

Nine of the most popular identical characteristic populations were used in an analysis of differences in spot and over-all speeds for unrestricted, restricted, and freeway locations. Figure 8 presents the results of this analysis. At the freeway locations there was little difference in the number of pairs in which record operator means and variances exceeded those of the no-record operators. At the rural unrestricted locations the mean speeds of the record operators frequently exceeded the speed of their no-record counterparts. At the restricted locations the differences were highly significant, with the record operators having greater mean speeds and variances than no-record operators in 18 comparisons and the no-record drivers being greater in only 5 cases.

OPERATORS WITH WORST DRIVING RECORDS

An analysis was also made of those operators with two or more responsible accidents or convictions in both the 1945-50 and 1951-57 periods. The results of the Virginia and US 44 studies are not presented because of the few drivers with this type of record observed in these studies. In the Connecticut freeway and city street studies, the operators with the worst records had speeds slightly greater than other operators with records, as shown in Table 5.

SPEED-CHANGE

An analysis was also made of the speed change between the first and second speed-measuring points. No significant differences were detected between operators with records and those without records by speed change, whether measured in miles per hour or in percentile differences.

OTHER OPERATORS

The results of the studies described in this paper apply only to those operators who, in addition to being licensed in 1950, in general have been licensed continually since that time. Several hundred operators who were licensed in 1950 do not meet these requirements and information on these operators is not presented in this report. A separate analysis was made for the 1945-50 period and there is general agreement between the results found for this group and the results presented in this report.

SUMMARY AND CONCLUSIONS

This study, conducted in two states, shows that for a group of more than 2,000 weekday, non-peak hour, long-time resident operators on a variety of different road facilities a small group has been consistently involved as a responsible party in a large percentage of accidents, and that the group with accidents and moving violations tends to operate at slightly higher average speeds and to be more variable in speed than those without records.

No characteristic of trip length, road familiarity, sex, age, ownership, or annual mileage individually or collectively contributed outstandingly to observed differences between the record and no-record groups. A tendency was noted for groups of operators with records to have higher average speed and more variability than groups without records as the road environment deteriorated from freeway conditions to restricted urban-type conditions.

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An Investigation of the Role of Psychological Factors in Motor Vehicle Accidents*

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● CONCERN WITH driver behavior as a major variable in motor vehicle accidents has drawn the interest and efforts of many investigators for at least two decades. These studies of human variables in accidents have ranged the broad spectrum of driver behavior, from a measurement of the most overt physical and psychophysical characteristics to an analysis of the most covert and subtle personality nuances.

A review of these studies is beyond the present intent. The purpose of this report is to describe a driver research study at the University of Colorado School of Medicine, which has attempted to extend this research by incorporating in one program the major methods and variables emphasized by other investigators, as well as specific innovations particular to this research study.

The three major features of this program included:

1. A comprehensive research design in which many driver characteristics, physiological, psychophysical, and psychological, were simultaneously studied.
2. A heightened concern with defining in operational terms such major variables as "accident", "attitudes", and "personality".
3. An emphasis upon repeated cross-validation of early findings to guard against premature and unwarranted conclusions.

The objective of this research has been to determine whether there are specific personal characteristics, and/or patterns of such characteristics, which clearly and consistently distinguish accident-repeaters from accident-free drivers.

From its conception in 1953, this driver research program has been financially supported by the Commission on Accidental Trauma, Armed Forces Epidemiological Board, and has been made possible through the interest and active cooperation of military personnel at Fitzsimons Army Hospital and Lowry Air Force Base, Denver, Colorado.

The two major phases of this research are discussed in the order of their temporal development.

PHASE I

The initial phase includes a series of studies during the period 1954 to 1956 focused exclusively upon airmen from Lowry Air Force Base.

This phase began in 1954 with a study of 110 airmen selected from the official Colorado motor vehicle accident files and Lowry Air Force Base ground safety records as having had one or more major (damage of more than $50.00), legally responsible, motor vehicle accidents during the immediately preceding 12-month period. In addition, all squadrons of the base were surveyed to identify and locate airmen who had no motor vehicle accidents during a minimum 12-month residence and driving in the area.

These 110 airmen accident subjects were administered a comprehensive battery of psychological tests and measurements which included the following:

1. Psychomotor functions, such as simple and complex reaction time, eye-hand-foot coordination, and depth perception.
2. Objective personality tests, such as the Minnesota Multiphasic Personality Inventory, and the Thurstone Temperament Schedule.
3. Clinical (individual) personality measures, such as the Rorschach, the Sacks

* A report of the Driver Research Project, University of Colorado.

Sentence Completion Test, and the Thematic Apperception Test.

4. Specific tests of personal characteristics, such as the Allport, Vernon and Lindzey Study of Values, the Taylor Anxiety Scale, and the Level of Aspirations Test.
5. Biographical questionnaires elaborating social background and personal history.

In addition, each subject was individually seen for a structured psychiatric interview, the latter portion of which was specifically directed to a detailed inquiry of the subject's lifetime driving history and his accident experiences.

By combining the official records available on these subjects with the subjective reports obtained in the psychiatric interview, the following two small groups of drivers were identified:

1. The accident-repeater group, which consisted of those airmen who had two or more major, responsible, motor vehicle accidents in the immediately prior 54-month period (N=15).
2. The accident-free group, comprised of those airmen who had no official or subjective record of accidents or hazardous violations for this same period (N=15).

These groups were matched for age, length of time driving, and miles drived per year. These selected and matched groups were then compared across tests, scales, and measurements of the comprehensive battery.

In recognition of the complexities involved and to preclude eliminating potentially promising areas of investigation, it was decided that items which differentiated accident and non-accident subjects at the 0.20 level of confidence or better would be retained for cross-validation.

In addition to this analysis of extreme groups, the data for all 110 airmen were subjected to a factor analysis to determine whether meaningful clusters of psychological and accident variables could be obtained, and to reduce the large number of measures to a more economical and efficient battery.

RESULTS OF 1954 STUDY

The correlations between accident variables and behavior measures were found to be low to moderate (none exceeding 0.27), due in part to the restricted range in the accident variables. The factor analysis based on this correlation matrix failed to reveal any significant over-all relationships between these two sets of variables, as indicated by factors heavily loaded on both accident and psychological measures. It was felt that this might be due partly to the restricted accident range, as well as to strong relationships among some of the psychological variables which would operate to mask any positive but weak over-all relationships between accident and psychological variables.

With regard to the analysis of the accident-repeater and accident-free groups, of the 51 measures on which they were compared, 11 reached or exceeded the predetermined 0.20 level of significance.

CROSS-VALIDATION (1955)

In a cross-validation study carried out in 1955, all discriminating psychometric scales, supplemented by additional objective measures, including the Siebrecht Attitude Scale and a paper-and-pencil psychomotor test (Nesberg and Smith Motor Decision Test), were administered to another small sample of accident-repeater and accident-free airmen drivers selected on the same basis as the previous groups (A=15; NA=25).

RESULTS OF CROSS-VALIDATION STUDY (1955)

Most of the psychometric measures which initially appeared to discriminate between these groups failed to discriminate in cross-validation.

One test, however, the Allport, Vernon and Lindzey Study of Values, proved highly stable. Cut-off scores for two scales of this test previously established on the 1954 group accurately identified the accident status of 73 percent of the 1955 subjects.

1956 CROSS-VALIDATION OF CLINICAL MATERIAL

In 1956, in a further study directed to the cross-validation of clinical (individual) personality tests, the Rorschach and Thematic Apperception tests, which had earlier discriminated between the 1954 groups, were administered to another sample of accident-repeater and accident-free drivers selected on the same basis as the previous groups (A=10; NA=10). This most recent study included physiological measures, such as blood pressure, galvanic skin response, muscle tremor, and respiration rates under resting and stress conditions, as well as individual intelligence tests and a test of driver ability (American Transit Motor Abilities Test).

In addition, the modified Allport, Vernon and Lindzey Study of Values was readministered and again identified the accident status of 73 percent of the subjects of this new sample.

OVER-ALL CONCLUSIONS

All conclusions discussed are derived from this series of studies on small groups of highly selected accident-repeater and accident-free airmen drivers.

Statistical analyses of the various scales and measures failed to reveal any significant difference between these groups with regard to physiological reactions, under either resting or stress conditions. There were no differences with regard to psychomotor functions such as coordination, discrimination, and simple or complex reaction time. In addition, most objective personality inventories and tests of such specific characteristics as manifest anxiety, level of aspiration, and I.Q., failed to discriminate between these groups.

Of the psychometric measures already cross-validated, two scales of the modified Allport, Vernon and Lindzey Study of Values have in several studies discriminated these selected groups at better than the 0.10 level of significance. The moderate but stable discriminating function of these scales deserves comment.

In a comparison of these two extreme groups, accident-repeater status appears associated with significantly higher scores on the A scale, whereas accident-free status appears associated with significantly higher scores on the R scale.

The possible meaning of these associations can best be understood, first by referring to the Allport, Vernon and Lindzey interpretation of these scales, then by a considered projection of these values into general personal-social behavior.

Allport, Vernon and Lindzey interpret a high A score to reflect a "heightened concern with aesthetic experience," including "the appreciation of harmony, beauty, and the artistic episodes of life." In social affairs, they suggest that "such persons tend toward individualism and self-sufficiency."

Projecting beyond this general interpretation, it is suggested that in the present context high A scores may represent not only the aesthetic appreciation which Allport, Vernon and Lindzey emphasize, but also two other, possibly more significant, features as well. The first is that this scale, associated with accident-repeaters, may reveal an overemphasis on self-determination and self-sufficiency, which, in their heightened emphasis on individualistic expression, may reflect a rejection of conformity standards and conventional modes of behavior. The second, and equally important, is that the prime requisite of "feeling" represented in the A scale may reflect a tendency to respond to events and to other persons on a highly-charged emotional basis.

With respect to the R scale, associated with accident-free status, a similar analysis may be proposed. Allport, Vernon and Lindzey interpret high scores on this scale to reflect an individual whose "highest value is a sense of unity" and who "seeks to comprehend the cosmos as a whole, to relate himself to its embracing totality." Projecting this value to a perhaps more narrow domain of self and society, one may also consider that this scale, in some part, reflects a tendency to conformity behavior and to the resolution of conflicts through the acceptance of conventional standards and practices. Coupled with this tendency to uncritically accept, believe, and act, there may also be reflected a lessened sense of self-sufficiency and a greater basic reliance on authority-prescribed modes of behavior.

This interpretation, that the stable differences found on these objective scales re-

flected underlying differences between these groups with regard to conventionality and to emotionalized responsiveness, generated the following hypotheses:

1. Accident-repeater subjects would be more unconventional in their opinions, attitudes, and social behaviors than the non-accident subjects.
2. Accident-repeater subjects, when compared with the non-accident group, would show a higher level of excitability or tensions, less ability to tolerate or sustain this tension, and hence a tendency to act out these emotions, tensions, or impulses in behavior.

These hypotheses were tested out in the most recent study, which consisted of an intensive psychological and psychiatric evaluation of each subject of the accident-repeater and non-accident groups.

Objective rating scales were developed, and the psychiatric interview transcripts, test protocols, and individual psychological reports were rated "blind" and independently for the variables of conventionality and impulse-control, as well as for twelve other variables hypothesized to be significantly related to accident frequency.

Accident-repeater and non-accident subjects differed significantly ($p=0.10$) on six of these variables, the accident-repeater group being rated high on tension (anxiety) and unconventional behavior, and low on hostility/control ratio and tension tolerance. These clinical and psychometric findings suggest that, for the airmen groups studied, acceptance or rejection of conformity standards and conventional modes of behavior, and the degree and effectiveness of impulse control, are major personal characteristics related to accident frequency.

PHASE II

The second phase of this driver research is a more recently initiated "predictive" study of young "pre-drivers". This research evolved from a recognition of some inherent limitations of the earlier studies. Primarily, these limiting features concerned the following:

1. The transient nature of the airman population of a training base. The resultant small number of 12-month residence drivers available for initial selection severely restricted the subsequent sample size of accident-repeater and accident-free drivers.
2. The necessity of obtaining a large amount of objective biographical data and selected psychological tests on this population, prior to their beginning driving experiences, so as to eliminate the possible confounding influence of any later accident experiences.

In 1956, the University of Colorado School of Medicine, in cooperation with the Denver Public Schools and the Colorado Motor Vehicle Division, initiated a large-scale, long-range study incorporating these essential features.

SUBJECTS

The subjects of this study consisted of the entire sophomore class, 4,500 pupils, of the five Denver public high schools. The sophomore group was selected because their median age of 15 years is immediately prior to the licensing age of 16, hence probably represents the closest approximation to the attitudes and characteristics subsequently active in the initial driving experiences.

METHOD

There are three basic components of this program, as follows:

1. Testing—A selected battery of psychological tests, including the Allport, Vernon and Lindzey Study of Values; the Guilford-Zimmerman Temperament Survey; an objectively scored group from the Thematic Apperception Test; and a project-designed measure of risk-taking attitudes, was routinely administered to all sophomores.
2. School Records—The Denver public school system maintains a cumulative record on each pupil dating from initial entry into the school system. These records provide

a valuable source of supplementary data, including biographical information; teacher ratings on a variety of personal-social behaviors; descriptions of assets and liabilities in peer and authority relations; test scores on standardized measures of intelligence, personality, aptitudes, interest, and achievement; and descriptions of any serious physical handicaps and disabilities. The cumulative record available for each sophomore subject has been microfilmed. Analysis of a random sample of these records indicates that in 65 percent of the sample these records have been maintained continuously since the first grade, thus providing 10 years of longitudinal biographical information on the subjects.

3. Driving Records—With the cooperation of the Colorado Motor Vehicle Division, a double-entry card system has been developed which insures that beginning with the initial licensing, all accident/violation experiences of these sophomore subjects will be recorded routinely on duplicate project cards, already inserted in the master files of the Colorado Motor Vehicle Division. Thus, a continuous, objective, and standard driving history record will be available for each project.

In 1957 this program was expanded to include the seven suburban high schools surrounding the metropolitan Denver area. With the addition of the 2,600 sophomores of these schools, approximately 7,000 subjects are now participating in this program.

Current efforts are directed to the scoring and classification of this voluminous information for I.B.M. coding and analysis. It is estimated that this data reduction phase will be completed within two years.

A preliminary statistical analysis of the relationships between test and biographical data, and driving records for selected subjects, is tentatively planned for 1960, at which time the majority of the subjects of the study will have had three years of driving experience.

In conclusion, the predictive nature of the second phase of this research must be emphasized. The goal of this current pre-driver study is to determine the possibility of predicting subsequent driving behavior, as defined by the presence or absence of motor vehicle accidents and/or hazardous violations, from an analysis of antecedent, pre-driving attitudes and personal-social characteristics.

Relationships Between Driving Records, Selected Personality Characteristics, and Biographical Data of Traffic Offenders and Non-Offenders

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In this paper are presented: (a) a synopsis of methods employed in arriving at an answer to each of four sub-problems posed in this study, along with a summary of the findings of each; (b) those conclusions which appear warranted on the basis of data revealed and statistical measures obtained; and (c) recommendations pertinent to the application of findings of this study, to the establishment and operation of driver improvement clinics, and to further research into driving performance.

●THE PURPOSE of the investigation reported herein was to determine what personality characteristics and biographical data differentiate motor vehicle traffic offenders from non-offenders, and to relate any such differences to records of their driving performance. The solution to this problem was determined by answering the following four sub-problems:

1. What personality characteristics, as revealed by responses to the Thurstone Temperament Schedule, distinguish offenders from non-offenders?
2. What biographical data, as revealed by the subjects in planned interviews, distinguish offenders from non-offenders?
3. What personality characteristics and biographical data, individually and in combinations, are most significant for purposes of distinguishing offenders from non-offenders?
4. How can these statistically significant scores of personaltiy characteristics and biographical factors be related to the actual occurrence of accidents and violations?

The populations studied consisted of an experimental group of 763 traffic offenders who were resident motor vehicle operators of the State of New Jersey and who had accumulated three or more traffic accidents and/or moving traffic violations since December 31, 1949, and a control group of 195 resident motor vehicle operators of the same State whose driving records were free of accidents and violations during this same period. The control group was equated to the experimental group in terms of estimated annual mileage driven, obtained through a specially prepared questionnaire. These subjects appeared at the New Jersey Traffic Accident Prevention Clinic in Trenton over a 22-month period ending August 31, 1955.

In answer to the first sub-problem posed in this investigation, statistically significant differences were found on three of the seven areas of this test device. Subjects of the experimental group were found to rate higher on the impulsive and sociable scales, but lower on the reflective scale, than the control subjects.

In analyzing biographical data obtained during the planned interview for purposes of the second sub-problem, statistically significant differences were found on eight of the thirteen categories investigated. The categories in which differences this great were obtained are as follows:

1. Age.
2. Marital status.
3. Education.
4. Driver education indicated.
5. Annual salary.
6. Present occupation.
7. Job turnover.

8. Reasons indicated for terminating employment.

The experimental group was characterized by younger, unmarried individuals. A greater proportion of this group had failed to complete high school or college and few were engaged in the professions or in managerial or official capacities. Moreover, they reported smaller earnings, higher job turnover, and termination of previous employment for reasons other than self improvement. More of the experimental population indicated driver education; however, because extant data did not permit investigation into either the type or quality of this experience, this item of biographical information was deleted from further statistical analysis.

In determining the answer to the third sub-problem, the multiple-cutoff method was employed. This technique necessitated the establishing of a critical score for each of the three statistically significant areas of the test device and for the sum of statistically significant biographical information. Once these critical scores had been established, test and biographical data for each subject were assessed to determine the number in each group who would achieve a critical score on one or more of these areas. It was found that critical scores on the impulsive scale and on the sociable scale of the Thurstone Temperament Schedule in combination with a critical score on the sum of statistically significant biographical data, provided maximum separation of the groups.

The fourth sub-problem was approached by selecting individuals of the experimental group who were likely to be representative of extremes of adjustment as indicated by test and biographical data. Subjects achieving a critical score on each of the four areas were considered as well-adjusted, subjects failing to achieve a critical score on any one of these areas were considered as poorly adjusted for purposes of this phase of the investigation. The well-adjusted group consisted of 24 subjects, each of whom achieved a critical score on each of the four areas. The poorly-adjusted group consisted of 112 subjects, each of whom had failed to achieve a critical score on any one of the four areas. Each of these two sub-groups then was compared with (a) the remaining members of the experimental group, and (b) with the other sub-group, in terms of their driving records as indicated by accident and violation experience. The well-adjusted group was found to have a better over-all driving record than either the poorly-adjusted group or the remaining members of the experimental group from which they were drawn. The poorly-adjusted group, conversely, exhibited a poorer driving record than either of the other two groups.

As an adjunct to the main portion of this investigation, 63 subjects, each of whom indicated a driving experience of 50,000 or more miles per year, were compared to the experimental group in terms of (a) test data, (b) biographical data, and (c) accident and violation data. Members of this high-exposure group were found to be more vigorous, more impulsive, more sociable, and less reflective than were members of the experimental group.

On items of biographical information, statistically significant differences were obtained between the groups on (a) job turnover, (b) present occupation, (c) annual salary, and (d) type of vehicle driven. Members of the high-exposure group were found to have a higher rate of job turnover and higher annual earnings than members of the experimental group. Moreover, as might be expected, a large proportion of these high-exposure subjects were professional chauffeurs or driver salesmen who drove various types of equipment in addition to passenger vehicles.

Inspection of driving records revealed the high-exposure group to have a violation history considerably poorer than that of the experimental group; however, their accident experience actually was better than that of the experimental group.

CONCLUSIONS

On the basis of (a) data revealed during the planned interviews with each subject, (b) responses to each of the seven areas of the Thurstone Temperament Schedule, and (c) in the case of the experimental and the high-exposure group of offenders, traffic accident and violations records, the following conclusions seem warranted.

For purposes of distinguishing traffic offenders from non-offenders, impulsive, sociable, and reflective traits, as measured by the Thurstone Temperament Schedule,

appear to provide for such differentiation, the offender group rating higher on impulsive and sociable, and lower on reflective, than the non-offender group. However, the active, vigorous, dominant, and stable traits, as measured by the Thurstone Temperament Schedule do not appear to be of value in distinguishing traffic offenders from non-offenders.

The following items of biographical information appear to be of value for purposes of distinguishing traffic offenders from non-offenders:

1. Age.
2. Marital status.
3. Education.
4. Occupation.
5. Number of positions held during the 5-year period preceding examination.
6. Reasons for terminating previous employment.
7. Annual Salary.

The categories of biographical data which do not appear to be of value for purposes of distinguishing between traffic offenders and non-offenders are as follows:

1. Number of children.
2. Languages written.
3. Hospitalization.
4. Types of vehicles driven.
5. Nature of driving experience.

The following combination of personality traits, as measured by the Thurstone Temperament Schedule, and biographical data, appears to be of most value for purposes of distinguishing traffic offenders from non-offenders: Impulsive and sociable traits, in combination with the biographical items of age, marital status, education, occupation, number of positions held during the 5-year period preceding examination, reasons for terminating previous employment, and annual salary.

The traffic accident and violation records of well-adjusted traffic offenders, as identified by a combination of test and biographical data, are likely to be superior to the records of poorly-adjusted traffic offenders as identified by the same criteria. Also, the driving records of these well-adjusted individuals are likely to be better than the records of traffic offenders who are considered neither well-adjusted nor poorly-adjusted. Driving records of poorly-adjusted traffic offenders, on the other hand, are likely to be worse than those of either of the other groups.

From a comparison of the driving records of traffic offenders whose driving experience was less than 50,000 miles per year with those whose driving experience was in excess of this amount, it appears that annual mileage has little effect on accident experience, but that violation experience seems to increase with driving exposure.

RECOMMENDATIONS

With the traffic problem as acute as it is, those active in traffic accident prevention efforts may be interested in possible application of the findings of this investigation. Therefore, the following recommendations are presented for consideration:

1. The items of a biographical nature revealed to be statistically significant be among those items included on application forms for prospective drivers and license applicants. The purpose here would be not that of selection, but of identification of individuals toward whom further investigation might be indicated. Likewise, it may be well to include these items on periodic inventories administered to driver personnel.
2. The areas of the Thurstone Temperament Schedule revealed to be statistically significant be included among the devices used in screening applicants for licenses or for positions as drivers with commercial, business, or industrial establishments. These areas of the test device may well prove of value with in-service drivers, and with traffic offenders as well, in assessing selected personality traits as an aid in establishing refresher and remedial activities.
3. The questionnaire on estimated driving experience, developed for purposes of

this study, be used in an effort to obtain reliable estimates of driving experience among motoring populations.

TABLE 1

COMPARISON OF STATISTICAL MEASURES OBTAINED ON TEST DATA FOR THE EXPERIMENTAL AND CONTROL GROUPS

Area [1]	Group	Mean	Std. Dev.	Std. Error of Mean	Std. Error of Diff. [2]	Critical Ratio
Active, A	Exp.	9.34	3.22	0.117	0.28	0.214
	Con.	9.40	3.53	0.253		
Vigorous, V	Exp.	11.88	3.42	0.124	0.31	1.10
	Con.	11.54	4.01	0.287		
Impulsive, I	Exp.	11.46	3.08	0.112	0.25	4.44[3]
	Con.	10.35	3.23	0.231		
Dominant, D	Exp.	10.49	4.67	0.169	0.39	1.18
	Con.	10.03	5.01	0.359		
Stable, E	Exp.	12.04	3.51	0.127	0.28	0.321
	Con.	12.13	3.45	0.247		
Sociable, S	Exp.	13.64	3.25	0.118	0.28	3.64[3]
	Con.	12.62	3.51	0.251		
Reflective, R	Exp.	8.18	3.19	0.115	0.25	3.00[3]
	Con.	8.93	3.20	0.229		

[1] Area of the Thurstone Temperament Schedule.
[2] Difference between two uncorrelated means.
[3] Statistically significant at the 0.01 percent level.

Because it is expected that several States will move in the direction of establishing clinics for driver improvement purposes, the following recommendations, which are based on (a) observations of clinic operation during the conduct of this study, and (b) a review of the literature on clinics, past and present, are advanced for the perusal of those individuals and groups interested in such activity:

1. A thorough and effective accident reporting system, operating with equal effectiveness throughout the populations to be affected, should be established if motorists truly representative of the offender population are to be reached. Ideally, reciprocity among the various States and the District of Columbia should be provided for the exchange of accident and violation information so that the driver's record may be as complete as possible.
2. A point system should be established for purposes of (a) assessing the individual's driving performance, (b) notifying him of this performance, and (c) providing data to the Department of Motor Vehicles, the courts, and persons associated with rehabilitative functions, including the clinic.
3. The reported findings of other traffic clinic operations should be pursued and evaluated before deciding on the procedure to be followed or the instruments to be used.
4. Clinics should be designed and evaluated by a group comprised of persons with preparation and experience in the fields of motor vehicle administration, law, education, sociology, psychology, psychiatry, and medicine. (The new clinic in New York State is being developed along these lines.) Public or privately supported institutions of higher learning appear to be the logical source for obtaining such personnel and consultative services.
5. Personnel used to staff such clinics should be of the highest quality and they should be thoroughly familiar with interviewing procedures and test administration.
6. The keynote of the clinic as it operates in driver improvement situations should be experimentation. New devices, techniques, and processes should be introduced just as soon as practicable when research or rational grounds indicate their possible value.

7. Clinic findings (including those of other individuals and agencies to whom the subject might have been referred) should be interpreted to the subject and whenever possible specific suggestions should be made as to how he might improve his driving performance.

8. Provision should be made for follow-up study of subjects examined at the clinic, such a follow-up to evaluate, in some measure, the effectiveness of clinical procedure.

Inasmuch as considerable emphasis today is being directed toward the role of the driver in traffic accident causation, it is expected that additional research will be conducted in this general area. Accordingly, the following recommendations are presented for the assistance of those undertaking such investigation:

1. That further research be conducted, using the Thurstone Temperament Schedule, on offender and non-offender populations where equating factors in addition to driving experience are considered.

2. That further research be conducted on offender and non-offender populations, using devices which probe more deeply into those relatively stable personality traits of impulsive, sociable, and reflective, as identified by the Thurstone Temperament Schedule.

3. That data of offenders be probed further to establish the relationship between violations and accidents.

4. That more extensive data of a biographical nature be obtained from subjects, because this type of data proved more discriminating than any area of the test device used in this investigation.

5. That test technicians, in cooperation with traffic safety specialists, develop test instruments which will probe more deeply into the impulsive, sociable, and reflective traits of personality as these relate to driving performance.

Through research such as that suggested and through implementation of the recommendations advanced here, it is believed that those active in the field of traffic safety will improve their understanding of why drivers commit traffic offenses, and will be better able to initiate and evaluate driver improvement activities.

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Age and Fatal Motor Vehicle Accidents

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A 2-year study (1955-56) of fatal traffic accidents recorded whether the fatality was a driver, a passenger, or a pedestrian. Separate plots of 5-year age groups from 0 to 85 and over were made by sex. The first year male fatalities comprised 285 drivers, 114 passengers, and 36 pedestrians; the second year, 315 drivers, 124 passengers, and 56 pedestrians. The same year, female fatalities comprised 48 drivers, 140 passengers, and 14 pedestrians.

Driver fatalities showed almost a 9-to-1 ratio of male to female for 1955 and about a 6-to-1 ratio in 1956. A table of expectancies was set up showing approximately 73.45 percent male and 26.56 percent female driver licensees for those years. Ages 15 and above were used in making calculations on drivers.

Further figures are given on the percentage of total licensed drivers by 10-year age groups as an estimate for the United States. These estimates are for use in figuring expectancies by age groups.

An analysis is made for the 2-year period by age and sex with an indication of relative proportions at each age level, as well as for the two sexes combined.

Estimates of driver fatalities per 100 million miles of vehicular travel are graphed by 5-year age groups for the two sexes. The over-all results show almost twice as many driver fatalities per 100 million vehicle miles of travel for men as for women. At only two points do the curves overlap—ages 25-29 and 60-64. The data indicate no need for frequent reexamination of drivers throughout the middle age groups.

● MANY STATISTICS have been released on the frequency of accidents among persons, but relatively few have taken into account the frequencies or size of the groups involved. When age groups of drivers or motorists are compared there are always larger percentages at one age level than another. The purpose of this study is to analyze the relationships of drivers, considering the numbers and the mileage driven, and to study the likelihood of fatal driver accidents at different age levels. When pedestrians, passengers, and drivers are all lumped together it is difficult to see the true picture from any summary given in lump terms.

This problem seems important in light of the fact that there is considerable attention being given to the driver's license in relation to a change and need for reexaminations. Some states have set up a licensing schedule to reexamine every driver every two years. This is laudable, but it imposes an enormous expense which may not be warranted. As one drives after obtaining a license he gradually becomes better for several years, with the exception of a few persons whose records get worse. The latter is true of men and women lumped together, but when all factors are considered seems to be mostly true of men alone. Thus it might be possible to find a point where licensing examinations might be carried on less frequently because of less need for examination when changes are least likely to occur. Because men drive considerably more miles than women, the problem of mileage must be taken into account. Younger men drive more miles than older men. Consequently, all of these factors have to be weighed into some kind of an evaluation system whereby they may be equalized and the results given would be more meaningful than those generally used.

It has appeared repeatedly that the sexes need to be separated in studies of driving. What applies to males does not apply to females, and vice versa. Therefore, any study which does not separate the sexes is not very useful from a practical point of view in evaluating the performance of each sex at different age levels.

In 1956 Schwenk (1) reported a study which dealt only with fatal accidents in Iowa for 1955. She tabulated all fatalities according to whether the person was a driver, a passenger, or a pedestrian. In 1957 a similar study was worked out for 1956 fatalities in Iowa. Inasmuch as the percentages of drivers and the populations could be estimated, it was though advisable to determine whether distributions were according to chance.

Swanson, working with the National Safety Council figures, had shown that pedestrian fatalities are much more frequent than chance would indicate in the older groups. Although no figures are available on the total number of pedestrians as compared with drivers and passengers, at least account can be taken of the number who are killed and some proportions were worked out on this basis. Swanson's finding would then support the need for a more careful study of the frequency of accidents at different age levels, particularly with respect to the frequency of accidents among drivers, which is the fundamental problem of this study.

Using Schwenk's data and by a method of ranking the differences in expected deaths for the two-year period in Iowa, and calculating the reliability coefficient, it was found that the consistency was around 0.86. This is considering a segment of the population, such as Iowa, having about 1,500,000 drivers. It seems to indicate a fairly consistent result as obtained from year to year in the accident figures. In other words, one does not get a high figure in an age group one year and a low figure the next year in a population of this size: The figure would be sufficiently stable for any ordinary use in prognosticating the results or for making use of figures obtained for estimating from one year to the next.

METHOD AND PROCEDURE

As already suggested, the method consisted of using available data to determine the distribution of accidents by age groups and by sex, as well as by classification as to driver, pedestrian, or passenger. Although no one knows exactly how many passengers there are, it is possible to figure the percentage of licensees and to get some kind of

TABLE 1

DRIVER FATALITIES, BY SEX AND AGE GROUP

Age	1955			1956		
	Male	Female	Total	Male	Female	Total
15-19	38	1	39	45	7	52
20-24	51	4	55	54	3	57
25-29	29	5	34	39	11	50
30-34	17	3	20	19	3	22
35-39	28	2	30	27	2	29
40-44	25	4	29	24	4	28
45-49	13	2	15	21	5	26
50-54	15	1	16	18	5	23
55-59	17	4	21	17	2	19
60-64	14	3	17	17	4	21
65-69	16	0	16	8	1	9
70-74	11	3	14	10	1	11
75-79	8	0	8	10	0	10
80-84	3	0	3	5	0	5
85-over	0	0	0	1	0	1
Total	285	32	317	315	48	363

an estimate on the number for comparative purposes by the use of census figures. It is possible to get an estimate of the amount of driving done at the different age levels which can be worked into an evaluation plan. By calculating these probabilities and working out to a final index, a graph could be constructed which indicates more or less the likelihood of a driver getting into an accident, or at least the rates of frequencies at which drivers of the two sexes get into accidents at different age levels. The first distribution plotted by Schwenk is shown in Table 1 for drivers, both male and female.

TABLE 2

SUMMARY OF ALL FATALITIES IN IOWA, BY AGE GROUP

Age	Male			Female		
	Driver	Passenger	Pedestrian	Driver	Passenger	Pedestrian
			(a) 1955			
0-4	0	10	7	0	13	2
5-9	0	5	9	0	4	6
10-14	1	9	3	0	5	2
15-19	37	17	0	1	18	1
20-24	51	13	0	4	10	1
25-29	29	7	0	5	10	0
30-34	17	5	1	3	6	0
35-39	28	9	0	2	4	0
40-44	25	5	0	4	8	0
45-49	13	4	0	2	2	1
50-54	15	6	0	1	3	1
55-59	17	14	2	4	8	0
60-64	14	6	3	3	5	1
65-69	16	6	1	0	10	2
70-74	11	2	4	3	10	2
75-79	8	3	0	0	1	1
80-84	3	2	4	0	1	0
85-over	0	1	2	0	1	0
Total	285	114	36	32	119	20
			(b) 1956			
0-4	0	10	6	0	9	1
0-9	2	7	9	0	7	4
10-14	2	7	6	1	5	1
15-19	41	34	0	6	24	0
20-24	54	13	3	3	8	0
25-29	36	6	1	11	8	0
30-34	19	3	1	3	7	0
35-39	27	6	1	2	12	0
40-44	24	5	1	4	6	0
45-49	21	4	1	5	7	0
50-54	18	6	1	5	8	2
55-59	17	7	3	2	4	1
60-64	17	3	5	4	9	1
65-69	8	5	4	1	8	3
70-74	10	3	7	1	8	0
75-79	10	4	3	0	3	1
80-84	5	0	3	0	6	0
85-over	1	1	1	0	1	0
Total	315	124	56	48	140	14

This is for a two-year period (1955 and 1956). These are the data used by Swanson for calculating an estimate of reliability.

It will be noted that the number of male drivers is high in proportion to the number of female drivers for both years and at practically all age levels. Only ages 15 and above were used because drivers are not supposed to be licensed below age 15. Although a few may drive, it is shown that a very small percentage of licensees is 14 years and under.

Table 2 includes the data of Table 1 plus the number of passenger and pedestrian fatalities. It will be noted that a large percentage of fatalities in Iowa for these two years consisted of drivers of the cars. Passengers constituted considerably less than one-half and pedestrians about one-tenth of the total number of male fatalities.

TABLE 3

PERCENTAGE OF LICENSEES BY 10-YEAR AGE GROUPS[1]

Age	Men	Women	Both Sexes
Under 14	0.02018	0.00000	0.02018
15-24	14.52881	5.17926	19.70807
25-34	18.34937	6.80702	25.15639
35-44	13.55350	6.18821	19.74171
45-54	11.39438	4.80259	16.19697
55-64	8.69712	2.50219	11.19931
65-74	4.89675	0.87441	5.77116
75-84	2.01116	0.20844	1.96400
85-over	0.25560	0.00000	0.25560
Total	73.45127	26.56212	100.01339

[1] Figures based on drivers licensed in Iowa and on 1955 census estimates. These are thought to hold approximately for the United States as a whole.

For women, the results were considerably lower, showing a smaller percentage of female driver fatalities, about the same proportion of female passenger fatalities as men, and somewhat less for pedestrians. These differences seem to reside in the extremes of the distribution, there being more frequent pedestrian fatalities among young boys than among young girls, and also a higher proportion of pedestrian fatalities among men than among women at an older age.

The results compare favorably for the two years. This was as expected from Swanson's calculation of the estimated reliability. One can tell approximately from the results of one year what to expect for another year, providing he has a large enough segment of the population to work with. In this case it involved about 2½ million people, about 1½ million of whom were licensed drivers.

For convenience the data are grouped in 10-year periods, as shown in Table 3. This table offers a basis for comparing the frequency of accidents at different age levels.

The results in Table 4 are derived from previous tables and calculation of the number of drivers, considering the frequency with which they are found in the population. Drivers only are considered. The results were calculated so as to show whether the percentage was in excess or was deficient with respect to the number in the population.

It will be noted that fatalities at age 14 and below are far more than would be expected for both boys and girls. This probably is due to the fact that there are fewer licensed to drive, but there is a certain amount of illegal driving being done throughout the State. The comparison indicates that these figures might be an indication of the amount of illegal driving being done at these ages.

Comparison of the magnitude of the percentages in the two columns readily points out the discrepancies. For example, in the 15-19 age group of male drivers, there were nearly 11.5 percent fatalities, yet they were only 6 percent of the male drivers. It will be noted that for male drivers the excess is rather marked to about age 30. After this the excess occurs occasionally throughout the age range, but it tends to fluctuate.

When the column for women is examined, it is noted that although there is an excess at the earlier age, before 14, the excess is less marked and there is a deficiency down until about the age of 60. In other words, women run a deficiency more or less throughout the age ranges when compared for the frequency with which they are found in the population of drivers.

TABLE 4

PERCENTAGE OF LICENSEES AND FATAL ACCIDENT DRIVERS IN IOWA BY AGE AND SEX

	1955-56 Accident Average (%)					
	Men Drivers		Women Drivers		Both Sexes	
Age	Fatalities [1]	Licensees	Fatalities [1]	Licensees	Fatalities [1]	Licensees
To 14	+ 0.73529	0.02018	+0.14706	—	+ 0.88235	0.02018
15-19	+11.47059	6.02676	-1.02941	2.04480	+12.50000	8.07156
20-24	+15.44118	8.50205	-1.02941	3.13446	+16.47059	11.63651
25-29	+10.00000	9.39665	-2.35294	3.77346	-12.35294	13.17011
30-34	- 5.29411	8.95272	-0.88235	3.03356	- 6.17647	11.98628
35-39	+ 8.08824	7.25768	-0.58824	3.24208	- 8.67647	10.49976
40-44	+ 7.20588	6.29582	-1.17647	2.94613	- 8.38235	9.24195
45-49	- 5.00000	5.97970	-1.02941	2.56272	- 6.02941	8.54242
50-54	- 4.85294	5.41468	-0.88235	2.23987	- 5.73529	7.65455
55-59	+ 5.00000	4.74205	-0.88235	1.51342	- 5.88235	6.25547
60-64	+ 4.55882	3.95507	+1.02941	0.98877	+ 5.58824	4.94384
65-69	+ 3.52941	2.98648	-0.14706	0.60537	+ 3.67647	3.59185
70-74	+ 3.08824	1.91027	-0.58824	0.26904	+ 3.67647	2.17931
75-79	+ 2.64706	1.21073	—	0.14790	+ 2.64706	1.35863
80-84	+ 1.17647	0.54483	—	0.06054	+ 1.17647	0.60537
85+	- 0.14706	0.25560	—	—	- 0.14706	0.25560
Total	88.2+	73.45127	11.76+	26.56212	100.+	100.01339

[1] + indicates more fatalities than expected; minus, fewer fatalities than expected.

For both sexes it is shown that there is an excess in the lower range, as would be expected, and a deficiency through the middle range, with an excess beginning again about age 64, 65 and 66. It is likely the very high range of ages when persons cannot drive much shows a deficiency again. This would be expected, as many older drivers hold their licenses but do not do much driving in traffic.

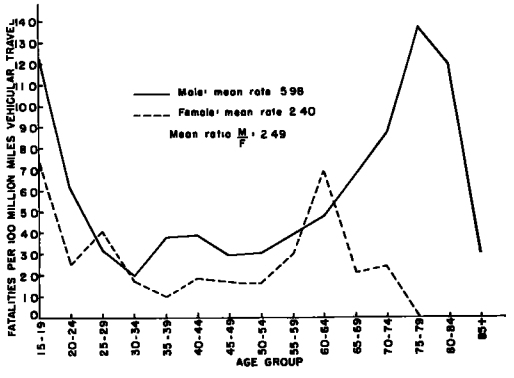

Figure 1. Two-year mean of male and female driver fatalities per 100 million miles vehicular travel for 1955 and 1956, considering drivers only.

To get these data into more meaningful form, corrections were further made for the estimated mileage of sexes for different age levels and the rates calculated for deaths per 100 million vehicle-miles of travel. Analysis of Figure 1 shows considerable difference, even when corrections are made for mileage driven. Young males drive considerably more miles, but the differences still persist in similar fashion throughout the age ranges.

Both sexes tend to improve their records up to around the ages of 30-35 and then remain more or less constant for about a 20-year period. There would be some question as to whether one would need to examine drivers so frequently during the first 15-

year period of their driving, inasmuch as they are improving and there is no reason particularly for calling them in every two years so far as physical traits are concerned. From 30 up to 60 years of age there is not a great deal of change taking place. Here again one might question the advisability of having a driver's examination every two years due to the nature of the changes usually noted. Undoubtedly some persons do change, but where there is illness, an eye operation, or something of similar nature, it would be expected that they would be automatically checked in any efficient system of licensing.

Beginning at about age 60-65 there is evidence that it would be advisable to have a driver's license check every two years. These periodic examinations would seem justified in line with the indication that changes of some type are undoubtedly taking place. It is likely they would be most effective at that time.

CONCLUSIONS

The general conclusions from this study, within the limitations of the data, and when drivers alone are considered, are as follows:

1. There are greater differences in the frequency of accidents among pedestrians, drivers, and passengers, than would be expected from the fact that not all persons are drivers or passengers. Pedestrians show the lowest percentage of fatalities, although they constitute a larger proportion of persons. Hence, it seems that the act of driving is the most serious menace to life in the traffic field. Considering the large percentage of pedestrians and the relatively small percentage of drivers operating at one time the problem becomes magnified.
2. Male drivers seem to be much more lethal to themselves and others than do female drivers. Particulary is this applicable since they exceed in the number driving at one time. Because there are more male drivers licensed, it is reasonable to assume that there are more men driving at any one time than there are women.
3. When mileage is taken into consideration and the best estimates established and graphed, the picture shows a similar result for the number of drivers involved. The differences are magnified, however, and the trend is slightly different. There are more fatalities among the male drivers proportionately and on a mileage basis than there are for female drivers. The ratio for men is about 2.5 that for women with correction for mileage driven.
4. Finally, it may be concluded that there is some question as to whether the driver's license examination every two years is warranted throughout the total age range. It is recommended that this be reviewed and possibly the reexamination set at longer periods up until the age of 55-60, after which it might be wise to make an examination every two years, or possibly every year for certain groups. Exceptions, of course, would be those who have reasons to be examined because of being in an accident or otherwise, who should be called in periodically for recheck in order to keep them in line.

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Final Report of Study on the Effect of A Periodic Refreshment Pause on Simulated-Automobile Driving Performance Efficiency

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During a 3-year period, 56 drivers were individually taken through an experimental 15-hr cycle. The first phase was to familiarize the subjects with the equipment and to minimize any practice effect that might be reflected. Because a pilot study showed that for variables of this type maximum performance was reached within the first 3 hr of driving, the practice period was limited to 3 hr behind the wheel.

The second phase studied driving efficiency over a 6-hr period of simulated automobile driving. An attempt was made to determine the performance curve for variables amenable to continuous measurement. A series of psychological, physiological, psychometric, and psychophysical tests was administered both before and after the driving period to detect any changes that occurred in performance on certain factors relevant to safe driving. The effect of periodic tea pauses on the onset and extent of work decrement was noted. A personal evaluation from each participant was compared with driving performance and test results.

The principal findings are as follows: (a) work decrement begins within the first 2 hr of simulated automobile driving; (b) tea pause prolongs the onset and reduces the work decrement resulting from a prolonged period of simulated automobile driving; (c) the effect of a tea pause can be detected most readily by measurements made while the subject is actually performing; and (d) drivers either cannot or do not accurately evaluate their own level of driving efficiency.

●THE PROBLEM of exhaustion and drowsiness among drivers has been of concern for sometime to those working in the field of traffic safety. As early as 1935 the National Safety Council (1) reported urgent need for scientific research to determine what effect continuous driving, long hours without sleep, and various mechanical aspects of vehicles, have on fatigue and to ascertain the recuperative value of various rest periods. Such research should also bring out, if possible, what degree of fatigue is dangerous and how different individuals vary in susceptibility.

In 1936 Ryan and Warner (2) completed a study on the effect of automobile driving on the reactions of the driver. They concluded that the tendency of long automobile drives is to produce a loss of effectiveness of certain sensory discriminations, association processes and motor reactions similar to those required in driving. These observations suggest that the effect of a long automobile drive may render a driver temporarily prone to accidents.

The present investigation is a study of driving efficiency. Experimentation covered a period of approximately 15 hr for each subject. The primary objective was to determine the effect of a periodic refreshment pause on performance efficiency with respect to a laboratory-driving task. The nature and extent of work decrement for driving performance were also studied.

The experiment was divided into two phases. The first or practice phase was introduced to familiarize the subjects with the equipment and to minimize any practice effect that might be reflected in performance. Because it was shown in a pilot study that for

variables of this type maximum performance was reached within the first 3 hr of driving, the practice phase was limited to 3 hr behind the wheel.

In the second phase the driving time was lengthened to a 6-hr period of performance on the simulated-automobile driving task. An attempt was made to determine the nature of the performance curve for certain variables amenable to continuous measurement.

A series of psychological, physiological, psychometric and psychophysical tests was administered both before and after the driving period in an effort to detect any changes that may have occurred in performance on certain factors deemed relevant to safe driving. Periodic refreshment pauses were introduced and the effect on the onset and extent of work decrement was noted. A personal evaluation was obtained from each participant about subjective feelings which could be compared with driving performance and test results.

METHOD AND PROCEDURE

The method was that of an experimentally controlled study using comparison groups matched as nearly as possible with respect to sex, age, and driving experience. The groups were balanced approximately in the ratio of seven men to three women, which is commensurate with that found in the driving population of the United States. The two groups were used in a simulated-automobile driving performance task.

During the first phase of the study the control group, henceforth designated as the no-pause group, drove for three consecutive hours without rest. The experimental group, hereafter referred to as the refreshment-pause group, spent the same amount of time behind the wheel but were given a 15-min rest pause with tea and additives as desired every 1½ hr during the experimental period.

In the second phase of the study the no-pause group drove for six consecutive hours. The refreshment-pause group also drove for 6 hr, but was given a periodic rest pause with tea as described every 1½ hr.

The first phase of this investigation was designed to test the hypothesis that performance of a task of the type studied is subject to improvement with practice which may be affected by refreshment pauses and basic efficiency changes in the organism.

The primary hypothesis set up for testing in the second phase of the study may be stated in the null form as follows: A periodic refreshment pause (namely, a 15-min rest period every 1½ hr during which time tea as described is served) has no effect on the simulated-automobile driving task performance of automobile operators.

A corollary hypothesis, that work decrement as a result of an extended period of simulated-automobile driving will not be reflected in performance on laboratory tests under the conditions stated, was also tested.

Fifty-six drivers, including 38 men and 18 women, served as subjects. They were recruited from among lay drivers in the vicinity of Iowa State College and other Central Iowa communities. The selection was restricted to drivers having had at least 3 yr or 10,000 mi of driving experience. A second restriction was imposed by the fact that the drivers be willing and able to devote a total of approximately 15 hr to participation in the study. Compensation was mostly at their regular hourly rate of pay. The selection was in order of availability of subjects as arrangements could be made.

The drivers ranged in age from 18 to 66 years. The median age was 24 years for the men and 25 years for the women, the mean being 28.75 years and 26.40 years for men and women, respectively.

Driving experience in terms of years driven ranged from 2 to 38. The median was 8 years.

Miles driven, as estimated by the subjects, ranged from 2,000 to 564,000, with medians of 70,000 and 16,000 for the men and women, respectively.

The experimental procedure began by having each subject fill out a preliminary information blank containing personal data and self-evaluation items. As soon as the preliminary information blank was completed a series of evaluation tests was administered in the following order:

1. Blood pressure. The Tycos self-recording sphygmomanometer was used for measuring blood pressure. This instrument is particularly adapted for use in this type

of study because it makes a graphic recording which increases the objectivity of measurements obtained.

2. Steadiness test. A stylus $\frac{1}{8}$-in. in diameter is moved down between two brass strips which are $\frac{3}{8}$-in. apart at the top and $\frac{1}{8}$-in. apart at the bottom. When either plate is touched a light flashes and the trial ends. The score is read from a calibrated scale on one of the plates. A series of ten trials, alternating hands each trial, constitutes the test.

3. Serial choice reaction time. The subject is seated with the right foot placed on a break-type switch adjacent to a simulated brake pedal and is instructed to hold the right foot on the switch just as though pressing the accelerator of an automobile.

Green, amber, and red stimulus lights are presented in random order. The subject is instructed to respond only to the red light; that is, as soon as the red light appears he is to move the right foot from the switch and place it on the brake pedal as quickly as possible.

The apparatus records only the reaction time to the red light. False or wrong reactions, such as responding to a green light, are merely counted. The test continues until the red light is presented 25 times. Several amber and green lights are interspersed as distraction stimuli in the series of 50 presentations. The number was constant for each subject.

4. Gross coordination. This is measured by a device developed at the Driving Research Laboratory, Iowa State College, for use with Army drivers (3). A tilting-table maze is controlled by means of two levers approximately 43 $\frac{1}{2}$ in. long. One lever tilts the table top upward or downward from front to back, the other tilts it in a similar manner from side to side. A steel ball can be guided around the lanes of the maze by manipulating the levers. At various places along the course are located 1-in. holes, through which the ball will drop if the levers are not manipulated properly to maneuver it around them. The object is to guide the ball through the maze without its falling into any of the holes. When the ball falls through, a trial is completed.

The holes are numbered progressively, so that the farther the ball advances around the maze before it falls through a hole, the higher the score, as the number of the hole determines the score value for the trial. In this experiment each subject was given five trials and the mean of the scores was recorded.

5. Grip endurance. (Not used in Phase I). The apparatus used was a Smedley hand dynamometer with pneumatic plunger attached to a tambour mounted on a Weiss-Renshaw polygraph, which in turn made an inked recording on ruled paper. The subject was asked to take the dynamometer in the preferred hand and grip it as hard as possible for 1 min. The percentage of loss from the original level attained was taken as the score.

6. Card sorting. (Not used in Phase I). The equipment consisted of a deck of Rook cards and four small boxes with one of the following colors printed on the front of each: yellow, red, green, or black. The cards were shuffled and handed, face down, to the subject with the instructions to turn the deck over, look at the top card, state aloud the color, then place it in the proper box. The subject was given only one chance for each card; thus, if a card were placed in the wrong box, it remained there. The object was to see how rapidly the cards could be sorted. The number of errors was also recorded.

7. Mental addition. (Not used in Phase I). Twenty addition problems, each composed of five two-digit numbers, constituted the test. One minute was allowed for computation. The number of problems attempted and number of errors were recorded. Alternate forms were used for the pre-testing and post-testing sessions.

8. Efficiency in observing, or attention to detail. This is a paper-and-pencil test consisting of several rows of the same letter. From one to four other letters of near-identical design were inserted in some of the rows. Two minutes were allowed for counting the number of odd letters in the several rows. Rows attempted and errors were recorded.

9. Galvanic skin response, pulse, and respiration. A Stoelting No. 22496 deceptograph was used for obtaining these measurements. The subject is seated comfortably in a lounging chair and told to relax as much as possible. A pneumatic cuff is placed around one wrist and inflated sufficiently to bring out the pulse beat.

A pneumograph is fastened around the chest tight enough to stretch and contract as the subject breathes. A finger electrode is attached with electrocardiograph jelly to the middle finger of each hand in order to obtain a measurement of skin resistance. A graphic record of pulse, respiration, and galvanic skin responses was obtained for a period of 1 min for each measurement before and after driving.

After the preliminary testing each subject in the refreshment-pause group was served tea. Subjects in the no-pause group went directly into the simulated-automobile driving task phase of the study. Upon entering the booth the subject was seated in the Drivometer, a device consisting of a mock-up landscape with a model car controlled from a control seat exactly as found in a regular automobile, and given instructions with respect to the driving task by means of a tape recorder to keep directions constant.

At the beginning of the driving period, a control test run covering a cycle of seven instructions was made on the Drivometer. During this time a red stop light was presented on five different occasions. Likewise, a train was made to emerge from a tunnel and pass in front of the driver on five other occasions at irregular intervals. The time required for the driver to do the driving task was measured by an electric time clock and recorded as total trip time. The steering score, stop light response time, train reaction time, and error time were measured and recorded each half hour.

The subjects were told to drive just as though they were on the open road as soon as the instructions ceased to appear in the aperture of the Drivometer panel. The red stop light was consistently presented five times each half hour. The train was made to emerge from the tunnel into the view of the driver on five different occasions each half hour. The steering score and number of belt revolutions were recorded for every half hour of driving. The several hours of simulated driving task has been called the intransit period.

After 1 ½ hr of continuous driving, the subjects in the refreshment-pause group were given a 15-min rest period and again served tea as previously described. The no-pause group drove for three and six consecutive hours in Phases I and II, respectively.

Ten minutes prior to the end of the last half hour of the intransit period, a second control test run was given. As soon as the simulated-automobile driving task was finished, the evaluation tests were administered again in the same order as previously described. The experimental cycle was completed by obtaining the driver's subjective evaluation of his level of efficiency by means of a specially designed form.

The results of Phase I were reported previously (3). Therefore, the remainder of this paper covers only Phase II of the study.

RESULTS

An analysis of covariance was made from the scores on the evaluation tests that were administered before and repeated again after the intransit period. The scores on the tests administered before the driving period were taken as the covariates. The results are presented in Table 1.

The drop in diastolic blood pressure by the no-pause groups as compared to practically equivalent measurements for the refreshment-pause group was statistically significant at the 5 percent level of confidence. The refreshment-pause group attempted more items in the test of efficiency in observing and got more items right than the no-pause group. However, they also made more errors. The difference was significant at the 1 percent level of confidence. To be sure that the difference was not spuriously inflated due to the fact that the number right was not controlled in the first analysis, a second analysis was made with the number right after the driving period taken as the covariate. The difference was still significant at the 1 percent level of confidence. A third analysis was made with the last grade of school completed taken as the covariate. The difference remained significant at the 1 percent level of confidence.

To compare the efficiency of the two treatment groups after the intransit period with respect to the variables measured during the control test run, an analysis of covariance was made with the scores on the initial performance taken as the covariates.

Regarding two of the factors, stop light response time and train reaction time, an

inspection of the data revealed that some individuals took an extremely long time to respond on a few occasions. The possibility that a few extremely long intervals might spuriously inflate the group means and thereby influence the results of the analysis was considered. It was decided to adjust the data for extreme values. To do this objectively, the method devised by Grubbs (5) was followed. Both the original and adjusted data were analyzed. The results for all variables considered in the control test runs are given in Table 2. No differences of sufficient magnitude to be statistically significant were revealed.

In the intransit period the instruments used for collecting data while the subject was behind the wheel of the Drivometer were read every half hour. There were twelve readings for each of the variables considered. Group mean scores were computed for each half-hour period. The results are shown in Figures 1 through 4.

TABLE 1

MEAN RESULTS OF EVALUATION TESTS

Variable	Refreshment-Pause		No-Pause		F
	Before	After	Before	After	
Choice reaction time:					
Mean	37.300	39.429	36.536	40.321	1.374
Average variability	6.768	6.757	6.811	7.875	0.405
False attempts	0.714	0.893	1.607	1.036	0.468
Coordination	59.286	55.679	58.214	55.536	0.046
Grip endurance	35.336	35.339	34.479	34.529	0.016
Steadiness	7.871	7.536	9.093	8.686	0.319
Strength of grip	40.354	42.136	38.568	40.004	0.253
Blood pressure:					
Diastolic	67.321	67.535	64.071	62.000	4.061[1]
Systolic	120.250	123.286	122.750	121.036	0.212
Galvanic skin response	127.262	111.900	98.771	76.737	0.266
Pulse:					
Rate	77.429	72.036	76.786	70.179	0.282
Regularity	1.003	1.001	1.008	1.014	0.526
Level of oscillation	1.071	1.107	1.000	0.964	0.400
Respiration:					
Frequency	16.107	16.643	15.250	15.821	0.138
Mean I/E ratio	0.771	0.721	0.837	0.781	0.286
Mean I/E variability	0.210	0.194	0.224	0.203	0.010
Efficiency in observing:					
Number attempted	25.607	34.393	25.679	31.071	3.465
Number right	22.071	29.286	22.464	28.179	0.843
Errors	3.536	5.107	3.214	2.893	13.068[2]
Card sorting:					
Time	44.500	42.857	44.536	40.500	1.747
Errors	0.357	0.286	0.321	0.429	0.244
Mental addition:					
Number attempted	16.429	16.036	17.643	16.964	0.018
Number right	15.500	15.179	17.214	16.357	0.232
Errors	0.929	0.857	0.429	0.607	0.168

[1] Significant at the 5 percent level.
[2] Significant at the 1 percent level.

The degree to which the car was kept in the proper lane on the road was objectively recorded by means of a counter that was activated every time the miniature car passed over one of a series of copper bars in the center of the right lane of the traveling roadway. The cumulative count constituted the steering score.

Figure 1 reveals that at the end of the first half hour of driving, the scores for the two treatment groups were practically equivalent. The refreshment-pause group consistently made the higher steering scores for the remainder of the driving period.

To obtain a measure of speed, the average number of Drivometer belt revolutions per minute was recorded for each half-hour period. The performane curves of the two treatment groups were compared graphically (Fig. 2).

TABLE 2

MEAN RESULTS OF CONTROL TEST RUNS

Variable	Refreshment-Pause		No-Pause		F
	Before	After	Before	After	
Error time	0.832	0.777	1.011	0.721	1.272
Steering	106.893	103.321	129.893	98.821	2.445
Stop light response time:					
Mean:					
Original data	1.021	1.282	1.071	1.185	0.298
Adjusted for extreme scores	0.835	0.863	0.872	1.063	2.879
Average variability:					
Original data	0.500	0.680	0.580	0.454	0.882
Adjusted for extreme scores	0.157	0.163	0.148	0.279	2.539
Total trip time	4.012	3.645	4.019	3.611	0.031
Train reaction time:					
Mean:					
Original data	0.780	0.774	0.898	0.742	0.795
Adjusted for extreme scores	0.735	0.720	0.744	0.701	0.143
Average variability:					
Original data	0.475	0.567	0.649	0.444	1.249
Adjusted for extreme scores	0.359	0.360	0.399	0.367	0.037

The refreshment-pause group consistently had the greater average number of belt revolutions per minute, which indicated that they drove somewhat faster than the no-pause group. The average number of belt revolutions per minute increased during the half-hour period immediately following each refreshment pause.

The groups also were compared with respect to steering score per simulated distance traveled. As a basis for the comparison, the steering score for each half-hour period was divided by the number of belt revolutions during that period. The result, called steering efficiency (Fig. 3) reveals how well the car was kept in the proper position on the roadway.

The red stimulus light was presented on five different occasions during each half hour of the driving period. The time required for the driver to notice the red light and respond by depressing the brake pedal was recorded as stop light response time. Both the mean and average variability were computed. The results (Fig. 4) show that the no-pause group consistently took a longer time to respond to the red light than the refreshment-pause group. They also showed more variability in stop light response time than the refreshment-pause group.

A few drivers occasionally took an extremely long time to respond. Adjustment for

extreme outliers was made according to the method devised by Grubbs (5). After the adjustment had been made for extreme scores the stop light response time for the two groups was practically equivalent through the third half hour. Beyond the third half hour of the driving period the no-pause group consistently took longer to respond than the refreshment-pause group.

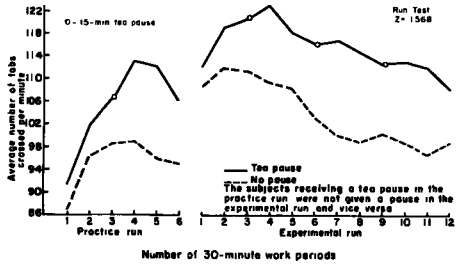


Figure 1. Results of steering tests.

of driving. The time elapsing between the emergence of the train from the tunnel and the driver's response by depressing the brake pedal was recorded as train reaction time. The mean and average variability of the two treatment groups were computed for each half hour of the intransit period. Similar computations were made after the data had been adjusted for extreme scores.

The average variability for the two groups after adjustment for extreme outliers was nearly equivalent through the eighth half hour, after which the no-pause group became increasingly more variable with respect to stop light response time than the refreshment-pause group.

An electric train was caused to emerge from a tunnel into the view of the driver at five different times during each half hour

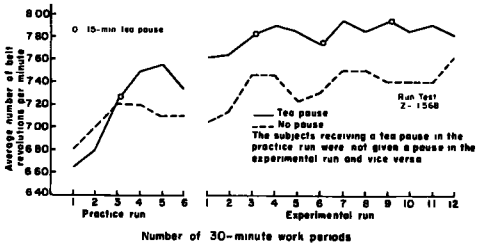


Figure 2. Speed vs driving time.

The performance of the two treatment groups was practically equivalent. No substantial differences were revealed (Fig. 5).

To test the significance of the differences between the treatment groups with respect to the factors studied during the driving or intransit period, the half-hour intervals were considered as split-plot trials and an analysis was made.

The resulting F-values for treatment groups, 30-min intervals, and interaction as obtained for each variable, are presented in Table 3.

The analysis revealed a highly significant F-value with respect to the number of belt revolutions (that is, simulated distance traveled) in each half hour of the driving period. This indicates a statistically significant difference in the number of belt revolutions among the 12 half-hour intervals.

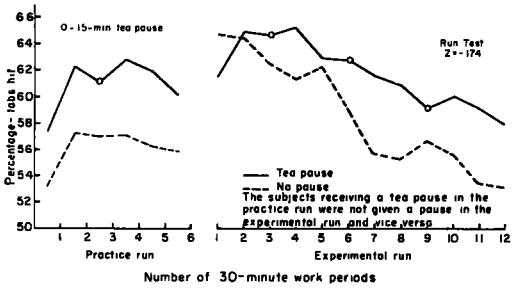
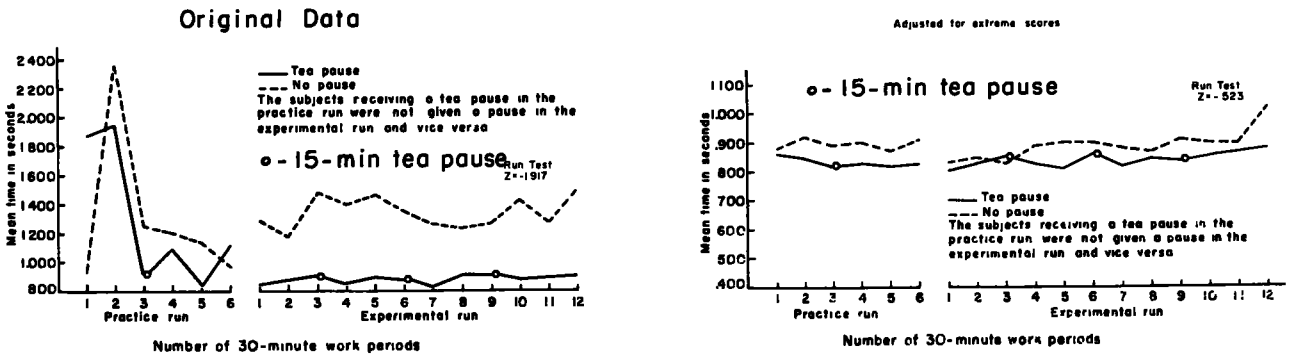


Figure 3. Steering efficiency vs time of driving.

Highly significant F-values were obtained for the 30-min intervals and the interaction between the treatment groups and the 30-min intervals for the steering score. Superior performance was demonstrated by the refreshment-pause group. This group was also superior in steering efficiency, as indicated by highly significant F-values for 30-min intervals and interaction.

A chi-square analysis of the number of extreme scores resulted in a value significant at the 5 percent level for stop light response time. The no-pause group had the greater number of extreme values.



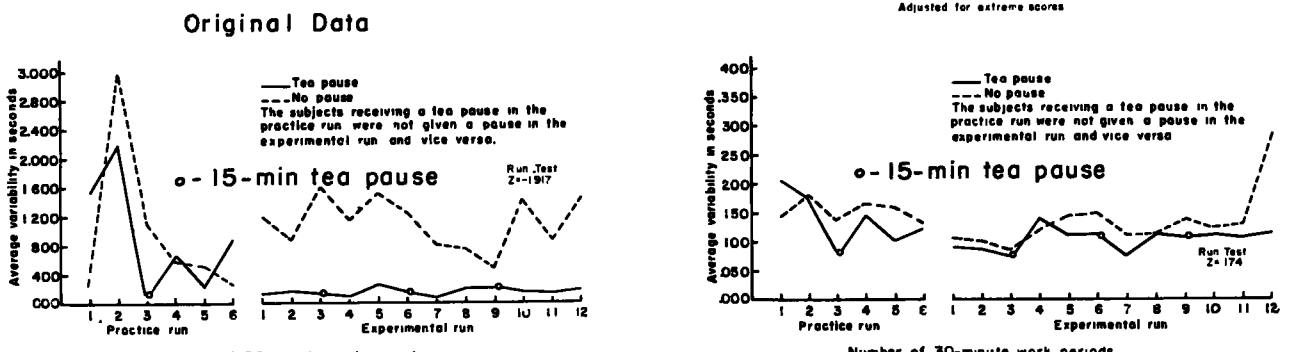
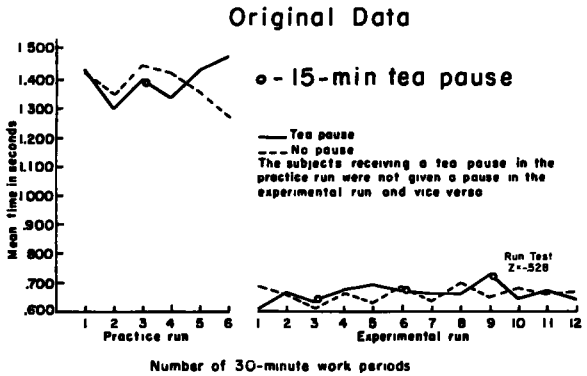
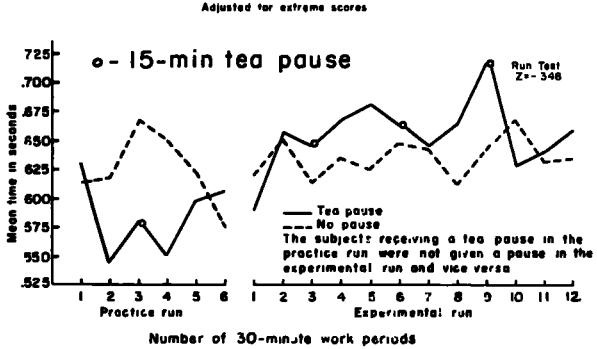


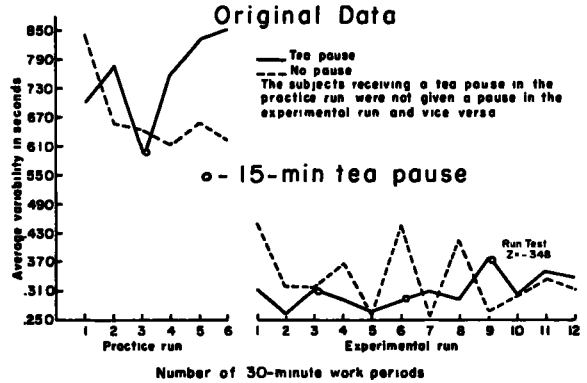
Figure 4.

Stop Light Response Time

(1) Mean time in seconds - original data
(2) Mean time in seconds - data adjusted for extreme scores
(3) Average variability in seconds - original data
(4) Average variability in seconds - data adjusted for extreme scores







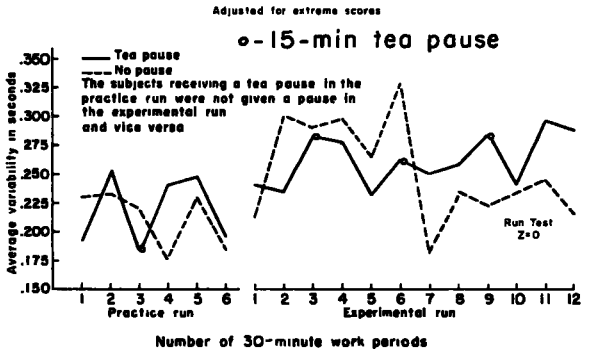


Figure 5.

Train Reaction Time

(1) Mean time in seconds - original data
(2) Mean time in seconds - data adjusted
(3) Average variability in seconds - original data
(4) Average variability in seconds - data adjusted for extreme scores

TABLE 3

VARIABLES STUDIED DURING THE INTRANSIT PERIOD

Variable	F			Superior Group
	Treatment Groups	30-Min. Intervals	Interaction	
Belt revolutions	2.319	27.490[2]	0.473	
Steering	3.318	29.326[2]	2.649[2]	RP[1]
Steering efficiency	1.229	12.627[2]	2.679[2]	RP
Stop light response time:				
Mean:				
Original data	1.747	0.488	0.384	
Adjusted for extreme scores	1.609	1.774	0.871	
Average variability:				
Original data	1.688	0.673	0.623	
Adjusted for extreme scores	2.527	1.250	0.667	
Train reaction time:				
Mean:				
Original data	0.004	0.483	0.862	
Adjusted for extreme scores	0.242	0.773	0.727	
Average variability:				
Original data	0.600	0.905	0.917	
Adjusted for extreme scores	0.207	1.417	1.333	

[1] Refresehment-pause group.
[2] Significant at the 1 percent level.

Each driver was given an opportunity to evaluate his own level of efficiency at the end of the experimental period. No group differences of sufficient magnitude to be statistically significant were revealed. Tiredness of eyes, physical discomfort, and nervousness were listed most frequently by the drivers as indicators of their own level of efficiency.

DISCUSSION OF RESULTS

It is in the area covered by the variables studied during the intransit period that the refreshment pause shows the most significant and potentially beneficial relationship to driving performance. It would seem that the refreshment pause not only increases the effectiveness of steering per half hour of simulated driving, but also tends to delay the onset and reduce the extent of decrement in performance. The same is true for the number of belt revolutions or simulated distance traveled each half hour of driving. This might tend to indicate higher concentration and greater zest on the part of the refreshment-pause group.

The subjects in the no-pause group made essentially the same estimate of their driving efficiency, as inferred from their responses to the subjective evaluation items obtained at the end of the 6-hr driving period, as that made by the subjects in the refreshment-pause group. No significant differences were shown. Because analyses of the objectively gathered data did reveal statistically significant differences between the two treatment groups with respect to several of the variables considered in this investi-

gation, it appears that the individual driver is not always able to or at least does not always accurately estimate his own level of efficiency. A driver may have reduced efficiency and not be aware of it.

The time of onset of decrement differed among the variables studied. In several instances a decline appeared after 1 hr of driving. It was not until 2 hr of driving had elapsed that decrement was shown for all variables considered.

The results seem to indicate that it would be well for the average motorist to limit the amount of continuous driving to a period of from 1 to 2 hr. It would seem that to be conservative one should stop for rest every hour.

CONCLUSIONS

Within the limitations of the design, number of subjects, and other conditions of this study, the following tentative conclusions may be drawn:

1. The onset of work decrement occurs within the first 2 hr of simulated automobile driving task.
2. The effect of a refreshment pause can be detected most readily by measurements made while the subject is actually performing the task.
3. A refreshment pause substantially prolongs the onset of fatigue and reduces the extent of work decrement resulting from a prolonged period of simulated automobile driving performance task.
4. Drivers either cannot or do not accurately evaluate subjectively their own level of driving performance efficiency.
5. Variability in performance seems to be an indicator of the efficiency level of performance of the type studied.
6. A refresehment pause will increase maximum efficiency of performance.
7. The main hypothesis, that a periodic refreshment pause has no effect on the simulated automobile driving performance of automobile operators, can be rejected for three of the variables studied during the intransit period (steering, belt revolutions, and steering efficiency).
8. A driver's efficiency may be lowered without his being aware of it.
9. Drivers become less efficient after 2 hr of continuous driving.

ACKNOWLEDGMENT

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