PB80-121064

DOT HS-805 086

TRI-LEVEL STUDY OF THE CAUSES OF TRAFFIC ACCIDENTS: FINAL REPORT

Volume II: Special Analyses

J.R. Treat, N.S. Tumbas, S.T. McDonald, D. Shinar,
R.D. Hume, R.E. Mayer, R.L. Stansifer, N.J. Castellan

Institute for Research in Public Safety
Indiana University
400 East Seventh Street
Bloomington, Indiana 47401

Contract No. DOT HS-034-3-535
Contract Amt. $1,531,466

PRINTED MAY 1979
FINAL REPORT

Prepared For
U.S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
Washington, D.C. 20590

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS 805 086		

4. Title and Subtitle	5. Report Date / 6. Performing Organization Code
Tri-Level Study of the Causes of Traffic Accidents: Final Report. (Volume I: Causal Factor Tabulations and Assessments; Volume II: Special Analyses).	March 31, 1977
7. Author(s) J. R. Treat, N. S. Tumbas, S. T. McDonald, D. Shinar, R. D. Hume, R. E. Mayer, R. L. Stansifer, N. J. Castellan	8. Performing Organization Report No. DOT-HS-034-3-535-77-TAC(1)
9. Performing Organization Name and Address Institute for Research in Public Safety Indiana University 400 East Seventh Street Bloomington, Indiana 47401	10. Work Unit No. 11. Contract or Grant No. DOT-HS-034-3-535
12. Sponsoring Agency Name and Address U.S. Department of Transportation National Highway Traffic Safety Administration Washington, D.C. 20590	13. Type of Report and Period Covered Final Report August 1972-March 1977 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This is the Final Report of the "Tri-Level Study of the Causes of Traffic Accidents," performed by the Indiana University Institute for Research in Public Safety (IRPS), under contract to the National Highway Traffic Safety Administration (Contract No. DOT-HS-034-3-535). Several Interim and special investigation reports have been released previously.

Volume I provides causal result tabulations from Phases II through V, and related analyses. Volume II presents several special analysis reports dealing with driver vision, knowledge, psychological make-up, etc. Phase I data differed in format, and were presented in a previous report.

Data were collected on three levels of detail. Police reports and other baseline data on the Monroe County, Indiana study area were collected on Level A. On Level B, teams of technicians responded to accidents at the time of their occurrence to conduct on-scene investigations; a total of 2,258 investigations were conducted during Phases II through V. Concurrently, 420 of these accidents were independently examined by a multidisciplinary team on Level C. Other special surveys were also conducted.

One or more human factors was cited by the in-depth team as a probable cause in 92.6% of accidents investigated in Phases II through V. Environmental factors were cited as probable causes in 33.8% of these accidents, while vehicular factors were identified as probable causes in 12.6%. The major human direct causes were improper lookout, excessive speed, inattention, improper evasive action, and internal distraction. Leading environmental accident causes were view obstructions and slick roads. The major vehicular causes of accidents were brake failure, inadequate tread depth, side-to-side brake imbalance, under-inflation, and vehicle related vision obstructions.

Vision (especially poor dynamic visual acuity) and personality (especially poor personal and social adjustment) were found related to accident-involvement. However, as measured in this study, knowledge of the driving task was not shown to be related.

17. Key Words	18. Distribution Statement
Traffic accident causes; driver errors; roadway design, maintenance and signing; vehicle defects, maintenance and inspection; driver vision testing; driver knowledge test; multidisciplinary crash research.	Availability is unlimited. Documents may be released to the public through the National Technical Information Service, Springfield, Virginia 22151.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
None	None	318	A14 - A01

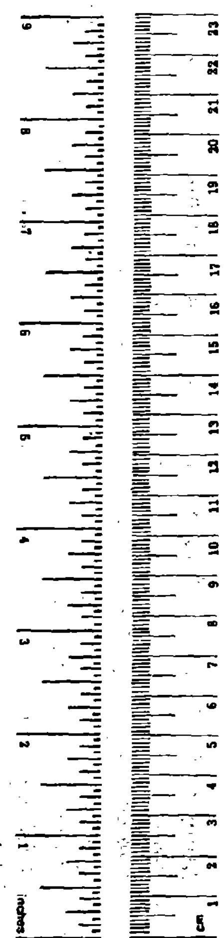
Form DOT F 1700.7 (8-69)

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

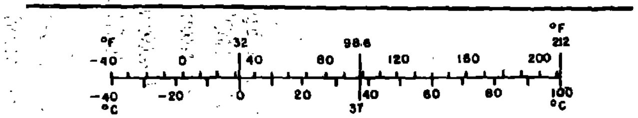
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



BEST COPY AVAILABLE

TRI-LEVEL STUDY OF THE CAUSES OF TRAFFIC ACCIDENTS: FINAL REPORT

VOLUME II Special Analyses
Report No. DOT-HS-034-3-535-77-TAC
Table of Contents

TRI-LEVEL STUDY OF THE CAUSES OF TRAFFIC ACCIDENTS: FINAL REPORT

Volume II Special Analyses
Report No. DOT-HS-034-3-535-77-TAC
List of Tables and Figures

1.0 Introduction

This is the final report of a three-year research program entitled "Tri-Level Study of the Causes of Traffic Accidents," performed by the Institute for Research in Public Safety (IRPS) of the Indiana University School of Public and Environmental Affairs. The study was performed for the National Highway Traffic Safety Administration (NHTSA), U.S. Department of Transportation, under Contract No. DOT-HS-034-3-535. The period of performance was from 15 August 1972 to 30 September 1975,[1] which coincides with IRPS data collection Phases III, IV, and V. Phase II data, acquired under a previous NHTSA contract (1),[2] are also reported. Phase I data appear in a previous report (1).

1.1 Research Objectives

The study was conducted to satisfy a broad range of NHTSA's needs for up-to-date data regarding traffic accident causation. The basic research question was "what causes traffic accidents?," and all potentially causative factors — human, vehicular, and environmental — were of interest. Accomplishment of this overall objective involved several specific objectives, including the following:

1. Identify those factors which are present and serve to initiate or influence the sequence of events resulting in a motor vehicle accident (Vol. I).
2. Determine the relative frequency of these factors and their causal contribution within a defined accident and driving population (Vol. I).
3. Assess the error/accident relationship as a function of driver age, driving knowledge, vision, driving experience, and vehicle familiarity (Vol. II).
4. Apply taxonomy development and group-identification concepts to the identification and definition of problem driver types, and from this to formulate recommendations for dealing with particular classes of drivers (particular attention was to be given to the alcohol-impaired driver, in order to identify the types of driving-performance mistakes made by particular types of alcohol-impaired drivers under particular types of conditions). (Vol. II).
5. Assess the potential benefit of radar and anti-lock braking systems in reducing the incidence and severity of automobile accidents (See Interim Report II, Vol. II).
6. Develop new methodologies for assessing the role of human factors in accident causation. (Vol. II).

---

[1] Later extended to June, 1977 for supplemental analysis tasks, to be separately reported.
[2] Numbers in parentheses refer to references which are listed near the end of this volume.

1.2 Report Structure

This final report is comprised of two volumes. Volume I reports causal factor tabulations and assessments, while Volume II reports several special analyses based on project data.

Several earlier (interim) reports of this three-year study have been published; in chronological order, these include:

- *Tri-Level Study of the Causes of Traffic Accidents: Interim Report I, Vols. I & II.*

  Prepared under Contract No. DOT-HS-034-3-535, August 1973, DOT Report Nos. HS-801-334 and HS-801-335. This was a final report of the first year of activity under the present three-year program. It provided causal factor tabulations for Phase III, as well as cumulative results for Phases II and III. Volume I included methodology, conclusions, and recommendations sections; causal result tabulations; comparisons of Phase II and III results; assessments of accident severity as a function of causal factor; an analysis of the model year distribution among vehicles involved in accidents as a result of vehicular problems; a comparison of results obtained on-site and in-depth; a comparison of accident and control sample populations; results of an initial cluster analysis effort; an assessment of relationships between various driver, accident and causal factor characteristics; and an assessment of the representativeness of study samples. The glossary section of Volume I included the overall causal hierarchy and causal factor definitions. Volume II provided a more detailed description of methodology, as well as the principal data collection forms and the detailed causal result data tables (2).

- *Tri-Level Study of the Causes of Traffic Accidents: Interim Report II, Volumes I & II.*

  Prepared under Contract No. DOT-HS-034-3-535. Volume I dated August, 1974; Volume II dated December, 1974 (Nos. HS-801-968 and HS-801-631). These were final reports of the second year of activity. Volume I provided a report of causal result tabulations and trends, while Volume II dealt exclusively with assessments of the potential payoff of radar warning, radar actuated, and anti-lock braking systems in preventing accidents or reducing their severity. Causal result data in Volume I included both Phase IV and cumulative Phase II, III, IV data. A third document (Volume III) was produced but not published. Instead, its contents were updated and incorporated in the present final report. It dealt with results of dynamic vision testing, driver knowledge testing, on-site and in-depth cluster analyses of data, an AID analysis relating driver characteristics and accident causes, and new methodology development, including profile scores of drivers (3).

The present document is a comprehensive final report of the three-year study. However, not all materials previously published have been replicated herein. For example, results of the radar/anti-lock assessments (Interim Report II, Volume II) are not included. The present report includes causal factor tabulations from the Phase V collection period, as well as cumulative data from Phases II through V.

Prior to the present study, IRPS was engaged in a related tri-level study under NHTSA sponsorship, entitled "A Study to Determine the Relationship Between Vehicle Defects and Crashes" (DOT-HS-034-2-263). In chronological order, relevant documents from that study were:

- *Interim Report of A Study to Determine the Relationship Between Vehicle Defects and Crashes: Methodology.*

  Prepared under Contract No. DOT-HS-034-2-263, November, 1971. DOT Report No. DOT-HS-800-661. Provides details of tri-level methodology. This document was produced during Phase I of IRPS' several data collection phases (4).

- *Results of a Study to Determine the Relationship Between Vehicle Defects and Crashes, Vols. I & II.*

  Prepared under Contract No. DOT-HS-034-2-263, November, 1972. DOT Report Nos. DOT-HS-800-850 and 851. Provided results from data collection Phases I and II. Although the emphasis was on the role of vehicular factors, human and environmental factors were also tabulated in a manner consistent with that employed in later phases. Volume I provided causal result tabulations, while Volume II dealt with comparisons of component outage rates in the accident and general vehicle populations, comparisons of results obtained at the on-site and in-depth levels, and the representativeness of study samples. The report was a product of data collection Phase II (1).

1.3 Status of Accident Investigation and Data Collection Activities

As described in the methodology overview (Volume I, section 2.0), a tri-level methodology has been employed featuring baseline data collection on Level A, on-site investigations of moderate detail on Level B, and in-depth investigations of intensive detail on Level C.

During Phase V IRPS continued to build both baseline and accident data files (Tables

1-1 and 1-2). Baseline data includes information describing Monroe County accidents reported to the state (location, date, etc.), drivers licensed in Monroe County (age, sex, vision as measured by the dynamic vision tester, etc.), vehicles registered in Monroe County (make, model, year, etc.), and Monroe County roadways (miles of surfaced and unsurfaced roads, etc.).

Throughout Phase V, twenty-four hour per day coverage was maintained on Level B, permitting a sizeable increase in the accident data files. An additional 894 on-site (Level B) and 102 in-depth (Level C) investigations were conducted, bringing the total for the three-year study to 1728 on-site and 269 in-depth. These data are generally compatible with those collected during Phase II (530 on-site, 151 in-depth) providing a total base of 2258 on-site and 420 in-depth accidents readily available for analysis. Also during Phase V, information was acquired on all 3068 Monroe County accidents reported to the state during this period, bringing the total number of state accident reports for the Phase II-V period to 13,568 (Table 1-2).

1.4 Background

The National Highway Traffic Safety Administration (NHTSA) has sponsored a variety of accident investigation studies since 1968. These studies to collect and analyze real-world accident data provide a foundation for development of safety strategies, rule-making plans, assignment of priorities, and measures of the effectiveness of countermeasure programs at the national level. Thus, the critical real-world data developed provide a technical base for intelligent planning and decision-making. In summary, specific objectives of the national accident investigation system are to:

- Identify the causes and mechanisms of motor vehicle accidents and subsequent injuries, so that effective measures, devices, and traffic safety programs can be initiated.
- Provide accident information and analyses on priority safety problems for research and rule-making.
- Assess the worth of motor vehicle and highway safety standards now in force, and predict the potential effectiveness of new standards under consideration.
- Pinpoint defects in motor vehicles or highway design as the basis for scientific investigation.
- Validate advanced accident investigation techniques in the field to improve the precision, accuracy, and efficiency of the collection of accident data while reducing the collection burden of on-scene investigators.

Table 1-1

Summary of Baseline Data Collected by IRPS

	File Name	File Description	Data Collection Period (source)	No. of Sampling Units	No. of Variables	Sampling Technique
PHASE II	PH2E30	Age and sex of Monroe Co. licensed drivers	May, 1972 (1971 driver's license applications)	1,061	3	Systematic sampling from a list
	ISP71	Monroe Co. Police reported accident data	April, 1972 (ISP)	3,914	56	Entire population
PHASE III	PH3E30	Age and sex of Monroe Co. licensed drivers	May, 1973 (1972 driver's license applications)	1,000	3	Systematic sampling from a list
	PH3E31	Make & model year of Monroe Co. passenger vehicles	June, 1973 (1973 Monroe Co. passenger vehicle registrations)	2,000	2	Systematic sampling from a list
	PH3E09	Monroe Co. driver–vehicle characteristics	29 April, 1973 to 3 June, 1973 (Monroe Co. drivers)	900	43	Quota sampling (stratified by age and sex)
	ISP72	Monroe Co. police reported accident data	April, 1973 (ISP)	3,272	56	Entire population
PHASE IV	PH4E30	Age and sex of Monroe Co. licensed drivers	April, 1974 (1973 driver's license applications)	980	10	Systematic sampling from a list
	PH4E60	Monroe Co. licensed driver vision	8 April, 1974 to 8 July, 1974 (Monroe Co. licensed drivers)	149	70	Quota sampling (stratified by age and sex)
	PH4E61	Monroe Co. licensed driver vision test–retest	8 April, 1974 to 8 July, 1974 (Monroe Co. licensed drivers)	51	112	Quota sampling (stratified by age and sex)
	PH4E62	Monroe Co. licensed drivers	August, 1974 (Indiana BMV)	63,000	16	Entire population
	PH4E63	Monroe Co. registered vehicles	June, 1974 (Indiana BMV)	33,921	35	Entire population
	ISP73	Monroe Co. police reported accident data	April, 1974 (ISP)	3,314	56	Entire population
PHASE V	PH5E30	Age and sex of Monroe Co. licensed drivers	July, 1975 (1974 driver's license applications)	2,081	18	Systematic sampling from a list
	ISP74	Monroe Co. police reported accident data	April, 1975 (ISP)	3,068	56	Entire population

Table 1-2

Summary of Accidents Investigated by IRPS Using Tri-Level Methodology

Data Collection Phases & Dates	Police Reports (Level A)	On-Site (Level B)	In-Depth (Level C)
I—10/70-5/71	3458 in 1970	469	68
II—6/71-5/72	3914 in 1971	530	151
III—6/72-5/73	3272 in 1972	306	64
IV—6/73-5/74	3314 in 1973	528	103
V—6/74-5/75	3068 in 1974	894	102
Combined Phases[1] II, III, IV, V	13,568	2258	420

[1] Phases II, III, IV, and V were assessed using the same causal assessment scheme, and are presented both separately and cumulatively. Phase I differed somewhat and, for the most part, is not reported herein.

Recent trends in accident research have led to a multilevel approach to national accident data collection, processing and analysis (see Figure I-1). The level of sophistication ranges from population data and the basic, minimal amount of data contained in routine police reports of all accidents, to the most comprehensive, in-depth data contained in special reports by professional accident investigation teams. In the basic level of collection, a small number of data elements are collected on the population at large and on a large number of accidents. Data from vehicle registrations and drivers licenses are utilized as supplement information at this basic level. At the top level, hundreds of data elements are collected on a small number of select accidents which are designated for study. Intermediate levels involve various additional data elements not routinely collected at the basic level in order to study some specific aspect on a subsample of accidents.

A composite approach, designated as a **tri-level study**, was devised from this multilevel national concept. Tri-level studies involve simultaneous accident data collection and investigation from three levels of detail, within a single study. Thus, **the three levels of the IRPS tri-level program, in order of increasing detail and cost per investigation and decreasing case volume are:**

- The collection of baseline data on the study county from police reports, vehicle registration files, driver license files, roadway inventories, and local surveys (Level A).

Figure 1-1 — Multi-Level Concept

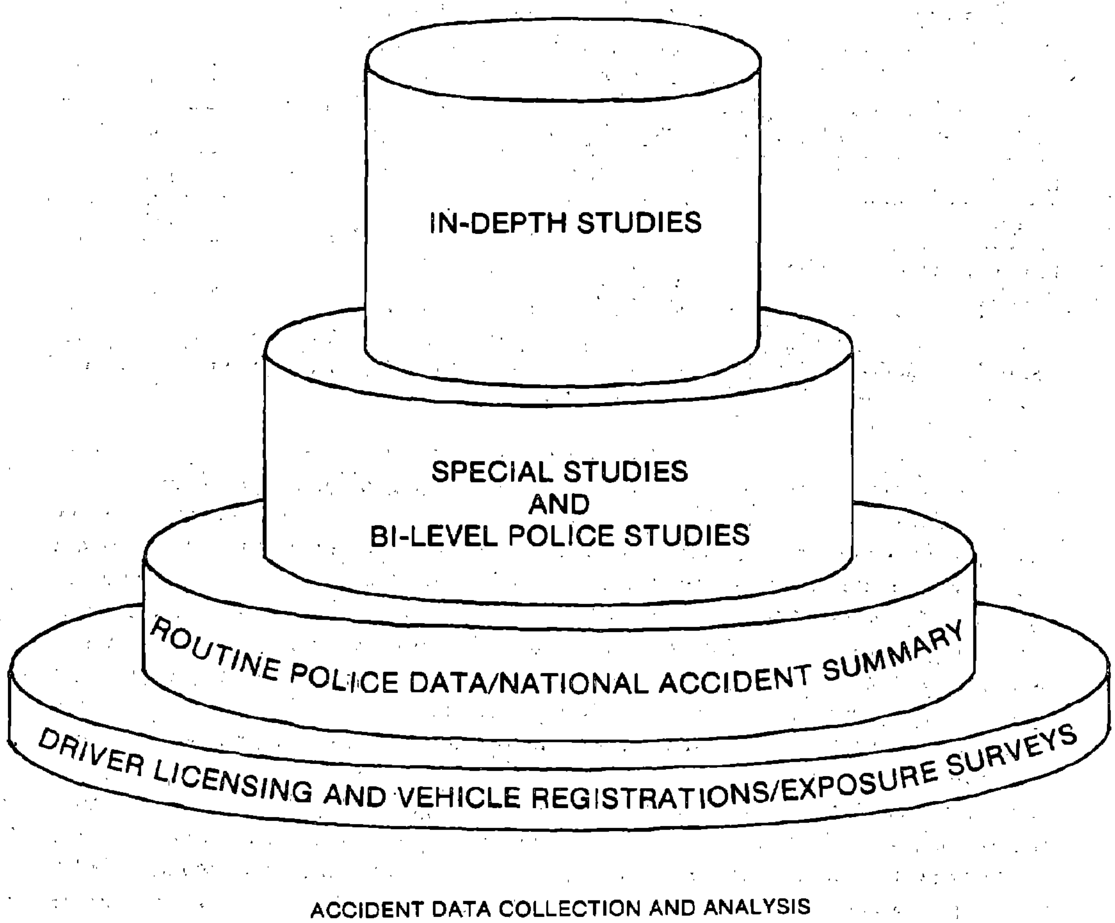


Diagram Courtesy of NHTSA.

- The on-site investigation of accidents immediately following their occurrence by teams of technicians (Level B).
- The independent, in-depth investigation of a subset of the accidents investigated on-site, by a multidisciplinary team (Level C).

Data collected on Level A enable the representativeness of study samples to be assessed, and also provide a basis for comparison of accident and general populations. The Level B (on-site) investigations enable moderately detailed information to be collected from a relatively large number of accidents. Since the extension of coverage in February, 1974 from 10 hours to 24 hours per day, IRPS has acquired accidents on Level B at the rate of approximately 70 to 80 accidents per month (840 to 960 per year). On Level C, a multidisciplinary team has conducted highly-detailed investigations at a rate which has averaged about 100 accidents per year.

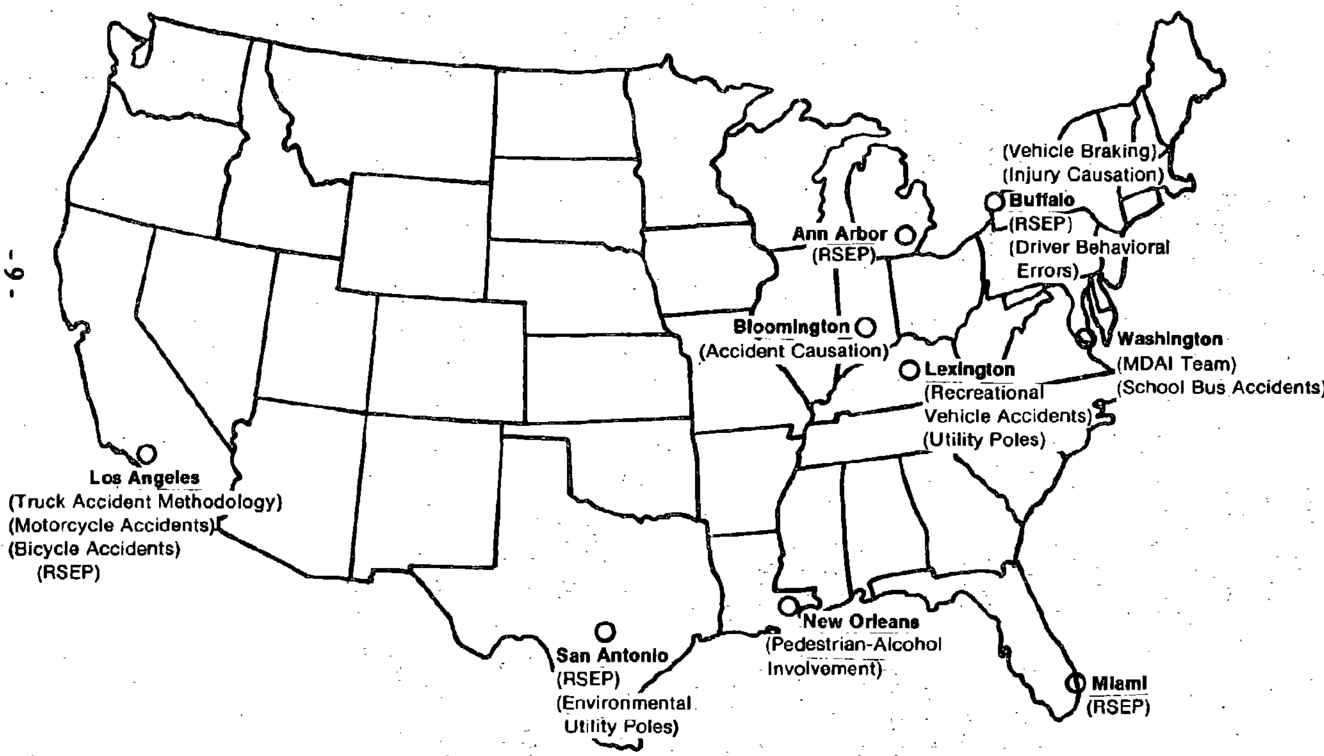
In Figure 1-2, the location of many of the teams currently funded by NHTSA is shown, including the present study of accident causation. Each of these is a "special study," focusing on a particular aspect of the highway traffic safety problem. At its core, each also includes a multidisciplinary accident investigation team composed of medical doctors, engineers, psychologists, and other accident reconstruction specialists who scientifically analyze accidents to determine accident and injury causation and to make recommendations for possible solutions. Increasingly, these studies are developing levels of data which provide for both clinical evaluations of accident and injury causation, as well as statistically significant information on specific priority problems.

Not reflected in Figure 1-2 are several previous NHTSA studies conducted during the first two years of the present study. These include a study of Intersection Accidents in San Francisco, Restraint Usage Comparisons in Salt Lake City, a study of Alcohol-Involved Accidents in Albuquerque, a study of Fatal Accidents in Oklahoma City, a study of Injury and Damages Indices in San Antonio, a Pedestrian-Alcohol Involvement Study in New Orleans, a Single Vehicle Accident study in Miami, and Alcohol Safety Action Project Evaluation teams in Baltimore and Boston.

The present IRPS study has built extensively on the earlier "Vehicle Defects Project," and differs most notably in directing increased attention to the role of human and environmental factors. Additional details concerning the study approach are provided in the methodology overview section (Vol. I, Section 2.0).

Figure 1-2

Multi-level Accident Investigation Studies



RSEP—Restraint System Evaluation Program Regional Team

(Reprinted by courtesy of the National Highway Traffic Safety Administration)

Fall, 1975

2.0 Driver Attributes in Relation to Accident Involvement and Causation

Grouped in this section are several separate examinations of relationships between selected driver attributes and measures of accident involvement. The latter include comparisons between groups which either have or have not had accidents within specified periods, and between those in accidents judged to have made causally-relevant driver errors and those adjudged error-free. Topics included are as follows:

- Section 2.1: Driver Vision (static and dynamic acuity, angular movement, and other measures using a device of advanced-design).
- Section 2.2: Driver Knowledge (tested via a short pen and pencil battery).
- Section 2.3: Driver Psychological and Personality Factors (based on measures of social and personal adjustment, impulsivity, information-processing ability, etc.).
- Section 2.4: Driver Characteristics and Culpability (focusing on age, sex, driving experience, vehicle familiarity, annual mileage, and road-area familiarity).

2.1 Driver Vision Test

The general purpose of this section is to obtain a closer look than afforded before, at the relationship between driving performance and vision. Despite the fact that visual information is generally believed to constitute over 90 percent of the driving-relevant input to the driver (Hartmann, 1970), the measured relationships between driving performance measures and traditional measures of visual acuity are at best tentative (c.f., Goldstein, 1961; Burg, 1964). Several factors may account for these results:

The Limited Range Effect—there typically is a reduction of the observed relationship between two factors when the range of values of either or both is limited. In driving, this effect is manifested in the typical elimination (through licensing) of all those people with a corrected foveal static acuity less (poorer) than 20/50.

The Limited Number of Visual Functions Studied—typically, only static foveal acuity and color vision tests are administered for licensing purposes. Yet, good driving performance requires adequate peripheral vision (Mourant & Rockwell, 1972), acuity in the presence of glare and low levels of illumination (Allen, 1970), and adequate dynamic visual acuity (Burg, 1968).

The Limited Data Base for Driving Performance—here the basic problem remains one of defining the driving task. Various approaches such as information processing (Rockwell, 1972) and functional taxonomies (McKnight and Adams, 1970) have been taken, and the resulting models of the driving task have been useful in generating the visual functions necessary for driving. However, to test the relevance of the visual functions one must compare the visual performance of drivers to **empirical** driving-task-related data. Typically driver records are used as indicators of driving performance (Burg, 1967, 1968; Fergenson, 1971). However, for the present purpose, accident and violation records are relatively crude and indirect measures of driving performance for the following reasons:

1. They do not contain information on the particular human error that caused the accident—or even the violation.

2. Assessment of culpability is based on legal considerations rather than human perceptual-motor limitations.

3. They contain data accumulated over a long period of time during which visual performance on selected visual functions may deteriorate significantly.

4. Drivers' accident and violation records are greatly influenced by more "central" factors such as risk-taking tendencies, and information processing rates (Fergenson, 1971), as well as personality characteristics (Herano, 1968).

2.1.1 Methodological Approach

In the present research the relationship between visual ability and driving performance is studied by measuring multiple visual performance abilities on the one hand and analyzing in-depth accident involvement on the other hand. Thus, this effort constitutes a methodological improvement with respect to the last two of the three confounding factors above—more visual functions studied and better data on driving performance. The following is a brief description of this approach (a more detailed description of the instruments and procedure is provided in Section 2.1.3).

The visual performance of accident-involved drivers was tested via a recently developed driver vision screening instrument specially designed by Systems Development Corporation and built under a Department of Transportation contract (Contract No. DOT-HS-009-1-009). This device, while only a prototype, may serve as a model for a new generation of vision screening devices planned to replace those now in use by many states in processing driver license applicants. It is the product of an extensive research and evaluation program conducted by Burg (1967, 1968) and Henderson & Burg (1973, 1974) that identified a number of visual capacities and skills thought to be crucial for safe accomplishment of the driving task. A repertoire of tests capable of measuring those visual parameters was developed. This repertoire was then incorporated into a single testing unit known as the "integrated driver vision test device," to be referred to here as the Dynamic Vision Test (DVT). Among the visual functions tested by the DVT are static and dynamic foveal acuity, static peripheral acuity, foveal and peripheral acuity for lateral movement and movement in-depth, and foveal acuity in the presence of spot and veiling glare. Initial research utilizing the DVT by Henderson and Burg (1974), showed that poor performance on several of the vision tests was related to poor driving record. Where such statistically significant relationships were obtained, the magnitude of the relationship was relatively small, and in many cases counterintuitive; i.e., **poor** visual performance was associated with **good** record. These counterintuitive results were attributed to the confounding of the vision and driving record variables with age; and the generally weak relationships may be attributed to limitations in Henderson & Burg's (1974) data base, i.e., driving records.

In the present research, driving performance was evaluated on the basis of an analysis of accident involvement behavior by a multi-disciplinary research team. This analysis yielded the types of driving errors that resulted in the accident. While accident involvement is an indirect measure of driving performance, the methodological approach is unique (and is an improvement over previous procedures) in that (1) visual performance is measured in close temporal proximity to the accident (within a week) and (2) the quality of the accident-describing data is much better than typically afforded from police and insurance files.

2.1.2 Objectives

The specific objectives of this research were: to test the reliability and practicality of the DVT as a screening device and to identify the validity of the DVT scores as factors related to driving performance

Reliability—to be a reliable and useful screening device the final DVT battery must meet several criteria:

1. The scores obtained for a given individual should be stable across short periods of time. This measure of consistency is typically obtained by calculating test-retest reliability.
   An initial assessment of the DVT's reliability was made by Henderson & Burg (1974). For the various visual performance measures, the test-retest correlations ranged from $r = .08$ to $r = .75$ for a group of 28 SDC employees; from $r = -.04$ to $r = .70$ for high school students; and from $r = .12$ to $r = 1.00$ for 99 paid volunteers with a revised battery consisting of a smaller number of visual-function tests, and more trials per test. The importance of a test's reliability becomes obvious when one considers the fact that the upper limit of a test's validity (the ultimate criteria for its usefulness) equals the square of its reliability (in terms of correlation value). Thus, it is felt that prior to the assessment of the relationship between visual and driving performance—a measure of validity—some measure of reliability must be obtained.
2. The visual performance score should be relatively insensitive to practice and familiarity with the DVT; i.e., learning should be minimal or a method to correct for it should be applied. Thus, in addition to the test-retest correlations, an absolute score difference between the two testing sessions should also be calculated.
3. The test score should not be examiner-specific; i.e., for a given individual the score should be the same with different administrators and scorers. For

this reason two different people were used for both test sessions.

4. Due to practical limitations the final DVT battery should be relatively short. Presently the DVT requires approximately 30-40 minutes to administer and score. A factor analysis should be applied to determine which of the tests measure similar capacities so that some of the redundant tests may be dropped.

Validity—the usefulness of the DVT for licensing purposes depends on its relationship to driving performance. Presently the battery can be said to have content validity since its construction was based on driving task analysis by experts (Burg, 1968). The specific objectives of the validation effort are to find whether:

1. Poor performance on any of the DVT measures is related to accident involvement.
2. There is a relationship between DVT performance and the human error that caused the accident (as assessed by the accident investigation team).
3. There is a relationship between specific accident configurations and visual deficiencies; e.g., do people involved in right angle accidents have poorer peripheral and dynamic acuity?

2.1.3 Method

2.1.3.1 The Vision Test

The dynamic vision tester (DVT) is a prototype of an experimental battery that incorporates visual tests which are **theoretically** relevant to the driving task. The DVT, developed by Henderson & Burg (1974), consists of 12 tests of binocular visual acuity, and presently requires 30-40 minutes to administer and score. A brief description of each of the tests and its rationale is given below. For a more technical and detailed description, see Henderson & Burg (1974).

In all tests except those for movement threshold, the target is a Landolt ring (a circle with a break in it) with the break at any one of the four positions: top, bottom, right or left. The subject's task is to identify the location of the break. In the movement threshold task the target is a filled circle, and the subject's task is to identify the direction of the movement. In all tests the target brightness is greater than that of the background (i.e., negative contrast). The tests are administered in the same order as described below.

1. **Static acuity**—Normal illumination (SA-N). Presently, the basic visual ability to resolve details of stationary objects projected on the fovea is the primary acuity criterion for passing or failing license applicants. Subjects are presented with Landolt rings in decreasing size. The range is from the Snellen equivalent of 20/175 to 20/20. Figure/ground contrast is .99[1]. The

[1] Contrast = $\frac{\text{Background fL} - \text{Target fL}}{\text{Background fL}}$

acuity score is in Snellen numbers of 175 to 20, with 20 being the best possible score.

2. **Central Angular Movement (CAM)**-Since most of the time the driver is moving, a state of relative movement exists between him and his surroundings. Thus, stationary objects adjacent to or on the road "achieve" angular movement just before he passes them, while opposing and passing traffic is perceived to be moving in depth (toward or away from the driver) once they are more than several hundred feet away. To measure angular movement threshold, a 2° circle of light moves across the subject's field of view from either right-to-left or left-to-right, for a constant one second duration. On each trial, in a sequence of 10, the extent of movement is decreased. The range decreases from 256′ to 2′ of arc. The entire test consists of two such sequences making up a total of twenty trials. The test yields two scores: threshold of movement detection and total number of trials correctly identified.

3. **Central Movement in Depth (CMD)**-This test is relevant to the ability to perceive a change in distance between the driver and cars ahead of him. The test is similar to CAM except that the target varies in size, creating a sense of movement in depth. The range of movement is from 190′ of arc to 2′ of arc from the initial size of 2°. The subject's task is to identify whether the circle is getting larger or smaller. The test yields three scores: two thresholds for increasing and decreasing circle size, and total correct out of twenty trials.

4. **Peripheral Angular Movement (PAM)**-The test is designed to test the driver's ability to identify movement in his peripheral visual field. The ability to perceive movement in the peripheral field is crucial in many situations where the driver is directing his gaze in one direction, e.g., straight ahead, but must be responsive to events elsewhere, such as a car pulling out from an alley, a child jumping into the road, etc. The task is to identify the direction of movement as in CAM while the eyes are fixated on a lateral point 45° away from the moving disc. To insure that the subject does not shift his fixation, the fixation point "jumps" on a random periodic basis and he must respond to these jumps by pressing a button, thus this task actually is a **time sharing** task between peripheral and foveal vision. The scores on this test are: threshold, and total number of movements correctly identified.

5. **Peripheral Movement in Depth (PMD)**-The rationale and procedures are similar to PAM except that the nature of the peripheral movement is as in CMD. The scores are: thresholds and total trials correct.

4-5. **Tone Count (TC)**-In tests 4 and 5, whenever the subject fails to press the button immediately following the jump of the fixation dot a high frequency tone is sounded. Thus, the total number of tones is a measure of ability to perform the secondary task, i.e., to foveally fixate and attend to the jumps. The best score here is 40, since the total number of tones is 40.

6. **Static Acuity-Low Level Illumination (SA-LL)**-In order to provide a measure of acuity under low level light conditions—such as dusk or night—the SA test described above is administered with Landolt ring brightness reduced from 2.3 fL to .02 fL, yielding a contrast of .05. The final score is the subject's threshold.

7. **Field of View (FV)**-This test is designed to measure the subject's ability to detect a change in brightness in his peripheral field. While the subject fixates on a central point a sequence of

small Landolt rings are flashed for a duration of .5 seconds at various angles away from his fixation. The range of angles is from 60° to 90° to either side. The subject's task is to state whether the light on each trial was to the right or to the left of the fixation spot. The ability measured here is different from that in PAM and PMD since it does not require that S be attentive to any events in his foveal field, and thus no time sharing is involved. Three scores are derived from the test: threshold angle of detection to the right, threshold angle to the left, and total number of trials correct out of 14.

8. **Detection-Acquisition-Identification of peripheral patterns (DAI-90)**-The test is assumed to measure S's overall visual search ability since it requires that he first **detect** a peripheral target, consisting of a Landolt ring, move his eyes (and head if necessary) to **acquire** (or fixate) it and then **identify** the position of the break. The targets appear in a random sequence anywhere from 60° to 90° away from the central fixation point. Target duration is .8 seconds and S's task is to identify the position of the break. The test yields three scores: threshold angles of identification in the right and left fields and total trials correct out of 14

9. **Detection-Acquisition-Identification of para-foveal patterns (DAI-35)**-The test is similar to DAI-90 except that the relevant target field is now 10° to 35° away from the central fixation, and its duration is only .5 seconds. The S's task and scoring procedures are the same. In terms of visual requirements, the task is different since the resolving power in the para-foveal region is sufficiently high so that no head movements are required at all and at the smaller angles no eye movements are required; and hence the motor mechanisms involved in the task are different. Almost all of the driver's traffic information is within the para-foveal range.

10. **Dynamic Visual Acuity (DVA)**-Critical information such as signs are typically in relative movement to the moving driver and hence, perhaps more important than static acuity, is dynamic acuity or the ability to resolve information from a moving pattern. The ability tested here is different since it is time dependent. In the test a Landolt ring moves across a 30° arc in the lateral plane at the rate of 60′/second. On each trial the ring size is decreased. The total range is from the Snellen equivalent of 20/200 to 20/30. The final score is the acuity threshold.

11. **Static Acuity with Veiling Glare (SA-VG)**-Under conditions of veiling glare, such as direct sunlight or strong reflections from the windshield and dashboard, figure/ground contrast is reduced and ability to resolve detail is impaired. In this test the glare is produced by flooding the visual field with a uniform white light of 40.25 fL resulting in a contrast of .05. The S's score reflects his Snellen threshold.

12. **Static Acuity with Spot Glare (SA-SG)**-The analogous driving situation is one where the glare source is a low lighting fixture or the headlights of an oncoming car. In the test the two glare sources are located on the two sides of the Landolt rings. The brightness level of each bulb is 40,000 fL. The test procedure and scoring are identical to the other three SA tests.

2.1.3.2 Subjects

Three hundred and fifty-eight licensed drivers were administered the DVT. The drivers were sampled out of two populations:

1. The Accident group consisted of 209 out of the 351 drivers who were actually involved in automobile accidents that were investigated by the in-depth (Level C) multidisciplinary teams during the period that the DVT was available for this project. Sampling was based on availability.
2. The Control group consisted of 149 drivers not involved in investigated accidents, representatively sampled by age and sex from the general driving population in Monroe County. For assessment of test-retest reliability 51 drivers from this control group took the DVT twice.

The degree to which the two groups are representative of their population in terms of age is illustrated in Table 2-1. For the accident group, in the sample of those taking the vision test the 35-54 year olds are underrepresented. (This bias is probably due to the fact that 35-54 year old people have less time to contribute, while the 16-24 year-old group typically has more time during regular working hours). The "reliability" drivers are highly representative of their population since the sampling was stratified by age and sex categories.

2.1.3.3 Driving Data

For all drivers the following information was obtained through questionnaires and clinical interviews:

Sex	
Age	
Exposure	— miles driven in the past year
Aided vision	— whether or not they wear glasses or contact lenses when driving
License restrictions	
Accident history	— number of accidents in the past 5 and 1 year periods and whether at fault or not
Traffic violations history	— number of and types of violations
Driving knowledge	— based on a forced-choice driver knowledge questionnaire (described in section 2.2 below)

In addition to the above information available for all drivers, the following information was obtained from all the accident group drivers:

- Detailed biographical information, and accident relevant information obtained in an hour long in-depth interview.
- Accident cause analysis which resulted in assigning each driver relevant (if any) human factors that might have caused the accident.

Table 2-1

The Age Distributions of All Groups of Drivers Administered the DVT.

	ACCIDENT GROUP				CONTROL GROUP			
Age	All In-Depth Drivers		Vision-Tested In-Depth Drivers		All Control Drivers		Reliability Drivers	
	N	%	N	%	N	%	N	%
16-19	67	19.2	53	25.4	23	15.4	8	15.7
20-24	112	31.8	75	25.9	26	24.2	12	23.5
25-34	82	23.3	47	22.5	39	26.2	12	25.5
35-44	36	10.4	16	7.7	19	12.8	7	13.7
45-54	40	11.3	11	5.3	15	10.1	6	11.8
55-64	5	1.6	3	1.4	11	7.4	3	5.9
65+	9	2.5	4	1.9	6	4.0	2	3.9
Total	351	100.0	209	100.0	149	100.0	51	100.0

Finally, each of the drivers was classified as belonging to one of three categories, based on his/her accident history in the last three years:

- Never been involved in accident.
- Involved but not at fault.
- Involved and at fault.

2.1.4 Results and Discussion

2.1.4.1 Introduction

Before any of the results can be discussed, it should be noted that several subjects failed to reach even the highest threshold level on some of the tests. Since a score of "0" is most inappropriate for all the tests (for the static and movement acuity tests "0" implies "perfect" performance), extrapolated scores—of one additional level beyond the poorest performance—were given on these occasions. Thus, complete failure is given a threshold value of 200 for the static acuity tests (SA-N, SA-LL, SA-SG, SA-VG); a value of 225 for the DVA; and a value of 512 for the movement acuity tests (CAM, CMD, PAM, PMD).

Statistical analyses were performed in parallel on two different scales. In the first scale the actual raw scores obtained by the drivers on each of the driving tests were used as the dependent measures. For all the tests these scores are clearly defined as points on a ratio scale on a physical continuum. However, these scores are probably not appropriate for a psychophysical scale; i.e., an interval scale defined on a psychophysical continuum. For this reason the second scale was developed.

It has been known for a long time that equal increments on a physical continuum correspond to decreasing increments on a psychophysical continuum. For example, an increase in the intensity of an illuminated sign from 1 to 2 foot candles (ft-c) is perceived as a much greater change than a change from 2 ft-c to 3 ft-c. A generally accepted relationship between the physical and psychophysical is a logarithmic function[2] originally proposed by Fechner in 1860 in which:

$S = a \log M + b$

where: S is the magnitude of the sensation on a psychophysical scale
M is the magnitude of the stimulus on a physical scale
a, b are constants which differ for individuals and sensations.

To illustrate, a case in point is the change from a score of 2 to 4 on the movement acuity tests (CAM, CMD, PAM, PMD). On a physical scale such a change is minute relative to a change from 128 to 256 but on a psychophysical scale they may be identical! Obviously, statistical analyses on the two scales will yield grossly different results, since the physical scale (spuriously?) gives more weight at one end of the continuum (256) than at the other end (2).

In the present study the constants in the logarithmic functions were arbitrarily determined in order to yield a numerically convenient set of points to correspond to the physically defined points. The transformation $S = 3.322 \log M$ was used for the movement acuity tests (CAM, CMD, PAM, PMD), and the function $S = 3.322 \log M - 3.322$ was used for the static acuity tests (SA-N, SA-LL, SA-SG, SA-VG) and the DVA. These functions are "convenient" since they yield a score of "1" for the highest acuity level tested and an increment of 1 for every doubling of the physical magnitude. The corresponding points on the physical and psychophysical scales are represented in Table 2-2. No transformations were needed for "total" scores and thresholds for the FV and DAI tests.

2.1.4.2 Test-Retest Reliability

Four of the vision tests were excluded from the retest session in order to increase the subject's cooperation by significantly shortening the test session duration. It was hoped that this would eliminate the fatigue and stress involved in the retest (see Henderson & Burg, 1974, p. III-14), and thus insure that motivation would remain high in both sessions. The tests excluded were those judged by Henderson & Burg (1974) to be the less predictive of accident involvement: DAI-90, PAM, and PMD; and SA-VG, which was previously found to have a high correlation (.80) with spot glare, and was thus assumed to be redundant.

Test-retest correlations and standard error estimates for the 15 measures derived out of the remaining eight tests are presented in Table 2-3, alongside the test-retest correlations obtained

[2] An alternative relationship, $S = M^b$ has been suggested by Stevens (1957).

Table 2-2

Threshold Levels on the Physical and Psychophysical Scales for All Tests of Static and Movement Acuity

Static Acuity and DVA		Movement Acuity	
Physical	Psychophysical	Physical	Psychophysical
20	1.00	2	1.00
25	1.32	4	2.00
30	1.58	6	2.58
35	1.81	8	3.00
40	2.00	12	3.58
50	2.32	16	4.00
60	2.59	32	5.00
70	2.81	64	6.00
85	3.09	128	7.00
100	3.32	190	7.57
125	3.64	256	8.00
150	3.91	512	9.00
175	4.13		
200	4.32		
225	4.49		

by Henderson & Burg (1974) in two independent SDC studies. Scatter plots for each of the tests on the physical scales are presented in Appendix A of this volume. These plots are very useful in determining why some tests yield a low or high reliability estimate.

In general, performance on the static acuity tests—for either stationary or dynamic targets—is more stable than performance on movement acuity and field of vision tests. SA-N and SA-SG are the only two tests that yielded high test-retest correlations in both the present and the SDC studies. Total number of trials correct appears to be a more reliable measure than the threshold level (for all tests except CAM), but this may change when a higher reliability is obtained (as in SDC-2). Compared with the reliability estimates obtained by SDC, the present results are more similar to the SDC-1 test than the SDC-2. Procedurally too, the tests here were more similar to SDC-1 in terms of control conditions and number of trials per test. The higher correlations obtained in SDC-2 are attributed to higher level of motivation and a greater number of stimuli or trials per test. However the exact changes that yielded these higher correlations are not specified by Henderson & Burg (1974).

Comparisons between the correlations obtained with the two scales reveal that correlations are either the same or slightly lower when the performance is scored on the psychophysical scale. On the three tests in which the correlations are lower—CAM, DVA and SA-SG—the higher reliability estimates with the physical scale can be attributed to the inflated effect of a

Table 2-3

Test-Retest Correlations and Standard Errors Obtained by IRPS with Corresponding Correlations Obtained by SDC

Test	SDC-1 (N=23) r	SDC-2 (N=99) r	IRPS (N=51) Physical Scale r	Physical Scale S.E.	Psychophysical Scale r	Psychophysical Scale S.E.
SA-N: Threshold	.69*	1.00*	.75*	1.73	.75*	.10
CAM: Total	.75*	.29*	.31	1.70		—
Threshold	.56*	.51*	.68*	3.56	.34*	.86
CMD: Total	.70*	.33*	.40*	1.62	—	—
Small-Threshold	.73*	.50*	−.03	3.38	.05	.95
Large-Threshold	.53	.12	−.11	6.33	−.04	1.06
SA-LL: Threshold	.71*	.75*	.54*	33.05	.56*	.45
FV: Total	.46	.62*	.63*	1.55	—	—
Left-Threshold	.64* }	.37*+	.51*	5.23	—	—
Right-Threshold	.57* }		.46*	3.94	—	—
DAI-35: Total	.24	.69* √	.39*	1.70	—	—
Left-Threshold	.17 } √	.89*+√	.14	2.93	—	—
Right-Threshold	.20 } √		.04	3.11	—	—
DVA: Threshold	.08	—	.88*	12.40	.61*	.41
SA-SG: Threshold	.51	.85*	.92*	12.06	.81*	.41

* Significant at $p \leq .01$
\+ Combined Extent
√ DAI - 40

single (legally blind) subject. In addition to providing a more realistic reliability estimate, the psychophysical scale provides a more meaningful measure of standard error. Thus the general decrement in acuity on the SA-LL test relative to DVA and SA-SG, resulted in a spuriously higher S.E. estimate on the physical scale (33.05 vs. 12.40 and 12.06), but not on the psychophysical scale (.45 vs. .41 and .41).

2.1.4.3 Additional Comments on the Individual Tests

SA-N

Performance on this most basic acuity function is relatively (compared to the rest of the tests) high, but still accounts for no more than 56% of the variance in the performance ($r^2 = .56$). The corresponding scatter plot (Appendix A) suggests that this estimate is spuriously low due to a ceiling effect—i.e., even though only one **S** exhibits a marked change (50 → 25) 84% of the **Ss** score on both tests either 20 or 25. The reliability estimate is the same when the psychophysical scale is used since the poorest score was 50.

CAM

Unlike the static and dynamic acuity tests where the probability of a correct guess is .25, the probability of a correct guess here is .5. Inevitably this increases the error in determining a correct threshold. The scatter diagrams (Appendix A) indicate that the low correlations for both total score and threshold are real and are probably not due to a limited range (either ceiling or floor) effect. One method to increase the reliability of this test may be to define the movement as both up or down and right or left, and thus lower guess level to .25. Apparently an increase in the number of trials (SDC-2) does not yield a more stable score on either measure. Experience in scoring this test indicates that this test lacks a good scoring criterion. Some examples that illustrate the difficulty are given in Appendix B.

CMD

This test was the least reliable here, and in the SDC-2 research. While a ceiling effect may be a contributing factor for the small-threshold score (Appendix A), this is not the case for the large-threshold or total score. The apparent shortcomings of this test are two: first, the number of trials for the determination of each threshold is half of that available for the CAM; secondly, as a result, given a true threshold, the probability of a shift in estimated threshold by one level up or down is .5. This may explain the much higher correlation obtained for the total score than for the threshold estimate (admittedly, this does **not** account for the result patterns obtained by SDC).

SA-LL

Despite the fact that procedurally this test is as robust as the other two SA tests, its test-retest reliability was significantly lower than the other two. The scatter diagram reflects this low correlation by showing neither consistent linear or non-linear trend, nor limited range effects. The correlation coefficient is only slightly higher with the psychophysical scale since the effect of three Ss who had large test-retest differences is offset by three Ss who scored poorly (> 150) on both sessions (Appendix A). The most probable explanation for this relatively low correlation is in the shortcoming of the retest battery. In the test session following the SA-N test the target luminance is lowered for the CAM, CMD, PAM, PMD and SA-LL. By eliminating the PAM and PMD tests from the retest session, the dark adaptation time available to Ss for the SA-LL test was reduced from approximately 8 minutes to 4 minutes. This difference is critical because of the complex nature of the dark adaptation curve (see Cornsweet, 1970, for details). For our present purposes it is sufficient to assume that during the retest session acuity was measured at different points on the dark adaptation curve. Thus the low correlation is as much a reflection on individual differences in the temporal dark adaptation function as it is a measure of performance under low levels of illumination with full adaptation. Note that the levels obtained in both SDC studies are higher and similar to the level obtained here for the SA-N. In both SDC tests the interval between the SA-N and SA-LL during which Ss could dark-adapt was longer than in the present retest.

FV

Although it appears as though the test is not very reliable, an inspection of the scatter diagrams in Appendix A reveals that while the reliability of the total score is easily reflected in the distribution of the scores, the smaller threshold correlations are due to a limited range effect: for both right and left field thresholds, 94% of the Ss achieved a score of 80 or 90 on both the test and the retest.

DAI-35

Inspection of the correlations along with the data plotted in Appendix A reflect a pattern similar to that observed for FV—the reliability estimate for the total score appears to reflect the distribution of scores, while the low estimates for the left and right field thresholds are due to a limited range effect. For both right and left field 90% of the Ss scored 30 or 35 on both tests.

DVA

This test, assumed to reflect a critical visual requirement for safe driving (Henderson & Burg, 1974, p. II-61) yielded a low reliability on the first SDC check for reliability, and was altogether omitted from the second (SDC-2) test. In the IRPS study this test turned out to be the second most reliable with a test-retest correlation of 88. Some of the problems encountered in the preliminary analysis may shed light on the low reliability obtained by SDC. First, a scoring error was found in which a complete failure was scored as zero rather than 225. Second, here too a significant proportion (53%) scored 30 or 40 in the two sessions, and the high correlation is due mostly to one deviating S who failed the first test and scored 200 on the retest. By excluding this S, the test-retest correlation for the remaining 50 Ss drops down to $r = .61$. The effect of this deviating S is also reduced when the scores are transformed to the psychophysical scale ($r = .61$).

SA-SG

The correlation obtained for this measure was the highest of all tests ($r = .92$), definitely greater than the correlation obtained for SA-N or SA-LL. Several reasons may account for this: first, the test is the last in the series and thus Ss are task-familiar by the time they perform it, whereas the SA-N test is the first in the series. Second, unlike the problems encountered because of the lengthy dark adaptation process involved in SA-LL, light adaptation is much faster and it is relatively safe to assume that by the time the threshold region is reached Ss are fully light adapted. Third, the degradation in performance almost eliminates the limited range effect encountered in the SA-N (compare plots in Appendix A).

2.1.4.4 Additional Measures of Stability

Three additional analyses were conducted to provide indicators of stability. In addition to overall test-retest reliability it was sought to determine the effects of test administrators, the effects of time of day at which the test is taken and the extent—if any—of learning effects.

Administrator Effect

Five different testers were trained in test administration and scoring. An analysis of variance test with the administrator as the independent variable and test score as the dependent variable revealed no significant ($p \geq .05$) administrator effect on any of the vision tests administered in the test (first) session.

Constancy of Time-of-Day and Administrator

If test performance is stable and the test is sufficiently objective in its administration and scoring procedure, then test-retest correlations should not be significantly affected by a change in the time-of-day and of the administrator between the two testing sessions. To test for this, partial correlations were conducted on the vision scores partialling out in one case administrator (same vs. different) and in another case time-of-day (same vs. different). The results are presented in Table 2-4. A comparison of the partial correlation columns with the original (zero partial) correlations reveals that a change in the administrator and time-of-day has no statistically or practically significant effect on any of the resulting scores.

Table 2-4

Partial Test-Retest Correlations Controlling for Operator and Time of Day. (N = 51) (Based on raw scores—i.e., physical continuum)

Test	Controlling for Operator	Controlling for Time of Day	Zero-Order Partials
SA-N: Threshold	.75*	.75*	.75*
CAM: Total	.33	.31	.31
Threshold	.68*	.68*	.68*
CMD: Total	.41*	.40*	.40*
Small-Threshold	-.04	-.02	-.03
Large-Threshold	-.11	-.10	-.11
SA-LL: Threshold	.53*	.54*	.54*
FV: Total	.64*	.63*	.63*
L-Threshold	.53*	.52*	.51*
R-Threshold	.47*	.47*	.46*
DAI-35: Total	.41*	.38*	.39*
L-Threshold	.13	.14	.14
R-Threshold	.03	.05	.04
DVA: Threshold	.88	.88	.88
SA-SG: Threshold	.92*	.92*	.92*

* Significant at $p \leq .01$

Learning

A valid test of visual performance should exhibit minimal learning effects, or improvement, as a result of previous experience with the test. T tests were conducted to compare performance on the test and retest sessions in each of the vision tests. Mean performance levels and t value for the difference is given in Table 2-5. As is immediately apparent, all the changes in performance (except on SA-LL) indicate improvement in the retest session. However, this change is significant for only four of the 15 measures. Three of these four are scores obtained from the first two tests indicating perhaps lack of understanding of the

Table 2-5

Mean Performance Scores on the Test and Retest Sessions, and T Values for the Difference Between the Two

Test	Test	Retest	Diff.	T Value
SA-N: Threshold	22.84	20.88	-1.96	-2.80*
CAM: Total†	15.73	16.92	1.20	3.27*
Threshold	12.00	5.37	-6.62	-2.67*
CMD: Total†	17.25	17.55	0.30	1.00
Small-Threshold	4.98	4.00	-0.98	-0.73
Large-Threshold	9.88	7.92	-1.96	-1.13
SA-LL: Threshold	97.06	101.86	4.80	.91
FV: Total†	12.43	12.80	0.37	1.53
Left-Threshold†	87.06	87.25	0.20	.24
Right-Threshold†	86.67	87.45	0.78	.94
DAI-35: Total†	12.35	12.69	0.33	1.10
Left-Threshold†	33.24	33.82	0.59	1.03
Right-Threshold†	32.55	33.43	0.88	1.22
DVA: Threshold	43.62	42.16	-1.47	-0.77
SA-SG: Threshold	45.20	37.30	-7.90	-4.56*

† Low score = poor performance; all other measures, high score = poor performance

* Significant at $p < .01$

task in the original test session resulting in spuriously low scores for this initial session. This may be especially true with the CAM test where initially subjects tend to respond "no movement" rather than guess small angular movements. Increased prodding on the part of the administrator to guess in the first two tests might eliminate the learning effect as well as increase the test-retest reliability. The large improvement in static acuity with spot glare (SA-SG) should be further investigated especially in light of the high reliability of this test. Presently it can only be hypothesized that increased motivation at the end of the retest session (due to shorter retest version), and a greater tendency to guess may be responsible for the improvement.

One interesting finding is the large but non-significant decrement in static acuity under low levels of illumination. This result supports the "dark adaptation" argument presented above. Because adaptation time is less in the retest, mean performance level is poorer; but due to large individual differences in the temporal dark adaptation process the change is not statistically significant.

2.1.4.5 Practicality Assessments

Presently, the administration of a typical vision test used for licensing purposes consumes less than one minute of the total test duration. Obviously any future vision tests will also be judged in terms of their brevity. The DVT used in the present study requires 30-40 minutes of the examiner's and examinee's time. It is therefore important to see which tests can be eliminated because they are either unimportant to driving, or redundant with other tests. This section investigates only the latter (i.e., redundancy), while the next section addresses the "importance" question.

Pearson correlations were conducted between all the test score pairs and are presented in Table 2-6. The correlations are based on the total sample of both accident and control groups having no missing data and not included in the reliability analysis (N = 290). Four points may be noted here:

1. For a given vision test the highest correlations are typically obtained for different measures obtained from the same test (note correlations enclosed in triangles). The only exceptions are the movement detection tests (CAM, CMD, PMD) which are probably the least reliable (Table 2-3).
2. The four measures of static acuity—SA-N, SA-LL, SA-VG, SA-SG—correlate higher among themselves than with any other variable.
3. The tone count, which was time-shared with the two peripheral movement tasks, is almost unrelated to the five PAM and PMD performance measures. Similar negligible correlations were obtained by Henderson and Burg (1974, p. F5). This independence suggests that the tone count and vision scores may be treated independently (rather than as covariates), as they are in the "measures of stability" discussion, above.

Table 2-6

Inter-Test Correlations[1] for the DVT

Variable	FV Total† 1	FV Left† 2	FV Right† 3	DAI-90† Total 4	DAI-90† Left 5	DAI-90† Right 6	DAI-35† Total 7	DAI-35† Left 8	DAI-35† Right 9
1	1.00	.81	.83	.53	.46	.40	.30	.24	.24
2		1.00	.69	.43	.42	.33	.22	.17	.19
3			1.00	.43	.39	.32	.30	.28	.25
4				1.00	.81	.83	.45	.29	.31
5					1.00	.66	.38	.26	.26
6						1.00	.37	.23	.27
7							1.00	.64	.72
8								1.00	.47
9									1.00

Variable	SA-N 10	SA-LL 11	SA-VG 12	SA-SG 13	CAM† Total 14	CAM Thresh. 15	CMD† Total 16	CMD Small 17	CMD Large 18
1	-.48	-.23	-.36	-.46	.24	-.38	.19	-.29	-.32
2	-.44	-.21	-.31	-.39	.18	-.32	.16	-.22	-.22
3	-.52	-.25	-.34	-.43	.29	-.49	.18	-.33	-.36
4	-.32	-.37	-.40	-.45	.26	-.21	.15	-.15	-.28
5	-.26	-.31	-.32	-.36	.17	-.18	.21	-.15	-.28
6	-.20	-.29	-.26	-.32	.20	-.13	.07	-.11	-.21
7	-.39	-.47	-.46	-.49	.28	-.35	.20	-.28	-.32
8	-.35	-.27	-.34	-.35	.29	-.44	.10	-.38	-.31
9	-.15	-.38	-.34	-.29	.14	-.10	.11	-.09	-.13
10	1.00	-.33	.56	.69	-.37	.73	-.21	.53	.46
11		1.00	.61	.53	-.23	.21	-.24	.19	.18
12			1.00	.78	-.26	.36	-.20	.25	.28
13				1.00	-.31	.48	-.25	.32	.34
14					1.00	-.56	.28	-.37	-.34
15						1.00	-.24	.75	.61
16							1.00	-.32	-.38
17								1.00	.51
18									1.00

Table 2-6 continued

Variable	PAM† Total 19	PAM Thresh. 20	PMD† Total 21	PMD Small 22	PMD Large 23	Tone† Count 24	DVA 25
1	.24	-.39	.18	-.12	-.25	.34	-.32
2	.27	-.39	.16	-.17	-.25	.29	-.31
3	.23	-.40	.19	-.16	-.28	.34	-.34
4	.23	-.20	.11	-.08	-.20	.43	-.30
5	.15	-.11	.11	-.03	-.20	.42	-.28
6	.19	-.16	.03	-.03	-.16	.41	-.18
7	.19	-.15	.25	-.07	-.20	.26	-.50
8	-.02	-.01	.12	.06	-.09	.14	-.32
9	.09	-.14	.23	-.08	-.16	.14	-.32
10	-.29	.39	-.38	.27	.45	-.34	.53
11	-.16	.23	-.15	.06	.18	-.17	.39
12	-.20	.28	-.22	.08	.30	-.17	.44
13	-.36	.44	-.34	.22	.40	-.25	.58
14	.35	-.22	.21	.00	-.27	.29	-.27
15	-.23	.29	-.22	.07	.34	-.28	.54
16	.25	-.18	.22	-.08	-.25	.15	-.24
17	-.11	.06	-.20	.02	.36	-.20	.40
18	-.24	.16	- 16	-.01	.36	-.26	.38
19	1.00	-.65	.35	-.20	-.30	.30	-.34
20		1.00	-.33	.32	.34	-.31	.41
21			1.00	-.61	-.57	.20	-.38
22				1.00	.30	-.11	.23
23					1.00	-.21	.40
24						1.00	-.24
25							1.00

† Low score = poor performance; all other measures, high score = poor performance

[1] N = 290; $p \leq .05 = r \geq .11$; $p \leq .01 = r \geq .15$

4. The DVA score correlates most highly with the static acuity measures. Theoretically the latter can be considered as a special case of the former. The relatively high correlations of DVA with most movement detection thresholds (CAM, CMD-Small, PAM, PMD-Large) suggest that these are additional visual capacities that are involved in the DVA task.

A factor analysis with a varimax rotation was conducted on the obtained correlation matrix. The variable loadings on the first seven factors—accounting for 70 percent of the variance—are presented in Table 2-7. The factor loadings support the observations made above and can be summarized as follows:

1. For vision tests yielding more than one score, all the different scores load

Table 2-7

Factor Loadings of Each of the DVT Measures on the Seven Rotated Factors (N = 290) (Variance Accounted for = 69.6%)

Variable / Factor	I	II	III	IV	V	VI	VII
1. FV-Total†	-.18	.28	.89	.10	-.08	-.14	-.09
2. FV-Left†	-.13	.21	.76	.06	-.08	-.14	-.16
3. FV-Right†	-.32	.19	.75	.12	-.08	-.12	-.13
4. DAI-90-Total†	-.11	.92	.21	.17	-.04	-.20	-.07
5. DAI-90-Left†	-.11	.77	.21	.16	-.05	-.14	.01
6. DAI-90-Right†	-.07	.81	.14	.13	.02	-.11	-.10
7. DAI-35-Total†	-.24	.23	.06	.82	-.06	-.27	-.05
8. DAI-35-Left†	-.37	.13	.07	.59	.05	-.16	.10
9. DAI-35-Right†	.01	.14	.11	.78	-.10	-.14	-.07
10. SA-N	.60	-.07	-.27	-.04	.25	.46	.13
11. SA-LL	.08	-.21	-.04	-.29	.04	.55	.10
12. SA-VG	.18	-.14	-.15	-.19	.10	.80	.04
13. SA-SG	.29	-.16	-.21	-.15	.20	.76	.20
14. CAM-Total†	-.53	.17	.03	.10	-.09	-.04	-.20
15. CAM-Thresh.	.94	-.00	-.17	-.06	.05	.16	.13
16. CMD-Total†	-.21	.07	.08	.11	-.17	-.10	-.11
17. CMD-Small	.75	-.00	-.14	-.08	.09	.09	-.10
18. CMD-Large	.58	-.16	-.13	-.13	.05	.10	.06
19. PAM-Total†	-.13	.14	.07	.04	-.25	-.09	-.65
20. PAM-Thresh.	.11	-.03	-.26	.01	.22	.18	.82
21. PMD-Total†	-.14	-.00	.04	.14	-.94	-.07	-.11
22. PMD-Small	-.00	-.02	-.05	.03	.61	.05	.16
23. PMD-Large	.26	-.08	-.10	-.03	.53	.19	.14
24. Tone Count†	-.21	.34	.17	.06	-.14	-.04	-.23
25. DVA	-.41	-.08	-.10	-.30	.22	.35	.25

† Low score = poor performance; all other measures, high score = poor performance.
Underlining indicates highest loading for each variable.

highest on a single common factor. Thus, some saving in the scoring--if not in the administration of the test--may be gained by using only the more reliable of the different scores obtainable.

2. Most of the tests appear to test functions that are independent of each other, with the exceptions specified below.

3. All static acuity tests may be measuring the same basic capacity; glare (and perhaps low level) causing a more-or-less constant shift in the level of performance on a basically stable function. Additional data might support the argument that only one foveal static acuity test is needed for a driver vision test. Parenthetically, note that SA-N is physically different from SA-LL, SA-VG, and SA-SG only in the figure/ground contrast.

4. Dynamic visual acuity has its highest loading on the same factor (I) as the SA-N and central movement detection tests suggesting that foveal acuity while tracking may be a combination of its static acuity and movement detection threshold. Furthermore, DVA is the only test that loads to a significant extent on all but two (II & III) of the factors. Thus, DVA may be argued to be a complex task that involves a combination of all measures of foveal sensitivity tested by the DVT along with peripheral movement detection ability.

5. The ability to detect movement in the central field may be a single process that determines both CMD-Large and CMD-Small as well as CAM. It is possible however that in a three-dimensional field--where stereopsis is a factor--CMD and CAM would load on different factors.

6. The ability to detect movement in the peripheral field is probably controlled by two independent processes, since PAM and PMD load heavily on two different factors (V and VII).

2.1.4.6 Validity Assessments

Given that the DVT battery -- or a selected sample of the tests -- is sufficiently reliable, the critical remaining question is whether the tests are also valid indicators of driving safety. Before any version of the DVT can be implemented as a screening device, it must be shown to be relevant to the overall licensing screening purpose, i.e., allow only "capable" drivers on the road. In the present study the safety criteria against which DVT performance was evaluated were all a function of the accident involvement-- and accident cause as assessed by the in-depth team--of the TAC in-depth sample of accident-involved drivers.

Validity Assessment—Involvement Analysis

The most intuitively relevant measure of the DVT validity as a screening device is **predictive**

validity: Do poor drivers score differently on the vision tests than good drivers? If the vision tests do not help distinguish between potentially poor drivers and good drivers, or if more straightforward measures (e.g., age) distinguish better, the DVT would be of dubious value in driver selection.

In order to provide information concerning the validity of the DVT as a licensing screening device, vision test scores were compared among three groups of drivers: (1) the Accident-At-Fault Group consisted of 112 accident-involved drivers who had received in-depth accident investigations and were determined to be at fault, (2) the Mixed Group consisted of 80 accident-involved drivers who had received in-depth investigations and were determined to be not at fault, and 28 control drivers who reported having been involved in one or more accidents during the previous two years, and (3) the Control-No-Accident Group consisted of 121 control drivers who had not been involved in any traffic accidents for two years.

Based on the foregoing analysis of the DVT, the more reliable tests were selected for the present intensive study. In addition two non-visual measures, a simple reaction time (SRT) and a choice reaction time (CRT), were included in this analysis. The relevance of reaction time to accidents was demonstrated by Fergenson (1971) who found that accident-involved drivers are slower information processors than non-accident involved drivers. The average scores for each of the selected tests, for each of the three involvement groups, is shown in Table 2-8. Separate one-way analyses of variance were conducted comparing the group means for each test (raw data) and comparing the group means on each test adjusted for age (age adjusted data).

Prior to adjustment for age, significant differences among the raw means were obtained for measures of Field of Vision (FV-Right) and Static Acuity (SA-N, SA-LL). However, on all three measures the performance of the at-fault drivers was significantly **better** than that of the control drivers. The surprising finding that the Accident-At-Fault Group performed better than the other groups on several tests could be due to the confounding of visual performance with age (Henderson & Burg, 1974). In other words, our Accident-At-Fault Group has a disproportionate number of young drivers relative to the other two groups; and there is evidence that young drivers perform better on certain vision tests. Support for this idea is reflected in the fact that differences among the involvement groups were not statistically significant for FV-Right or SA-N when scores were adjusted for the effects of age. In addition, the ANOVAs based on the age adjusted data revealed significant differences among the groups for DVA and CAM-Threshold, favoring the Control-No-Accident Group. However, ANOVAs on the age adjusted data still yielded significant differences among the groups in Static Acuity (SA-LL) favoring the Accident-At-Fault Group. Thus, there is no evidence that the relatively superior performance of the Accident-At-Fault Group on this test is a function of age. Nonetheless, it is unlikely that good static acuity is a direct cause of accident involvement. It is, however, possible that drivers with above average visual acuity may take more risks and thus be involved in more accidents.

The fact that Accident-At-Fault drivers performed better on the relatively simple or uncomplicated tests of Static Acuity but were worse in Dynamic Visual Acuity and Central

Table 2-8

Selected DVT Scores by Involvement Group

Vision Test	Involvement Group: Accident At-Fault (N=112)	Mixed (N=108)	Control No-Accident (N=121)	ANOVA (raw data) F	p	ANOVA (adjusted data) p
FV-Left*	87.9	87.3	87.2	<1.00	ns	ns
FV-Right*	88.5	87.0	86.9	2.20	.10	ns
DAI-90-Left*	75.6	76.5	74.1	1.04	ns	ns
DAI-90-Right*	76.3	73.8	73.6	1.48	ns	ns
DAI-35-Left*	33.4	32.9	33.1	<1.00	ns	ns
DAI-35-Right*	32.8	33.0	32.5	<1.00	ns	ns
SA-N	21.4	26.3	23.9	2.86	.06	ns
SA-LL	86.1	87.5	96.4	2.74	.07	.05†
SA-VG	62.5	67.4	69.3	1.35	ns	ns
CAM-Threshold	9.4	15.5	8.6	1.68	ns	.06††
CMD-Small	4.1	5.7	4.4	1.01	ns	ns
CMD-Large	9.6	13.1	11.8	<1.00	ns	ns
DVA	46.4	46.4	43.0	1.10	ns	.09†††
SRT	.475	.474	.494	1.44	ns	ns
CRT	.573	.552	.547	1.89	ns	ns
(CRT-SRT)	.097	.078	.052	6.34	.002	.09††††

* High score indicates good performance; for other tests low score indicates good performance.

† When adjusted for age, the mean scores for the three groups were 87.7, 85.6 and 96.5.

†† When adjusted for age, the mean scores were 12.5, 14.4 and 6.8 degs.

††† When adjusted for age, the scores were 48.1, 46.1 and 42.4.

†††† When adjusted for age, the scores were .089, .109, and .038 secs.

Angular Movement, relative to Control-No-Accident drivers, suggests that there are differences between the groups in terms of the amount of complexity they are sensitive to. The hypothesis that higher level information processing mechanisms, or personality characteristics, may be involved deserves more careful study in future investigations.

The above comments are limited to the extent that separate ANOVAs do not provide a unified picture of the effectiveness of the DVT, and because in the course of performing 20 F-tests it would be expected that one would reach statistical significance at the .05 level or two at the .10 level by chance alone. In order to provide additional information concerning the validity of the DVT as a unified battery, and to overcome these objections, a discriminant analysis was performed on the age adjusted data.

The discriminant analysis revealed that the main variables in distinguishing the Control-No-Accident Group from the Accident-At-Fault Group were, in order of importance: age, complex RT, and DVA. In other words, the single most important visual function in distinguishing between the three groups was dynamic visual acuity. Although the discriminant function based on this analysis was able to reliably distinguish among the groups ($p < .001$), even with all variables included it would have correctly "predicted" only 62 out of 179 for the Accident-At-Fault Group (17% of the total sample); 37 out of 165 for the Mixed Group (14%), and 88 out of 121 for the Control-No-Accident Group (32%). Using this battery, one can therefore correctly identify 63% of the drivers compared to 36% based on assigning all drivers to the largest group. It appears that the present battery would not provide a sufficiently strong licensing criterion.

The general results with respect to the predictive validity of the DVT are not overly promising when accident involvement is the criterion variable; i.e., these measures do not discriminate very well between drivers who were judged to be "culpable" in an accident, drivers who were involved in at least one accident in a two year period (not necessarily culpable), and drivers who had not been involved in an accident over a two year period. Of all the tests investigated, Dynamic Visual Acuity was the best in distinguishing poor from good drivers, and was the only test in which the control (good) performed significantly better than the at-fault (bad) drivers. Performance on the central angular movement test also distinguished between good and poor drivers but was not very useful when considered with the rest of the battery (discriminant analyses). It is likely that DVA incorporates some of the sensitivity requirements for CAM and therefore the additional value of CAM is minimal. One reason the other tests may not have yielded better discriminability is that they measure very specific visual abilities; our analysis of driver performance in actual accidents may have been too general, or too crude, for these detailed visual variables. Therefore, the following section attempts to use slightly more detailed measures of driving performance.

Validity Assessment—Recognition Error Analysis

A more detailed question concerning the validity of the DVT is whether the occurrence of certain types of driving errors is related to performance on certain vision tests. Since a sizable proportion of at-fault drivers were judged to have committed "recognition errors"—including improper lookout, external distraction, etc.—one important question is whether drivers who commit such errors perform differently on the vision tests from drivers who commit other types of errors (e.g., decision errors) or no errors. Information on this question is provided by comparing the test scores of accident-involved drivers who committed recognition errors (Non-Recognition Error Group, n=42), and accident-involved drivers who committed no errors (No Error Group, n=80).

The same vision tests were selected for this investigation as in the previous section, and the average score on each of the basic vision tests for each error group is shown in Table 2-9. Separate one-way ANOVAs were conducted comparing the group means for each test (raw

Table 2-9

Selected DVT Scores by Error Group

Vision Test	Error Group: Recognition Error (N=70)	Other human error (N=42)	No error (80)	ANOVA F	ANOVA P	Age Adjusted P
FV-L*	87.4	88.8	88.1	1.02	ns	ns
FV-R*	88.2	88.8	88.1	1.00	ns	ns
DAI-90-L*	74.4	77.8	77.4	1.43	ns	.10+
DAI-90-R*	75.7	77.3	74.9	1.00	ns	ns
DAI-35-L*	33.3	33.5	33.6	1.00	ns	ns
DAI-35-R*	32.8	32.9	33.0	1.00	ns	ns
SA-N	21.3	21.5	22.4	1.00	ns	ns
SA-LL	85.6	86.9	80.3	1.00	ns	.02++
SA-VG	62.9	61.9	60.7	1.00	ns	ns
CAM-Th.	9.8	8.6	9.8	1.00	ns	ns
CMD-Sm.	4.0	4.3	4.3	1.00	ns	ns
CMD-Lg.	9.9	9.3	10.8	1.00	ns	ns
DVA	45.0	48.9	45.3	1.00	ns	ns
SRT	.48	.47	.46	1.00	ns	ns
CRT	.58	.56	.56	1.00	ns	ns
CRT-SRT	.10	.09	.09	1.00	ns	ns

* High score indicates good performance, for other tests low score indicates good performance.

+ When adjusted for age effects the means are 73.9, 78.0, and 77.8.

++ When adjusted for age effects the means are 88.3, 89.9, and 74.8.

data) and comparing the group means on each test adjusted for age (age adjusted data).

None of the tests yielded significant differences between the three groups, based on the raw data. When adjusted for age effects, DAI-90-L became marginally significant, and SA-LL became highly significant. In both tests drivers who committed recognition errors performed worse than accident involved drivers who committed no errors at all. Conclusions based on these findings, especially concerning the DAI-90, should again be qualified because of the high likelihood of a single significant effect due to chance alone.

A discriminant analysis conducted on the three groups yielded a significant function but the function was able to accurately assign drivers to their respective category in only 45 percent of the cases compared to the 42 percent accuracy obtainable by assigning all drivers to the largest category.

These results, like those in the previous section, do not provide overwhelming evidence for the validity of the DVT as an accident predictor. The finding that most vision test scores are apparently unrelated to recognition errors was surprising. Since the most common recognition errors committed by the drivers were improper lookout, inattention, and internal and external distraction, these results suggest that most recognition error accidents are the result of the visual information not reaching the sensory system at all (e.g., improper lookout due to looking in the wrong direction) or at a more central level in the information processing system—not processing information that was available to and physically resolvable by the visual system (e.g., inattention due to being preoccupied). In the latter case the driver may be described as a single-channel information processor whose central processing system is temporarily blocked to incoming visual inputs.

Validity Assessment—Collision Type and Specific Visual Impairments

There still remains the possibility that the variety and complexity of accidents make any expectation to find a simple relationship between accidents and vision unrealistic. In this sense it is possible that our classification of error types was not sufficiently sensitive to reflect the effects of visual limitations on driving. An alternative approach, originally taken by Babarik (1968) would be to look at specific accident configurations and hypothesize which visual functions would have been involved. Thus a specific visual impairment such as tunnel vision (i.e., narrow visual field), may be a causal factor in a specific type of collision such as right angle accidents. To test for such a possibility right angle (RA) accidents were singled out. The hypothesis to be tested was that people involved in RA accidents will have a narrower effective peripheral field or, in terms of performance on the DVT, will have lower scores on the FV test and peripheral movement detection tests than drivers involved in rear end (RE) accidents (which can be considered as a control group). Similarly, predictions were made with respect to other tests; specifically, DAI, DVA, peripheral and central movement detection. It was predicted that of the drivers with poor DAI, PAM, and PMD, the proportion involved in RA accidents will be greater than the proportion involved in RE accidents. The reverse prediction was made with respect to CAM and CMD, for which it was expected that poor vision drivers will be involved more in RE accidents than in RA accidents. The relationship of DVA to involvement in the two collision types was also tested (simply because most previous analyses have shown it to be the most relevant vision test) though no a priori prediction was made.

Contingency analysis of each of the above mentioned vision tests as a function of the collision type was conducted, and the significant findings are shown in Table 2-10. Two measures of peripheral sensitivity showed that involvement in RA accidents increases as (1) the ability to identify targets in the peripheral field decreases (DAI, Table 2-10a), and (2) the ability to detect movement of objects approaching the driver from his peripheral field decreases (PMD-Large, Table 2-10b).

The first measure, DAI-90-Left, indicates that as the ability to rapidly detect and identify targets in the left field decreases, the involvement in RA accidents relative to RE accidents decreases. It is interesting that this relationship exists for the left field only, since this is typically the side of the road with a greater unobstructed field of view. Perhaps more surprising is that none of the Field of View measures were significantly related to accident type. It suggests

Table 2-10

Contingency Tables for Involvement in Right Angle (RA) and Rear End (RE) Accidents as a Function of Vision Scores (Numbers in Parentheses Represent Percentages)

DAI-90-Left (10a)

Accident	50 - 70 n %	80 n %	90 n %	Total
RA	29 (40)	29 (40)	14 (20)	72
RE	9 (20)	18 (41)	17 (39)	44

$X^2 = 7.38$, $p = .12$

PMD-Large (10b)

Accident	2 - 6′	8 - 190′	Total
RA	23 (35)	42 (65)	65
RE	28 (67)	14 (23)	42

$X^2 = 19.44$, $p = .02$

CAM-Threshold (10c)

Accident	2′	4 - 8′	12 - 64′	Total
RA	21 (30)	23 (33)	27 (37)	71
RE	7 (15)	31 (67)	18 (18)	56

$X^2 = 15.75$, $p = .03$

DVA (10d)

Accident	20/30	20/40 - 20/100	Total
RA	22 (31)	49 (69)	71
RE	9 (20)	36 (80)	45

$X^2 = 11.01$, $p = .05$

NOTE: The X^2 and significance levels are based on the same tables **prior** to collapsing across several levels of scores on the vision tests.

that more important than a large field is the ability to effectively monitor the field with foveal fixations.

The PMD measure was both highly significant ($p < .02$) and highly characteristic of actual right angle traffic conflicts in which either one of the two drivers is not aware of the approaching car, i.e., the peripheral movement in-depth **toward** the driver (PMD-Large). The effect of CAM was also significant but hard to interpret since the proportion of RA accidents was greater than RE accidents for both the drivers with the poorest and best CAM scores. The trend was reversed for the majority of drivers who fell between the two extremes.

Finally, dynamic visual acuity—by far the visual ability that is most consistently related to accidents—was also significantly related to accident type; poor DVA increases the involvement in both accident types, but the increase is slightly greater for RE accidents (Table 2-10d).

Validity Assessment—Case Studies

During Phases II-V of the TAC project, in only eight cases was reduced vision cited as a causal factor. Of these eight, five of the assessments were based on DVT performance while the other three were based on the drivers' own reports (Phases I-III, before the DVT was available). The only conclusion that can be drawn from these data is that reduced vision played a minor role in the accident sample obtained in this study; i.e., in only two percent of the accidents. This, no doubt, is due to the over-representativeness of young drivers in Monroe County (college town)—i.e., high accident drivers with good vision. Notwithstanding these qualifications, it might be noted here that in the remaining five cases SA-N was 20/30 or better, but other measures—DAI, DVA, and PMD—indicated impaired vision. Interestingly, these are the same measures that were statistically significant in the previous analysis, where collision type was related to specific visual impairments.

2.1.5 Summary, Conclusions, and Recommendations

Methodology and Results—A Driver Vision Test (DVT) which is an integrated battery of 12 different driving related tests was administered to 358 drivers. The tests are assumed to measure the following visual skills.

1. Static acuity—In normal illumination, low-level illumination, veiling glare, and spot glare.
2. Foveal movement acuity—The ability to detect direction of small angular movement and movement in-depth.
3. Field of vision—The effective visual field for target detection, and identification (with and without eye movements).
4. Dynamic visual acuity—The resolution threshold for angularly moving targets.
5. Peripheral movement acuity—Same as 2 except that the observer views the target peripherally.

Reliability analyses were conducted on 51 drivers stratified by age and sex according to accident involvement for the general population. These drivers were administered eight of the 12 tests on two occasions, approximately one week apart.

The main findings pertaining to the reliability, practicality and validity of the DVT in its present form can be summarized as follows:

1. Test-retest correlations were statistically significant on most of the tests, but were adequately high on only three tests: static acuity in normal illumination (r = .75), static acuity in the presence of spot glare (r = .92), and dynamic visual acuity (r = .88).

2. Significant learning effects (improved performance during the retest) were observed for only three of the tests (static acuity—normal and with spot glare, and foveal angular movement). These changes were attributed to lack of understanding of the task during the initial test session.

3. An in-depth analysis of the "less reliable" tests revealed that in all but three of the tests (foveal angular movement, foveal movement in-depth, and static acuity with low levels of illumination) the low test-retest correlations were due to a limited range effect—i.e., the differences in visual capabilities between the drivers tested were small to begin with; consequently magnifying changes in performance between the two sessions.

4. The practicality of the DVT was assessed with partial test-retest correlations controlling for change of test administrator and change in the time-of-day (morning vs. afternoon) between test and retest. None of the correlations were significantly affected by these two variables.

5. Inter-test correlations and a principal component factor analysis were conducted to see if any of the tests can be eliminated on the basis of redundancy considerations. The main results showed that all four tests of static foveal acuity correlated with each other more than with any of the other tests, and dynamic visual acuity correlated highly with most of the measures reflecting movement threshold acuity. These results suggest that for licensing purposes the DVT could be significantly shortened.

The usefulness of the DVT as a valid indicator of drivers' accident involvement was assessed by measuring the relationship between drivers' DVT performance scores and their accident involvement. The main results from these analyses indicated that:

1. Dynamic visual acuity (DVA) is the single best test that discriminates between accident-at-fault drivers and the control group drivers, once the effects of age are controlled for.

2. Static acuity under low levels of illumination of drivers judged to have committed

perceptual recognition is significantly poorer than the acuity of drivers judged to have committed no errors (20/88 vs. 20/75).

3. Individual case by case analysis of right angle collisions relative to rearend collisions revealed that involvement in right angle collisions increases as peripheral awareness and acuity decreases, while involvement in rearend collisions increases as the ability to detect angular movement straight ahead decreases.

Conclusions and Recommendations--These results suggest that the DVT can be considered adequate for testing foveal static acuity under normal and glare conditions but may be less than satisfactory for measuring static acuity under low levels of illumination unless a sufficient dark adaptation period is provided. In addition, the DVT yields a stable measure of dynamic visual acuity and effective visual field. The present administration and scoring procedures make measures of both central and peripheral movement acuity too unreliable to be useful.

For licensing purposes the administration of the DVT requires too much time and the equipment is bulky compared to the devices presently in use (e.g., Keystone Telebinoculars). An improvement in both respects could be obtained by retaining only those tests which are definitely related to driving ability, and are independent of each other. The factor analysis and **validity analyses suggest that two such tests may be foveal static acuity under low levels of illumination, and dynamic visual acuity.**

Before such recommendations are implemented, the reliability of the presently unreliable tests must be improved. This is necessary before any definite conclusions about their relevance to driving ability and accident involvement can be made. The general pattern of the results obtained here suggests that reliability can be greatly improved by increasing the possible range of scores on the one hand, and accuracy of measurement of the other hand. A methodological improvement incorporated in a newer version of the DVT presently being developed by Honeywell, Inc., is aimed at achieving these goals.

In summary, in its present form, of the more reliable measures obtained from the DVT, **DVA (dynamic visual acuity) appears to be the only variable which is consistently and significantly related to accident involvement.** Static acuity under normal illumination—presently the only visual screening criterion in licensing tests—is apparently not a causal factor in accidents; or at least not within the range of foveal acuities tested in this study. The importance of other measures of visual performance (e.g., SA-LL, PMD-Large) cannot be determined before the reliability of these measures is improved.

2.2 Driver Knowledge Test

2.2.1 Introduction and Overview

The National Highway Traffic Safety Administration (NHTSA) has gathered a pool of multiple choice items concerning many facets of information relevant to safe driving. Since tests of driver knowledge are used in state licensing, and in industry, the NHTSA pool allows for a more careful analysis of the effectiveness of a driver knowledge test.

The purpose of the present investigation was to evaluate the extent to which knowledge of the driving task—as measured by a paper and pencil test—correlates with accident involvement. Although the results reported below do not support the notion that the two measures are at all related to each other, the repeated examination of this issue and its practical implications for driver training and screening programs warrant a detailed description of the rationale underlying this study, the methodology used, and the results obtained.

The implicit assumptions underlying the use of paper and pencil knowledge tests by both state licensing agencies and in the present study have been aptly stated in an interim synopsis of an NHTSA contract for the "Development of a National Item Bank for Tests of Driving Knowledge" as follows:

> Measuring driver and driver-trainee knowledge of driving principles and regulations through paper and pencil tests has long been a feature of most driver licensing and driver education programs. Such cognition measures are logically assumed to be predictors of individual driving success. That assumption, however, is based on two somewhat tenuous contentions—one, that knowledge required for safe, efficient driving is completely specifiable and, two, that a driver's knowledge is highly correlated with his driving behavior. To a large extent, evaluation of the second contention depends on successful completion of the first. (Highway Safety Research Institute, University of Michigan, under NHTSA Contract No. FH-11-7616; February, 1972.)

The present study was conducted at the Institute for Research in Public Safety (IRPS) as part of an ongoing accident investigation effort, in order to establish the usefulness of tests of driver knowledge as indicants of accident involvement. It was hoped that, based on the University of Michigan study quoted above, and the systematic item selection procedure detailed below, the first contention would be satisfactorily completed so that the second one—the relationship between knowledge and accidents—could be validly measured.

2.2.2 Method

Subjects

The subjects were 178 drivers from an Accident Group and 133 drivers from a Control Group, as described in Section 2.1.3 of this volume (subjects were the same as used in the vision testing program).

Selection of Items

Table 2-11 shows the set of 20 multiple choice, four-alternative, questions concerning driver knowledge that was selected from a pool of 246 items collected by the University of

Table 2-11

In-Depth Human Factors Form
Driver Knowledge Questionnaire

5 5 3 Duplicate columns 04-14 from page 1 from Array 55.
01 02 03

IN-DEPTH HUMAN FACTORS FORM
DRIVER KNOWLEDGE QUESTIONNAIRE

In-Depth Case Number:

Traffic Unit Number:

Please read each question carefully and select the one response that you feel best answers it. Indicate your choice by placing an "x" in the corresponding blank on its left. Be sure that you answer every question and that you mark one and only one response!

1. Under normal conditions the top speed limit for driving in a business district is:

__(1) 15 mph
__(2) 20 mph
__(3) 25 mph
X (4) 30 mph

15

2. If there are no painted lines on the road you:

__(1) May drive anywhere on your side.
X (2) Should drive as if there were lines.
__(3) Should drive wherever traffic is moving the fastest.
__(4) May drive in the center of the road.

16

3. When driving at dusk or dawn, or on an unusually dark day:

__(1) Turn on your parking lights.
__(2) Keep your sunglasses on to cut down headlight glare.
__(3) Turn your lights on high beam.
X (4) Turn your lights on low beam.

17

4. If your brakes are not holding because they are wet, you should:

__(1) Continue driving and they will dry off.
X (2) Keep one foot on the gas and one lightly on the brake until dry.
__(3) Stop on the side of the road and wait for them to dry.
__(4) Don't use your brakes until they are dry.

18

5. For driving on sand or snow, the best forward traction can be attained:

__(1) By letting air out of the rear tires so they are several pounds below.
__(2) By letting air out of the rear tires and adding weight over the driving wheels.
__(3) By simply keeping the tires at their recommended pressure.
X (4) By adding weight over the driving wheels and keeping them at recommend or slightly higher pressure.

19

6. When you want to make a right turn into a driveway you should:

X (1) Avoid stopping on the road.
__(2) Swing to the left before making the turn.
__(3) Signal after you begin to turn.
__(4) Signal the traffic behind you to pass.

20

7. If you come to an intersection that is hard to see around because of trees or buildings:

__(1) Proceed as if there was a yield sign at the intersection.
__(2) Stop near the center of the intersection and then continue when it is safe.
__(3) Slow down and blow your horn to warn drivers who cannot see you.
X (4) Stop at the intersection and edge forward slowly.

21

8. The most dangerous time to drive in the rain is:

__(1) Just before the rain starts because it gets dark but most motorists have not slowed down yet.
X (2) Just after the rain starts because the rain mixes with road film making the roads slick.
__(3) After it has rained for about 30 minutes because the rain has washed away all the grit that gives you traction
__(4) Just after the rain stops because other motorists can see again, and start to drive faster but the streets are still wet.

22

9. If brakes are applied continually, such as is necessary when coming down a long, steep grade, they may become very hot. When this happens:

__(1) The brake warning lamp on the dashboard will come on.
X (2) The brakes will loose their stopping ability.
__(3) The brakes will improve in effectiveness; brakes work best when hot.
__(4) The brakes should operate normally, since heat has very little effect on them.

23

IN-DEPTH HUMAN FACTORS FORM
DRIVER KNOWLEDGE QUESTIONNAIRE

10. If you are driving at high speed and have a blowout, you should:

__(1) Let go of the steering wheel because the car will straighten itself automatically.
__(2) Step hard on the brakes to stop as quickly as possible.
X (3) Apply the brakes gently, with extreme caution.
__(4) Pull off the road first then slow down. 24

11. If the rear of your vehicle is skidding to the left you should:

__(1) Move the steering wheel back and forth in a zig-zag pattern.
X (2) Turn the top of your steering wheel to the left.
__(3) Hold your steering wheel from moving until out of the skid.
__(4) Turn the top of your steering wheel to the right. 25

12. If you cannot stop in time before hitting another vehicle, it is best to:

__(1) Gradually slow down and then hit the other vehicle.
__(2) Blow the horn and continue at normal speed.
X (3) Try to steer around the vehicle and avoid braking hard.
__(4) Remove your foot from the gas and put on the brake as hard as possible. 26

13. If you have locked your vehicle's brakes and you are sliding toward another vehicle, you should:

__(1) Attempt to steer around the vehicle.
__(2) Sound your horn and flash your lights.
X (3) Pump your brakes and attempt to steer around the vehicle. 27
__(4) Use your emergency brake.

14. If you know that you will soon be making a turn you should:

X (1) Look well ahead to locate the turning point.
__(2) Blow the horn several hundred feet before you turn.
__(3) Flash your bright lights to warn other traffic.
__(4) Speed up so as to avoid making other vehicles wait. 28

15. If the signal at a railroad crossing does not indicate that a train is coming you should:

__(1) Speed up and cross the track quickly.
__(2) Continue at the same speed and check for a train before crossing.
X (3) Slow down and look both ways.
__(4) Come to a complete stop before continuing across. 29

16. When passing a vehicle you should return to the right side of the road when:

__(1) You are 50 feet in front of the passed vehicle.
__(2) The other driver signals you to do so.
__(3) You have cleared the front bumper by a vehicle length.
X (4) You can see its entire front end in your rearview mirror. 30

17. It is best to check tire pressures:

X (1) After the car has been parked for a long time and the tires are "cold".
__(2) After the car has been driven vigorously and the tires are "hot"
__(3) Whenever convenient; it doesn't matter if the tires are hot or cold.
__(4) With the car on a lift, so that there is no weight on the tires. 31

18. When driving through fog at night, you should use your:

__(1) High beam headlights.
__(2) Parking lights.
X (3) Low beam headlights. 32
__(4) 4-way flashers.

19. Before leaving the road to avoid a head-on crash you should slow down by:

X (1) Pumping the brakes.
__(2) Applying constant pressure on the brakes.
__(3) Turning off the engine. 33
__(4) Shifting into neutral.

20. At night you should drive slow enough to be able to stop within:

__(1) 5 car lengths.
X (2) The distance lighted by your headlights.
__(3) The time it takes for a light to change from yellow to red.
__(4) 10 seconds from the time you hit the brake. 34

Michigan (under the above-referenced contract), and from a pool of items contributed by appropriate members of the staff of the Institute for Research in Public Safety. The latter were added to fill apparent subject-matter voids, particularly in the area of vehicle maintenance and effects of degradation. First, to eliminate questions in which performance is confounded with verbal ability, all items from the NHTSA/Michigan pool that correlated with verbal ability above the first quartile ($r \geq .09$) were eliminated. In addition, items with test-retest correlations below the median ($r \leq .47$) were also eliminated from consideration. (Note that verbal skills and test-retest information of this kind was not available for the IRPS-contributed questions). The conjoint application of both criteria yielded a pool of 61 items (out of the original 246). Second, judges from the IRPS multi-disciplinary team who were familiar with human, vehicular and environmental factors rated each of the 61 NHTSA items and each of the items suggested by the IRPS staff on their "importance" for traffic safety. The summed ratings produced a ranked ordering for the items. The resultant Driver Knowledge Test consisted of the 11 most highly ranked items from the NHTSA pool and the nine most highly ranked items from IRPS staff suggestions, with all seven of the content areas cited by NHTSA being represented.[3] Time constraints on the already-extensive in-depth driver interview precluded any lengthier testing.

Procedure

Accident Group drivers took the 20-item driver knowledge test (DKT) as part of their in-depth interview. Control Group drivers took the DKT along with the battery of tests for dynamic vision (DVT) described earlier (Section 2.1).

2.2.3 Results and Discussion

2.2.3.1 Age Analysis

Table 2-12 shows the average score on the driver knowledge test by question for drivers in each of seven age groups. Separate analyses of variance were performed on each question. There were significant effects due to age for questions 1, 12, 13, 14, and 16, and marginally significant age effects for questions 2, 3, 6, 9, 11, 17, 19, and 20. In addition, the total DKT scores of drivers in the seven age groups differed reliably. The general pattern for total score, and for most of the individual questions, was for very young drivers to score relatively low, 20-34 year old drivers to progressively score higher, and for scores to fall progressively after age 35, with the over 65 group scoring the lowest of all.

This general curvilinear relation between age and DKT suggests that age alone is not the only influence on driver knowledge. The fact that DKT scores tend to increase progressively with age only up to age 35 and then drop off suggests that the first years of driving may add useful knowledge, but after about the age of 35, additional experience does not add to DKT scores.

[3] Preoperative procedures, basic knowledge, driving situations, vehicle care and driver conditions, driver responsibilities, vehicle code-laws and regulations, and traffic control signs, signals and markings.

Table 2-12

Proportion Correct Response by DKT Question for Drivers in Seven Age Groups

Ques.	AGE GROUP							Total	Age Effects	
	Below 20	20-24	25-34	35-44	45-54	55-64	64 over		F	P
1	.49	.44	.35	.13	.08	.33	.11	.33	5.51	<.01
2	.98	1.00	.98	.95	.97	.87	.89	.97	1.91	<.08
3	.86	.86	.96	.95	.95	.87	1.00	.91	1.61	<.15
4	.55	.55	.57	.55	.51	.67	.67	.56	.24	ns
5	.39	.29	.33	.26	.27	.13	.22	.30	.83	ns
6	.75	.67	.75	.76	.59	.47	.44	.69	2.08	<.06
7	.61	.53	.62	.63	.68	.67	.67	.61	.54	ns
8	.77	.80	.85	.92	.87	.93	.89	.84	.98	ns
9	.47	.66	.68	.76	.76	.60	.55	.65	1.80	<.12
10	.84	.92	.92	.92	.97	1.00	1.00	.92	1.34	ns
11	.70	.82	.74	.79	.57	.71	.78	.74	1.60	<.16
12	.68	.76	.72	.71	.51	.79	.11	.68	3.88	<.01
13	.63	.65	.73	.50	.46	.36	.33	.60	2.96	<.01
14	.97	.96	.99	.97	1.00	1.00	.78	.97	2.47	<.03
15	.72	.80	.81	.82	.73	.64	.78	.77	.67	ns
16	.72	.87	.82	.63	.78	1.00	.66	.79	2.61	<.02
17	.39	.49	.50	.57	.54	.14	.22	.46	2.10	<.06
18	.95	.93	.95	.90	.97	.93	.89	.94	.44	ns
19	.61	.75	.69	.74	.69	.71	.22	.69	2.10	<.06
20	.54	.63	.77	.74	.61	.57	.44	.65	1.98	<.07
T-DKT	14.0	14.8	15.1	14.6	14.1	13.3	11.9	14.5	3.48	<.01
N	57	76	79	38	37	15	9	311		

2.2.3.2 *Sex Analysis*

Table 2-13 shows the average score on the driver knowledge test by question for males and females within seven age groups. Separate analyses of variance were performed on each question. Males performed significantly better than females on questions 4, 9, 13, and 20; males performed marginally better on questions 10 and 15; and females performed marginally better on question 19. As can be seen in the table, the superiority of males over females for questions 4, 9, 13, and 20 is found in nearly every age group, and the general trend of higher scores for males is reflected in the fact that the total score was significantly higher for males. The questions best answered by males seem to concentrate on handling in emergencies and mechanical considerations rather than on general driving style or laws.

2.2.3.3 *Driver Education Analysis*

Table 2-14 shows the average score on the driver knowledge test for drivers who received formal driver training vs. drivers without formal training within seven age groups. Separate analyses of variance revealed that the driver training group performed significantly better on questions 1, 6, 13, 16, and 20. The questions best answered by driver training people (predominantly young) seem to emphasize general driving style and laws rather than emergency handling or mechanics.

The fact that the drivers with formal training perform better on the DKT provides some encouragement for the effectiveness of drivers' training courses. It is not possible, however, to determine whether this finding is due to the effectiveness of the course or to "self selection"—the fact that conscientious, knowledgeable drivers are the ones who are more likely to register for driver training courses.

In addition, the fact that proportionately more young drivers had had driver training than older drivers makes comparisons within age groups difficult, and also confounds the general comparison between training groups. In general, however, these results are consistent with the intuitive notion that formal driver training should increase drivers' knowledge.

2.2.3.4 *Factor Analysis*

Another question concerns the internal structure of the DKT—for example, does it measure one general driving ability or several independent basic abilities? Does each question tap a separate type of knowledge or are some of the questions redundant? In order to answer these questions, a factor analysis was performed on the DKT scores of all drivers. Since questions 2, 3, 10, 14, and 18 were extremely easy, and therefore nondiscriminating among drivers (answered correctly by over 90% of the drivers), the factor analysis was conducted on the remaining 15 items only. No stable factor structure could be obtained, suggesting that each of the 15 items was a separate factor. Interestingly, the items within content areas are as independent of each other as items between content areas. Thus, the analysis suggests that each question measured a separate, independent and specific kind of driving knowledge.

Table 2-13

Proportion Correct Response by DKT Question for Males and Females by Seven Age Groups

	Male								Female								Sex Effects	
Ques.	Below 20	20-24	25-34	35-44	45-54	55-64	65 & Over	Total Male	Below 20	20-24	25-34	35-44	45-54	55-64	65 & Over	Total Female	F	P
1	.53	.43	.33	.11	.04	.40	.00	.33	.42	.48	.38	.15	.14	.20	.50	.34	.00	ns
2	1.00	1.00	.97	.94	.96	.90	.86	.97	.95	1.00	.98	.95	1.00	.80	1.00	.97	.07	ns
3	.84	.88	.95	.89	.96	.90	1.00	.90	.89	.80	.97	1.00	.93	.80	1.00	.92	.26	ns
4	.62	.59	.56	.61	.70	.70	.86	.62	.42	.48	.58	.50	.21	.60	.00	.47	6.89	< .01
5	.34	.29	.28	.28	.26	.10	.14	.28	.47	.28	.39	.25	.29	.20	.50	.34	1.23	ns
6	.79	.63	.78	.78	.57	.30	.29	.67	.69	.76	.73	.75	.57	.80	1.00	.72	.91	ns
7	.61	.55	.56	.72	.61	.60	.71	.60	.63	.48	.68	.55	.79	.80	.50	.62	.23	ns
8	.71	.82	.90	1.00	.96	.90	.86	.86	.90	.76	.80	.85	.71	1.00	1.00	.82	.83	ns
9	.55	.71	.80	1.00	.91	.70	.57	.74	.32	.56	.58	.55	.50	.40	.50	.51	18.27	< .01
10	.87	.92	.97	.94	1.00	1.00	1.00	.94	.79	.92	.88	.90	.93	1.00	1.00	.89	2.74	< .10
11	.61	.80	.82	.83	.61	.78	.71	.74	.90	.84	.67	.75	.50	.60	1.00	.73	.01	ns
12	.63	.75	.80	.78	.57	.78	.14	.69	.79	.80	.65	.65	.43	.80	.00	.67	.14	ns
13	.76	.67	.84	.67	.55	.44	.43	.69	.37	.60	.63	.35	.29	.20	.00	.47	15.44	< .01
14	.95	.96	1.00	1.00	1.00	1.00	.86	.97	1.00	.96	.98	.95	1.00	1.00	.50	.97	.06	ns
15	.74	.84	.82	.83	.74	.78	.86	.80	.68	.72	.80	.80	.71	.40	.50	.74	1.75	< .19
16	.74	.90	.84	.56	.83	1.00	.57	.80	.68	.80	.80	.70	.71	1.00	1.00	.77	.59	ns
17	.34	.47	.51	.67	.70	.22	.29	.48	.47	.52	.49	.47	.29	.00	.00	.44	.52	ns
18	.95	.92	.95	.94	.96	1.00	1.00	.95	.95	.96	.95	.85	1.00	.80	.50	.93	.40	ns
19	.53	.77	.68	.72	.61	.67	.29	.65	.79	.72	.70	.75	.85	.80	.00	.73	2.29	< .14
20	.53	.69	.85	.89	.68	.56	.57	.70	.58	.52	.70	.60	.50	.60	.00	.59	3.55	< .06
Total DKT	14.1	14.9	15.5	15.5	14.9	13.5	12.3	14.7	13.9	14.5	14.7	13.7	12.9	13.0	10.5	14.0	5.87	< .02
N.	38	51	39	18	23	10	7	186	19	25	40	20	14	5	2	125		

Table 2-14

Proportion Correct Response by DKT Question for Drivers with Formal Training and Drivers Without Training by Seven Age Groups

	No Training								Training								Training Effect	
Ques.	Below 20	20-24	25-34	35-44	45-54	55-64	65 Over	Total No Training	Below 20	20-24	25-34	35-44	45-54	55-64	65 Over	Total w/ Training	F	P
1	.50	.39	.32	.10	.07	.33	.11	.22	.49	.47	.37	.22	.13	—	—	.42	13.47	< .01
2	.83	1.00	1.00	.83	1.00	.87	.89	.95	1.00	1.00	.97	1.00	.88	—	—	.98	2.29	< .10
3	.67	.83	1.00	.93	.97	.97	1.00	.92	.88	.86	.94	1.00	.88	—	—	.90	.51	ns
4	.50	.39	.56	.59	.48	.67	.67	.54	.56	.60	.57	.44	.63	—	—	.57	.34	ns
5	.67	.17	.29	.31	.24	.13	.22	.26	.35	.33	.35	.11	.38	—	—	.33	1.84	ns
6	.83	.44	.67	.76	.55	.47	.44	.60	.75	.74	.79	.78	.63	—	—	.75	8.53	< .01
7	.83	.44	.56	.66	.69	.67	.67	.63	.59	.55	.65	.56	.63	—	—	.59	.31	ns
8	.83	.67	.80	.93	.83	.93	.89	.84	.77	.85	.87	.89	1.00	—	—	.84	.00	ns
9	.67	.44	.64	.79	.72	.60	.56	.66	.45	.72	.71	.67	.88	—	—	.64	.05	ns
10	.83	.94	.92	.97	.97	1.00	1.00	.95	.84	.91	.93	.78	1.00	—	—	.89	3.54	< .05
11	.67	.78	.75	.79	.59	.71	.78	.72	.71	.83	.74	.78	.50	—	—	.75	.29	ns
12	.83	.72	.76	.72	.48	.79	.11	.65	.67	.78	.70	.67	.63	—	—	.71	1.47	ns
13	.67	.56	.79	.52	.41	.36	.33	.53	.63	.67	.70	.44	.63	—	—	.66	5.22	< .05
14	1.00	1.00	.96	.97	1.00	1.00	.78	.97	.96	.95	1.00	1.00	1.00	—	—	.97	.03	ns
15	.83	.67	.76	.83	.72	.64	.78	.75	.71	.85	.83	.78	.75	—	—	.79	1.00	ns
16	.50	.61	.75	.62	.79	1.00	.67	.72	.75	.95	.85	.67	.75	—	—	.84	6.38	< .01
17	.17	.44	.36	.61	.52	.14	.22	.42	.41	.50	.57	.44	.63	—	—	.50	1.86	ns
18	.83	.94	.96	.93	.97	.93	.89	.94	.96	.93	.94	.78	1.00	—	—	.94	.00	ns
19	.83	.89	.58	.76	.68	.71	.22	.69	.59	.71	.74	.67	.75	—	—	.68	.00	ns
20	.33	.44	.68	.76	.54	.57	.44	.59	.57	.69	.82	.67	.88	—	—	.70	4.11	< .05
Total	14.2	13.4	14.3	14.9	13.9	13.3	11.9	13.9	14.0	15.2	15.4	13.6	14.9			14.8	9.56	< .01
N	6	18	25	29	29	15	9	131	51	58	54	9	8			180		

2.2.3.5 Involvement Analysis

In order to determine whether driver knowledge is related to driver performance, average scores on each question of the driver knowledge test (DKT) were compared among three groups of drivers as described in Section 2.1.4.6: 1) Accident-at-Fault Group; 2) Mixed Group; and 3) Control-No-Accident Group.

Table 2-15 shows the average proportion correct on each of 15 questions for each of the three involvement groups. Separate ANOVAs comparing the groups for each question and for total DKT score revealed no statistically significant differences among the groups. Thus, there is no evidence, in this analysis, to support the idea that driver knowledge as measured by the DKT is related to accident involvement.

One possible reason for the failure of the DKT to distinguish among the groups could be that the test covered basic information that any driver would have acquired during a short

Table 2-15

Proportion Correct Response by Driver Knowledge Test (DKT) Question for Three Involvement Groups

Question	Involvement Group				
	Accident At Fault	Mixed	Control No Accident	F	P
1	.30	.32	.37	.63	ns
4	.60	.54	.55	.38	ns
5	.31	.23	.35	1.45	ns
6	.67	.72	.68	.32	ns
7	.62	.62	.59	.18	ns
8	.82	.87	.83	.51	ns
9	.64	.61	.69	.70	ns
11	.78	.71	.72	.79	ns
12	.68	.72	.66	.42	ns
13	.60	.60	.60	.00	ns
15	.80	.74	.78	.48	ns
16	.74	.77	.84	1.68	<.19
17	.52	.47	.41	1.41	ns
19	.65	.67	.73	.77	ns
20	.65	.60	.69	.87	ns
Total	9.49	9.31	9.48	.18	ns

NOTE: The Total row represents mean number of correct responses out of the 15 items. N for each group is 95, 87, and 120.

period of driving experience. **Secondly**, the fact that accident-involved drivers may have acquired new driver knowledge as a direct result of their accident would seriously limit the effect of DKT scores given after the accident. A third problem—similar to that with the DVT—may be that the DKT covers many very specific kinds of knowledge, and that our criterion of accident involvement is too broad. The following section is an attempt to inspect driver behaviors in more detail.

2.2.3.6. Error Analysis

In order to determine whether specific accident-causing driver behaviors are related to specific areas of driver knowledge, a more detailed analysis was performed. For this analysis, ten hypotheses on the relationships between **specific** accident causes and knowledge in specific areas were generated. Each hypothesis is represented in Table 2-16 and was formulated as follows: Drivers failing to answer question number X correctly will be more likely than not to be involved in an accident caused (at the certain and/or probable level) by factor Y. A Chi square analysis in which the answer was scored correct or incorrect and the factor was listed as cited or not cited was conducted on each of the hypotheses; and the results, as shown in Table 2-16, do not reveal any significant relationships. The one marginally significant result obtained (P = .16) was for the hypothesis relating knowledge of proper recovery from skidding (No. 11) and the "improper driving technique" causal factor.

Table 2-16

The Relationship Between Specific Accident Causes and Specific Causal Factors.

DKT question number	Causal Factor	Chi Square df=1	Significance
2	Ambience related	.11	ns
7	Improper lookout	.14	ns
8	Slick roads	.76	ns
10	Vehicle factors	.01	ns
11	Improper driving technique	1.98	.16
11	Improper evasive action*	—	—
12	Improper evasive action*	—	—
13	Improper evasive action*	—	—
17	Vehicle factors	.14	ns
19	Improper evasive action*	—	—

*This hypothesis could not be tested since none of the accident group drivers taking the DKT were cited for improper evasive action.

These generally negative results show that even at this level of focused examinations, accident involvement and driver knowledge **as tested here** are independent. It is very likely, however, that the driver knowledge test results were biased due to discussions that the drivers had with friends and/or family about their accident just prior to the in-depth interview. In fact, several drivers even stated that "now they know" what they should have done. This gain in knowledge—while useful in itself—would probably wash out any relationship that might have existed between the accident cause and driver knowledge at the time of the accident.

2.2.4 Conclusions and Recommendations

The general trends of the present analysis of the driver knowledge test (DKT) are:

1. DKT performance is related to age, with older drivers performing most poorly and middle-aged drivers performing best, in general.

2. In general, males obtained higher DKT scores than females.

3. For some questions, drivers with formal training obtained higher scores than drivers without training.

4. Each question may be considered to be measuring a separate, independent aspect of driver knowledge.

5. There was no evidence of a relationship between DKT score and accident involvement.

6. There was no evidence of a relationship between the performance on specific DKT questions and type of driving error committed.

Despite the discouraging results obtained here, it is quite unlikely that all aspects of driving performance are unrelated to all the content areas identified by NHTSA or all the required driving skills identified by McKnight and Adams (1971). The results obtained here suggest that when driving performance is measured by accident involvement, other skills and knowledge not measured by the DKT may be relevant. Since the intent of this research is to identify accident-causing behaviors and remedial approaches to these behaviors, it might be argued that more specific and relevant definitions of driver knowledge should be tested. The following are two general recommendations based on such definitions:

1. Driver knowledge should be tested in the areas that have been determined to be the major causes of accidents; and immediately following the accident, before any additional learning takes place. Questions that assess proper lookout techniques, awareness of inattention risks, proper evasive maneuvers, etc., are probably more relevant to accident avoidance than questions dealing with maintenance and knowledge of traffic regulations.

2. Driver knowledge of accident avoidance maneuvers should be tested under temporal stress. Drivers frequently report that they "know" that they performed an inappropriate avoidance maneuver but responded "instinctively." When taking the DKT, these drivers often answer these questions appropriately. If a new test is designed, it should test both whether drivers know the right answer and how much time they need to reach this decision. If passive knowledge—even under temporal stress—is not enough, then knowledge of avoidance maneuvers should be measured in an active simulation environment where the driver will be required to actually perform the appropriate motor response.

2.3 Methodology Development: New Driver Measures

2.3.1 Introduction

This section presents the results of an effort to develop new driver measures which would be useful in the context of accident investigation studies to better understand the question of "**who** makes **what kind** of on-road behavioral errors leading to accidents."

Results were consistent with the idea that personal maladjustment and social maladjustment are related to accident involvement. To a lesser extent, cognitive abilities (as measured by a test of clerical abilities) and impulsivity were also found to be related to accidents.

The materials in this section are organized around the following sequence of activities:

1. Literature review
2. Pilot test on pool of 23 high accident and 23 no accident college students.
3. Validation study on 7 high accident and 7 no accident college students.
4. Post-hoc study of 287 drivers based on in-depth accident investigations already completed.

2.3.2 Background

One question which has generated considerable interest within the traffic safety literature is what could be called the "human factors problem"—the problem of ascertaining the distinguishable characteristics of the over-involved or "problem driver." Most research in this area has involved comparing the demographic, biographic, attitudinal, personality, driving knowledge/experience, or skill characteristics of "problem drivers" (generally defined by number of accidents or violations per time frame) vs. the characteristics of the general driving population. Such studies have produced an impressive list of variables, to be discussed in the remainder of this section, which have been found to distinguish between problem and normal drivers; however, this work has produced few theories useful for training and remediation, nor have relations involving theoretically interesting human factors been very strong (for reviews see: McFarland, Moore and Warren, 1955; Goldstein, 1961, 1962; Miller and Dimling, 1969; Selzer and Vinokur, 1974). This work has also generated some potentially important measurement devices for detection of the "problem driver;" but such devices give few clues as to the "causes" of poor driving behaviors, are based on locating "the problem driver" rather than locating tendencies towards various **types** of poor driving behaviors, and have achieved only limited success in selection when validated against accident/violation rates (see: Haner, 1963; Pelz and Schuman, 1970; Schuster and Guilford, 1964; McGuire, 1956; Selzer and Vinokur, 1974).

The present review attempts to advance, and hopefully clarify, this worthwhile research effort by suggesting more integrated investigations of independent variables (i.e., measures of human factors) and more detailed analyses of dependent variables (i.e., measures of driving behaviors). First, rather than deal with the myriad of human factors on the level of raw empiricism (as was so successfully done, for example, in the famous "California Studies"), the independent variables to be considered in the present paper will be limited to a number of theoretically interesting human traits which may be related to on-road behaviors involving risk-taking, poor decision making, and driving skill. Second, rather than simply relate these basic human traits to accident or violation rates, dependent variables will be investigated which involve a set of driving behaviors characteristic of different **types** of problem driving.

2.3.3 Independent Variables: Basic Human Traits and Characteristics

A review of the recent literature provides a lengthy list of individual factors which have (in at least two studies) reliably distinguished between poor and normal drivers. These factors are derived from several main sources including demographic and biographic information, medical/physiological data, alcohol/drug use, prior driving record and experience, records with social institutions, data concerning personal problems, personality test scores, attitude test scores, and cognitive-perceptual-skill test scores. The most frequently cited factors which are predictive of poor driving are: drivers under 25 or over 60 years old; male drivers; unmarried or separated/divorced drivers (except for drivers under 25); lower occupational, educational and income levels; prior accident/violation history; heavy alcohol/drug use; records of conflicts with social institutions; current life changes and personal problems; depression; anti-social feelings; and poor impulse control. While the validity and reliability of many of these factors have been seriously challenged, the factors listed in Table 2-17 seem to be likely candidates for further study, based on our current state of knowledge.

A list such as the one given in Table 2-17 is obviously a helpful first step, but it does not provide a clear understanding of why humans with these characteristics have more violations or accidents, and many of the relations are quite weak. Based on patterns of these observable data, several basic internal mechanisms or traits have been proposed, however, and the current level of knowledge now allows the preliminary assessment of some of these theories of how driver traits influence driving behavior. The main sets of traits which have been proposed can roughly be grouped into several categories:

1. no traits (chance theory and carelessness theory);
2. medical/physiological theory;
3. inexperience theory;
4. drunk/drugged driver theory;
5. social maladjustment theory;
6. personal maladjustment theory;
7. impulse non-control theory; and
8. information processing defect theory.

No Traits Theories

The chance theory (discussed by Froggatt and Smiley, 1964; Shaw and Sichel, 1971) rejects the idea that humans differ in traits related to "having an accident" and states instead that most

Table 2-17

Observable Human Characteristics Which May Distinguish Problem Drivers from General Drivers

Demographic Characteristics
- Age: 16-25, over 65 groups
- Sex: Male
- Marital Status: Divorced/separated or non-married (except males under 25)
- Education: Low
- Income: Low
- Job Status: Low

Medical/Physiological Characteristics
- Medical history: chronic medical illness
  (Note—Tests of vision, physical handicap and related physiological factors produced no reliable relations to accidents/violations except for extreme cases.)

Drinking/Drug Usage Record
- Alcoholic Consumption: Chronic or Binge
- Drug Consumption: High
- Cigarette Consumption: High

Driving Experience and Record
- Prior accidents: High
- Prior violations: High
- Prior license suspensions and loss of insurance: High
- Driving experience: Low
- Driving knowledge: Low

Record with Social Institutions
- Prior non-traffic arrests and convictions: High
- Employment record: Many job changes and firings
- Marital record: Divorced or separated
- School record: Truancy, low dropout age, low grades
- Home and family history: Broken, unhappy home
- Mental health services: Previous treatment, previous suicide attempt.
- Financial record: Poor credit rating
- Public health and welfare: Frequent contact

Current Personal Stress
- Interpersonal conflicts including marital: High
- Personal tragedy or loss: High
- Vocational problems: High
- Financial problems: High
- Parent-child problems: High
- Change in responsibility: New family, new job

Table 2-17 continued

Personality Tests
- Neuroticism, emotional unstability: High
- Anxiety, depression, suicidal: High
- Extroversion: High
- Aggressiveness, hostility, anger: High
- Anti-sociability, rebellion, lack of social responsibility: High
- Impulsivity, intolerance of ambiguity, need to act out, inability to delay gratification, feeling of repression: High

Attitudes and Values
- Anti-social, rebellious, anti-academic, anti-religious: High
- Intolerance, inflexibility: High
- Internal locus of control: High
- Enjoy working on cars and emotional release from cars: High

Perceptual, Cognitive, and Motor Tests
- Dynamic vision: Poor
- Motor task performance: Poor
- (Note—Memory and intelligence do not seem to be strongly related to driving performance. There is insufficient evidence to judge the predictive power of perceptual and motor skills.)

accidents can be explained as random events. The chance theory predicts the accident population for any given time span ought to have the same characteristics as the general driving population; however, there now exists a massive data base (summarized in Table 2-17) which contradicts this prediction and which shows that accident drivers tend to have different characteristics than normal drivers. Hence, it seems prudent to suggest that the chance theory be modified to include different "probabilities of accidents" (and different "probabilities of poor driving behaviors") for different drivers. It then remains to understand the factors which influence these individual differences.

The carelessness theory, like the chance theory, rejects the idea that drivers may differ in traits related to driving performance. The theory states that accidents are largely due to drivers being temporarily careless and that if drivers would be more careful, accidents would be reduced. The implication is that all drivers are equally well equipped to drive safely and the only factor contributing to human error is a sort of laziness on the part of the driver. The carelessness theory may be rejected on the same grounds as the chance theory– if carelessness were randomly distributed among equally capable drivers the accident population would not differ significantly from the overall population in variables such as demography, personality, attitudes, etc.

Medical/Physiological Theory

The medical/physiological deficiency theory states that accidents occur largely due to drivers having inadequate health or some other physical handicap. There have been many studies of the physical defects of drivers, including autopsies of fatally injured drivers (Finch and Smith, 1970; Baker, 1970) and analyses of records of drivers with disabilities (McFarland, Domey, Duggar, Crowley and Stoudt, 1968; Cresswell and Froggatt, 1963), but there is no consistent evidence of an unfavorable relationship between physical deficiencies and accidents or violations. In fact, McFarland et. al. report that 625 disabled drivers sustained significantly less accidents and violations than a sample of non-disabled drivers; however, there was no control for exposure and since disabled drivers may be expected to drive less than non-disabled drivers there is difficulty in interpreting these findings. Only extreme cases such as near blindness or personally upsetting medical problems such as chronic illness, seem related to poorer driver performance (Waller and Goo, 1969; Crancer and McMurray, 1967; Crancer and Quiring, 1968; Crancer and O'Neal, 1969). Unfortunately, however, as Burg (1972) points out, the Washington State Studies conducted by Crancer and his associates produced equivocal results with chronic illness related to poorer driver records in some studies but not others, and the California Study conducted by Waller compared 2672 drivers who had chronic diseases with a controlled group that differed in demography—thus, making interpretation difficult. Even if chronic illness is related to driving behavior, it is not clear whether the physical problems caused by chronic illness or the physiological problems caused by such illness are responsible for the noted higher accident rate. In summary, there is reason to suspect that physical and medical defects per se may not be important predictors of driving behavior.

Inexperience Theory

The inexperience theory states that accidents occur largely due to drivers not knowing traffic laws and/or having inadequate experience in actual driving situations. This theory is strongly implied by the repeated finding that drivers under 25 years old are over-represented among problem drivers (Solomon, 1964; McFarland and Moore, 1960; Harrington, 1970). However, in these studies age and experience are heavily confounded since most American drivers begin as teenagers; evidence that experience, rather than age per se, is related to accidents comes from several sources. In a study of German drivers—many of whom began driving as adults rather than teenagers—more accidents occurred within the first 3-4 years regardless of age (Munsch, 1966). Similarly, comparing the one year driving records of newly licensed Canadian drivers and experienced drivers matched for age, Brezina (1969) found the inexperienced group had generally poorer records. Ferdon, Peck and Coppin (1967) also report that teenagers who drive less tended to have more accidents. Unfortunately, there is the problem of "self selection" in these studies—poorer drivers may choose to drive less or to put off learning to drive precisely because they are poor drivers. In a study which overcomes this particular criticism, Farmer and Chambers (1939) found that bus drivers had less accidents as experience with the company increased up to one year; however, after one year experience was not a factor.

In studies uncontrolled for age, there is additional evidence that minor (property damage only) crashes are over-represented in groups of drivers with less than two years of experience (McFarland, 1968) but there is also evidence of an **increase** in accident/violation rates of a more serious nature (personal injury and fatality) in the two to five years of experience group (Pelz and Schuman, 1968). In addition there is only occasional and mild support for the claim that drivers who had drivers' training have less accidents (Harrington, 1972), and such results are often subject to the problem of "self-selection"—good drivers choose to take (or are afforded the opportunity of taking) driver training.

These findings suggest that while lack of minimal experience and knowledge may account for minor accidents and violations, it cannot account for an increase in crashes identified by Pelz and Schuman, nor the fact that poorer driving records occur over the entire nine year age span from 16 to 25. Apparently, other factors besides experience alone are responsible for the importance of the demographic characteristic of age; one possibility to be discussed later is that this age period is accompanied by a number of life changes and stress (e.g., employment, marriage, moving, etc.) which may produce personal adjustment problems. Thus, while experience may be a contributing factor for a short time, it is probably not the cornerstone of a very strong theory.

A similar idea is that drivers with poor prior driving records are likely to be poor drivers in the future due to poor driving techniques which have developed. Mild support for this idea has been found by many researchers including Schuster (1968), Crancer (1967), Coppin, McBride and Peck (1967); however, lack of control for exposure limits the generalizability of such findings, nor do such findings provide useful information on the underlying causes of chronic poor driving.

The Drunk/Drugged Driver Theory

The drunk/drugged driver theory states that accidents are largely due to temporarily impaired mental efficiency due to consumption of alcohol or drugs. Almost without exception, studies of this issue have found the group of accident drivers contains a disproportionate number of DUI/DWI people and/or chronic problem drinkers (Baker, 1970; Barmack and Payne, 1961; Finch and Smith, 1970). Because of the importance of this factor it has received more attention than any other factor; however, as an explanation, the drunk/drugged theory is inadequate because it offers no explanation of why drivers drink or why they mix drinking and driving. The next theories view drinking as a manifestation of deeper causes, and therefore, we now turn to them.

Social Maladjustment Theory

The social maladjustment theory, first popularized by Tillman and Hobbes (1949), states that problem drivers are people who show a pattern of conflicts with society and social institutions; i.e., are people who do not feel part of society and who do not feel a strong degree of social responsibility. Such people are more apt to drive irresponsibly (i.e., dangerously) because they do not feel a part of society's rules, have fallen into a pattern of rule-breaking which extends into their on-road behaviors, and hence, they are likely to be over-represented in the pool of accident/violation drivers. They are likely to be characterized as aggressive, hostile, anti-social, irresponsible, non-conforming. The fact that drivers of lower socio-economic status (SES)—as measured by the demographics of low income, low occupational level, low educational level—tend to have more accidents/violations is consistent with the social maladjustment theory only if it can be shown that low SES drivers, on the average, feel less a part of society and less responsible to society. Unfortunately, studies which investigate the role of social adjustment while controlling SES or which investigate the role of SES while controlling for social adjustment are not available; so the problem of confounding is present in the studies presented below, and should be considered.

Biographic Data: There is a wealth of information concerning the social adjustment idea, based mainly on comparing the biographic characteristics of "problem" drivers with normal drivers. For example, in the classic Tillman and Hobbes (1949) study of Canadian taxi drivers, the biographic records of 96 accident repeaters were compared with 100 matched controls. The table below shows that problem drivers were far more likely to have a history of contact with social institutions including adult court, credit bureaus, juvenile court, public health agencies, and social service agencies.

	Adult Court	Credit Bureau	Juvenile Court	Public Health	Social Service	At Least One
Repeaters	34%	34%	17%	14%	18%	66%
Controls	1%	6%	1%	0%	1%	9%

In what was essentially a validation study, McFarland and Moseley (1954) attempted to predict future accidents by using a measure of social maladjustment based on biographic factors such as repeated contact with social agencies, truancy, poor employment record, non-traffic arrest, broken home, etc., as well as prior driving record. Based on these factors, U.S. truck drivers having three or more accidents in one year were reliably distinguishable from those having two or less. Thus, a history of conflicts with social institutions seems to be related to on-road behaviors; however, one problem with these studies is that they involved unusual drivers—taxi and truck drivers—and thus, their generality may be questioned.

Replicative support involving "normal" car drivers is available and seems to be consistent with the above results. For example, Crancer and McMurray (1968) investigated the driving records of 415 automobile drivers who had good credit ratings vs. the driving records of 339 drivers who had poor credit ratings. The importance of factors indicating social adjustment was again demonstrated in the finding that a significantly higher accident rate was obtained in the poor credit rating group. In an earlier study, Dennis (1930) developed a measure of "good citizenship" based on twenty biographic traits. As would be predicted by the social adjustment theory, non-accident drivers obtained the highest average score, drivers involved in non-reckless crashes had the next highest average score, and drivers who caused accidents due to recklessness had the lowest citizenship scores. Further supporting evidence for the social adjustment theory comes from studies focusing on young drivers which show that problem drivers differ from general drivers by having more academic and discipline problems in school (Carlson and Klein, 1970; Asher and Dodson, 1970; Harrington, 1972; Kraus et. al., 1970; Pelz and Schuman, 1968), a rebellious attitude towards parents and leaving home (Rommel, 1959; Harrington, 1972), parents who do not participate in community activities or who have a criminal record (Tillman and Hobbes, 1949; Carlson and Klein, 1970; Beamish and Malfetti, 1962), a lower grade in "Citizenship" in high school (Harrington, 1972), a history of violent behavior (Pelz and Schuman, 1968), less automobile liability insurance (Coppin and Van Oldenbeck, 1966), poor job stability (Heath, 1959; Brody, 1957), a non-traffic criminal record (Kraus et. al., 1970; Willett, 1964; Barmack and Payne, 1961). Thus with professional drivers, young drivers and general drivers there is consistent and reliable evidence that a history of anti-social behaviors is related, at least moderately, to driving behavior.

Attitudes: Attitude tests concerning aggression and hostility against society provide a further source of information. Intensive interviews by Tillman and Hobbes (1949) of twenty accident repeaters and twenty controls revealed an attitude of intolerance and aggression towards authority on the part of poor drivers. Goldstein and Mosel's (1956) factor analysis of the Driver Attitude Inventory indicated a reliable correlation between a cluster of questions measuring competitiveness-aggressiveness and violations or accidents for a group of 254 male drivers; similar findings were obtained for female drivers but the correlations were not statistically significant due to small sample size. Similarly, Selzer and Vinokur (1974) obtained a mild but reliable correlation between aggressive attitudes and accidents. In interviews and tests of the attitudes of young drivers, problem drivers scored reliably higher on questions involving anger, rebellion, and hostility (Pelz and Schuman, 1971) and lower in "conformity" (Beamish and Malfetti, 1962); similarly, Levonian (1969) found that the attitude of orienting towards self benefit at the expense of others was significantly correlated with traffic violations for a group of over 1000 10th grade students, even when controlling for sex, exposure, SES, and other personality measures. Finally, intensive analyses of six truck drivers, recognized for their driving excellence including 20 years of safe driving, indicated that they differed from the norm neither in physical nor intellectual traits, but rather in the personality characteristic of social stability and conformity (Malfetti and Fine, 1962). One problem with taking attitude measures from groups of known poor or good drivers is that a driver's record may influence his attitudes, e.g., poor drivers may try to justify their records, and there has been insufficient work in validating attitude scores against **future** driving. For example, a study of young drivers in Michigan (Kenel, 1967; O'Leary, 1971) revealed that the Mann Attitude Inventory—measuring aggressiveness—and driver training instructors' ratings of aggressiveness related to future violations, for 24 and 60 months after testing and for accidents 24 months after testing. However, these findings taken as a whole are consistent with the social adjustment theory and provide an independent line of support.

Personality: A third source of information concerning the social adjustment theory is studies comparing the personality test scores of problem and general drivers. McGuire (1956a; 1956b) gave items from the Minnesota Multiphasic Personality Inventory (MMPI) to matched groups of Marines and found that the most important scale for distinguishing problem drivers from non-problem drivers was the Psychopathic Deviate scale (Pd)—a scale designed to measure anti-social tendencies or deviance from social norms. Similarly, Rommel (1959) found that poor, young drivers scored reliably higher than matched controls on the Pd scale and the Ma scale (Hypomania or excess activity). Brown and Berdie (1967) gave the MMPI to 993 male college students and found a very small but reliable correlation between accident/violation rates and score on the Pd scale; only the Pd scale was able to distinguish the 100 best from the 100 worst drivers in the group. In a study of U.S. Airmen (Conger, et. al., 1957, 1959) the Pd scale distinguished accident repeaters from non-repeaters with marginal reliability, but failed to do so in a follow-up study. It is interesting to note that the only scale on the MMPI which has consistently been found to be related to poor driving is the scale which measures deviance from social norms, or what could be called social maladjustment. It is of particular significance that the Pd scale was not designed to locate problem drivers, nor does it investigate primarily driver-related areas—thus the fact that it does reliably distinguish problem from general drivers is an independent source of support for the social adjustment theory. Unfortunately, as a driver screening test the Pd scale still is far too weak and inaccurate to be used (Miller and Dimling, 1969), but as an independent support for the social adjustment theory it is valuable.

Other tests have also been used with less replicative support. For example Shaw and Sichel (1972) report a study of accidents of South African bus drivers who were given projective tests such as the Thematic Apperception Test (TAT). The correlation between what was called the E-factor (measuring social irresponsibility, anti-social tendencies, psychopathic deviance, lack of control and impulsivity) and the number of accidents was an astounding r = .61. This relation is considerably higher than other correlations cited in similar studies and may be due to the power of combining a set of measures into the single E-factor, or to a peculiarity in the way the TAT was administered and scored. Further replications, especially with typical automobile drivers, are needed before accepting these findings.

In three separate studies involving U.S. Airmen, Conger et. al. (1957, 1959) found that the Allport-Vernon Study of Values test successfully distinguished repeaters from non-repeaters. Accident drivers scored lower in Religious Values—which Conger et. al. suggest reflect conventional social mores—and higher in Aesthetic and Theoretical Values—reflecting more sophisticated, and possibly non-conventional mores.

There have also been failures to distinguish problem drivers from general drivers based on standardized tests of social traits such as extroversion (Quenalt, 1967), and others (Preston and Harris, 1965), and as Goldstein (1962) has pointed out, many of the relationships involving personality characteristics are quite weak. However, there seems to be considerable evidence that tests measuring anti-social tendencies do distinguish problem from general drivers, and continued replication especially involving predictive validation of such findings would provide a badly needed independent line of support for the social adjustment theory.

Apparently, the existing findings suggest that problem drivers tend to feel less social responsibility and less affiliation with social rules, on the average, than general drivers. Further research in this area should be directed towards determining how these measures of social adjustment relate to demographic characteristics, especially SES, whether drivers scoring high in social maladjustment are more apt to be involved only in certain **types** of accidents or all types of accidents equally, and whether special training and remedial techniques can be developed for this type of problem driver.

Personal Maladjustment Theory

A second theory which attempts to get at the "root" cause of accidents is the personal maladjustment theory, the idea that accident drivers are people under personal stress going through a difficult period in their lives. The personal pressures facing the driver may reduce his driving judgment or decision making ability, or may actually be intense enough to manifest itself as a suicide wish while driving, and thus result in higher accident/violation rates. Such drivers are likely to be characterized as emotionally unstable, depressed, anxious, neurotic.

Biographic Data: As with the social adjustment theory, there is also an impressive research literature concerning the personal adjustment idea, based on comparing the biographic characteristics of problem and normal drivers. Both the stress related to "life changes" and stress related to immediately preceding events affecting "pre-crash state" have received close attention. For example, Selzer, Rogers, and Kern (1968) compared the life change stresses impinging on 96 driver fatalities vs. 96 matched controls and Brown and Bohnert (1968) did the same for 25 driver fatalities vs. 25 matched controls. The table below shows that the fatal drivers as a group were more apt to be under personal stress due to personal and interpersonal conflicts, personal tragedy or loss of dear one, job problems, or financial problems.

Seltzer et. al.	Personal Conflict	Personal Tragedy	Job Problems	Financial Problems	One or More Stresses
Fatalities	32%	9%	30%	10%	53%
Controls	7%	5%	4%	7%	18%

Brown & Bohnert	Inter-personal Problem	Loss of Dear One	Job Problems	Financial Problems	One or More Stresses
Fatalities	56%	16%	40%	40%	80%
Controls	12%	0%	8%	8%	12%

Such results provide solid support for the idea that drivers who have personal problems may drive in a way to hurt themselves; however, since fatalities represent such a small, and perhaps atypical number of accidents, the generality of such results may be called into question. A further problem with investigations of fatal crashes is that first hand data may not be collected, and researchers must rely on interviews with those who knew the deceased.

For these reasons it is particularly important to investigate the role of life changes and other stress-arousing events related to non-fatal accidents. McMurray (1968) investigated the driving records of 410 drivers who obtained divorces in order to determine whether the stress produced by the divorce proceedings affected driving behavior. The accident/violation rates of divorced persons for the six months before and after the court proceedings were reliably higher than the average. Schuman, Pelz, Ehrlich, and Selzer (1967) found that young drivers who were married and working full time had reliably more accidents than young drivers who did not have to adjust to a new marriage or new job; in a followup study it was also found that life changes such as change in marital status, new responsibilities, family events, and change in job, each related to poor driving records for young males (Pelz and Schuman, 1971). Similarly, a recent study by Selzer and Vinokur (1974) obtained a small but reliable correlation between measures of traumatic life events and stresses and number of accidents. Thus, the findings in studies of non-fatal accidents seem to be consistent with that of fatal accidents—personal problems and accidents seem to happen together.

Many researchers have also reported that a disproportionate number of problem drivers incurred personally upsetting events such as an argument or bad news within 24 hours of the crash (Selzer, Rogers, and Kern, 1968; Brown and Bohnert, 1968). In comparing the pre-crash state of 25 fatal drivers and 25 controls, Finch and Smith (1970) reported that fatal drivers were more apt to have been feeling suicidal, depressed or angry and less apt to have been in a normal emotional state. Selzer, Rogers and Kern (1968) also found that fatal drivers were more apt to have been in suicidal, depressed, or violent states as compared to controls. The life stresses idea has been underlined by Paykel's (1969) argument that adjustment to life changes is closely related to clinical depression and emotional unstability.

Such results suggest that personally troubled persons may be driving poorly as an expression of depression or even suicidal tendencies. Adams (1972) reported a correlation of r=.86 between per capita accident rate and suicide rate for selected localities; this indicates geographic localities with high suicide rates also tend to have high accident rates, but no causal inferences may be drawn. Crancer and Quiring (1968) investigated the driving records of 438 persons hospitalized for suicide attempts. The suicide group had almost twice the accident rate and twice the violation rate of the general population; in addition, the suicide group tended to have more serious accidents (injury/fatality) and more serious violations (automatic mandatory license suspension) than the general population. Similar results were also obtained with suicide patients studied by Selzer and Payne (1962) and by MacDonald (1964). The suicide idea is also consistent with the finding of Sterling-Smith and Fell (1973) that of 75 drivers who killed themselves in automobile accidents, 50 died in single car accidents. In addition, of 110 drivers who were responsible for crashes involving fatal injury, 21 (19%) had documented suicide histories; however, the suicide idea seems inconsistent with the additional puzzling finding that drivers who killed others were more likely to have a suicide history than drivers who killed themselves. These findings taken together strongly imply a relation between suicide history and problem driving behaviors, and since depression and suicidal tendencies may be the result of unsuccessful adjustment to life changes, life changes may be related to crashes.

Attitudes and Personality: To complement the biographic measures of personal maladjustment (e.g., life stresses and changes) a second source of information involves the relationship between driving behavior and personality test scales for personal adjustment. An early study conducted by the ENO Foundation (1948) found that accident repeaters received higher scores in personal instability on the Cornell Word Forms Test than did accident-free drivers. In comparing 84 young male traffic offenders with two or more accidents with 186 drivers matched for age and sex, Beamish and Malfetti (1962) found a significant difference in the emotional stability of the two groups, and in a study comparing young drivers who were fatally injured in accidents with matched controls Kaestner (1964) also noted a difference in the emotional maturity of the two groups. More recently, Selzer and Vinokur (1974) obtained mild but reliable correlations between scores on a test of manifest anxiety and number of accidents. One reason the correlation was low could have been the distribution of accident frequencies; if most drivers had very few accidents then correlation may not be the best indicator of a relationship and a comparison of anxiety test scores of accident repeaters vs. non-repeaters may have been more informative. In a study involving more accidents, Shaw and Sichel (1972) report the results of an investigation of the correlation between accidents sustained by South African bus drivers and their scores on the TAT. The N-factor, consisting of measures of neuroticism, anxiety, depression, etc., correlated $r = .47$ with number of accidents. However, Quenalt (1967) failed to obtain reliability for the "neuroticism" scale of the Maudsley Personality Inventory, and as has been discussed in the previous section, the personal adjustment scales of the MMPI do not seem to distinguish accident from general drivers. Thus, personality measures of anxiety and depression offer mixed support for the personal maladjustment idea, with some indication that emotional unstability often is related to poorer driving behavior.

In the "psychological autopsy" studies of fatally injured drivers, fatal drivers were judged significantly higher than matched controls in personality disorders or general psychopathology (Finch and Smith, 1970; Selzer, Rogers, and Kern, 1968). The Katz Adjustment Scales (KAS) have been used in a number of psychological autopsy studies to investigate the personality characteristics of fatal drivers (Fischer, 1972; Shaffer et. al., 1972, 1974; Schmidt et. al., 1972). Drivers who killed themselves in crashes scored reliably higher in general psychopathology, belligerence, negativism, hyperactivity, and lower in withdrawal than norms. The idea that anxiety may manifest itself as a sort of suicide gesture while driving was supported by the finding that non-traffic suicide victims showed a similar but stronger KAS profile as compared to fatal drivers, and that fatal drivers involved in single car accidents were significantly higher than the norms in general psychopathology and the other disorders listed above, while fatal drivers involved in multi-car accidents did not differ reliably from the norms. Although there are serious methodological problems in administering the KAS, e.g., the tendency for respondents to "justify" the fatal driver's behavior, these results do provide striking independent support for the personal adjustment theory. Adams (1972) suggests that suicide may not necessarily be the goal of some troubled persons; rather, drivers with personal problems may be attempting only to injure themselves and thus make their problems "acceptable" or "justifiable." Unfortunately, there are insufficient data available to directly interrogate this suggestion.

These findings do, however, strongly suggest that inability to adjust to personal problems, stress and anxiety, is an important factor—at least in some cases—influencing driving behavior. Especially noteworthy is the suggestion that, in some cases, reckless driving may be a manifestation of anti-personal feelings, just as it was suggested in the previous section that some cases of poor driving may be manifestations of anti-social feelings.

Impulse Non-Control Theory

Although drivers may possess intense anti-social or anti-self dispositions, the ability to control these and related impulses may be another factor influencing driving behavior. The impulse non-control theory states that some drivers are less able to control their impulses while driving, more apt to allow driving to serve as an emotional release, and thus more likely to engage in accident related behaviors. For example, Klein (1974) has suggested that some drivers may have no outlets for their expressions of independence and achievement (e.g., lower SES workers on routine, fixed jobs) and thus use driving to express emotions which have to be repressed elsewhere.

Biographic Data and Attitudes: The relationship between biographic information concerning impulse control and accidents is one source of data. A questionnaire developed by Pelz and Schuman (1968) was given to young drivers, and it was found that problem drivers had a history of poor impulse control, that they more easily expressed impulses (e.g., had been in fist fight recently), that they derived emotional release from driving (e.g., drive to "blow off steam"), and that they felt powerful while driving (e.g., customized and raced cars) as compared to other young drivers. In line with Klein's idea, young problem drivers were more apt to be in low paying, routine jobs rather than in school (i.e., less chance to express independence and achievement).

Other attitude inventories given to young drivers reveal that problem drivers more often than non-problem drivers view driving as tension releasing, ego-building, and as a way of making oneself powerful (Rommel, 1959); a source of pleasure (Asher and Dodson, 1970); a way to avoid feeling held down and a way not to have to consider the consequences of one's behavior (Beamish and Malfetti, 1962); and as a way to escape worries and tension (Harrington, 1972). Unfortunately, the bulk of these studies concerns drivers under 25 years old; thus the generality of the impulse control factor can be questioned. Furthermore, since most of these studies involve questioning known groups of poor drivers, it is possible that "impulsive" attitudes were formed as consequence of—or means of justifying—poor driving records. Clearly, the strength of the impulse non-control theory would be increased by predictive or validational studies conducted on the general driving population.

Personality: Personality tests for impulsivity have also been related to driving behavior. For example, the impulsivity scale of the Thurstone Temperment Schedule was found to be related to accidents (Heath, 1959). Conger et. al. (1959) reported that inability to control hostility or tolerate tension was a main factor distinguishing poor and good drivers, and Whittenberg, Pain, McBride and Amidei (1972) also report several studies in which measures of inability to control hostility and tension were related to accident rates (Hertz, 1970). Measures of manifest aggressiveness and impulsivity correlated with number of accidents in Selzer and Vinokur's (1974) study, and impulsivity was a factor used in the design of other tests of driving (McGuire, 1956; Schuster and Guilford, 1964; Haner, 1963). Although impulsivity score has not been strong enough to merit use as a single criteria of driver selection, the fact that high impulsive drivers tend to have poor driving records provides support for the impulse non-control theory, and adds another **type** of poor driver.

Information Processing Defect Theory

Another factor which may underlie driving behavior is the perceptual and motor ability of the driver. The information-processing or perceptual-motor skill theory states that problem drivers may have accidents due to information processing problems such as difficulty in recognizing relevant stimuli, in processing them effectively and in performing the required motor response. Perceptual-motor deficiencies may be a factor responsible for the disproportionately high number of accidents/violations obtained by drivers over the age of 60; however, there is insufficient data to test this idea.

Perception Processes: One source of information involves tests of perceptual ability. An early ENO Foundation report (1948) compared serious accident repeaters with a matched group of accident-free drivers on a series of perceptual tasks. Reliable differences favoring the accident-free group were obtained for some tests—e.g., acuity with both eyes, depth perception, resistence to fatigue—but no differences were obtained for other factors—e.g., dark adaptation, peripheral perception. More recently, Burg and Henderson (Burg, 1972; Henderson and Burg, 1973; Henderson, Burg, and Brazelton, 1971) have reported that several tests of dynamic vision given to a sample of California drivers were reliably related to accident/violation rates. Although the differences were not great in these studies, and although there was no good explanation of why some tests "work" and some do not, such findings do suggest that further study of perceptual factors is warranted.

Decision Processes: A second source of information involves tests of general cognitive ability such as decision making and intelligence. Cobb (1939) and Shaw and Sichel (1972) report studies in which small negative correlations between accident rate and intelligence tests score were obtained. However, there are also instances of no relationship (e.g., Farmer and Chambers, 1939). Thus, there is insufficient evidence at this time to draw any strong conclusions concerning cognitive abilities, but it seems appropriate that future research be directed towards measures of cognitive ability that are more closely related to driving, such as decision making.

Response Processes: Finally, tests of human performance have received some attention. For example, on a test of moving a long stylus through a narrow winding pathway without touching the sides of the path, accident repeaters made twice as many errors as a group of matched controls (Eno Foundation, 1948). A small negative correlation between reaction time and accident rate was reported by Shaw and Sichel (1972). In addition, Miller and Dimling (1969) have reviewed a series of experiments involving driving simulators and other driving performance devices, and suggest that there has been some success in relating various human performance abilities to driving ability.

Unfortunately, perceptual-motor theory still lacks a rich body of research literature, but it seems to be a good candidate for further study, and may produce yet another type of problem driver.

2.3.4 Dependent Variables: Risk Taking, Poor Decision Making, Poor Recognition and Poor Motor Skill

Most of the studies of the "human factors problem" as applied to highway safety research have relied on criteria of driving performance, such as accident and/or violation rates. In this section, it is suggested that a richer understanding could be achieved by analyzing problem driving behaviors into various **types**. The traits and conditions existing within a person—such as those described in the preceding section—may be translated into certain driving styles or patterns once one gets behind the wheel. The basic types of driving styles or propensity under primary consideration in the present section are risk taking, poor decision making, and poor recognition or motor skills.

Risk Taking

Risk taking refers to the intentional creation of a dangerous situation by the driver. Much progress has been made in the development and successful use of a taxonomy of human driving behaviors which cause or influence the severity of crashes (consult: Institute for Research in Public Safety, 1973). Based on data collected by IRPS, the most common risk taking behaviors seem to be excessive speed, improper maneuver, improper driving technique, and insufficiently defensive driving. Cluster analytic techniques and other possible coding systems are required to determine exactly which behaviors best characterize risk taking, and the propensities discussed below.

Poor Decision Making

Poor decision making refers to drivers making improper decisions about what response to make to dangerous situations once they are recognized. Based on data collected by IRPS, the most common poor decision behaviors are improper evasive action and false assumption. (For purposes of this section, "excessive speed" is considered a "risk-taking" factor rather than a decision error).

Poor Recognition Skill

Poor perceptual or recognition skill refers to improper processing of stimuli necessary for recognition of a dangerous situation. Common recognition problems cited by IRPS are internal distraction, improper lookout, and inattention.

Poor Motor Performance Skill

Poor motor performance refers to improper execution of responses which have been determined necessary by a driver for remediation of a dangerous situation. The most common driving behaviors cited by IRPS which seem to imply poor motor control are overcompensation and inadequate directional control.

2.3.5 Resultant Plan for Future Research

Based on the literature review, suggestions were made here for a series of related studies—some of which were then performed by IRPS under this contract, as reported further on in the section.

The recommended sequence is as follows:

1. A preliminary test of several theories derived from the literature review, comparing high and no-accident drivers.
2. A follow-up validation of the above study, if the expected relationships emerge.
3. A pilot study using information already collected in the course of past IRPS in-depth investigations. Existing questions on IRPS' in-depth human factors form will be used to form ad hoc scales for such measures as personal and social maladjustment.
4. A study in which an entire battery of questions specifically designed around these scales are prospectively given to a stratified, representative sample of the general driving population, while also collecting data on previous crashes and violations.
5. A final, major study in which the entire revised battery is administered to a representative sample of accident-involved drivers (as part of a series of prospective, in-depth investigations). The objective here would be to examine in detail the extent to which different types of accident causing behaviors are related to different basic human traits. At least 50 to 100 accident drivers would be included. A follow-up study would monitor driving records for a future period, to determine the predictive validity of the measures used.

Studies one, two, and three from the list above were completed as part of this project, and are reported later in this section. Note that studies four and five were in no way within the scope of the current contract, and are merely recommendations for future research.

The following discussion provides added details on studies three, four, and five from the above list.

General Approach and Background

Table 2-18 shows the basic human characteristics and traits (independent variables) which may be related to various on-road behaviors characteristic of risk-taking, poor decision making, and poor perceptual-motor skill (dependent variables). One direction for future research suggested by this review is to determine which human traits are related to which types of driving behaviors; for example, whether information processing deficiencies are related mainly to poor recognition and motor performance driving errors or whether social maladjustment is related mainly to risk taking behaviors, etc.

Thus instead of asking, "How do each of several dozen human characteristics relate to having accidents/violations?", the proposed study asks, "How do these few basic human traits and conditions relate to various types of driving behaviors characteristic of risk takers, poor decision makers, poor recognizers and poorly skilled drivers?" Rather than attempt to validate a measurement device for the "problem driver" against accident/violation rate, the proposed study will investigate the possibility of generating several scales for different **types** of problem drivers.

The general design of these studies, as indicated below, is to use as independent variables each driver's score on various demographic and biographic questionnaires, and personality,

Table 2-18

Development of Independent and Dependent Variables

OBSERVABLE HUMAN CHARACTERISTICS	INTERNAL HUMAN TRAITS (IVs)	DRIVING PROPENSITY	DRIVING BEHAVIOR (DVs)
Demographic & biographic data	Demography	Risk taking	Excessive speed Improper maneuver Improper driving technique
Records with social institutions	Driving experience & record		
Personal data	Alcohol/drug usage	Poor decision making	Improper evasive action False assumption
	Social adjustment		
Personality test scores	Personal adjustment	Poor recognizing and motor skill	Inattention Improper lookout Internal distraction View obstruction
Attitude test scores	Impulse control		
Perceptual-Motor skill test scores	Inadequate information processing		Overcompensation Inadequate directional control

attitudinal and perceptual-skill tests, and to use as dependent variables a classification of the specific driving behaviors engaged in by accident drivers.

Human Traits (Independent Variables)

1. Demographic Characteristics
   a. Age
   b. Sex
   c. Marital Status
   d. Socio-economic Status
   e. Etc.
2. Experience/Exposure/Familiarity
   a. Driver Knowledge
   b. Driver Experience
   c. Driver Exposure
   d. Prior accidents and violations
3. Alcoholism/Chronic Drug Use
4. Personal Adjustment
   a. Presence of stressful life changes and situations
   b. Type N personality traits: depressive, anxious, emotionally unstable
5. Social Adjustment
   a. Record of anti-social behaviors, contacts with social agencies, social non-participation
   b. Type E personality traits: anti-sociability, hostility, psychopathic deviation, aggressiveness
6. Impulse Control
   a. Record of impulsive behaviors, especially while driving.
   b. Type R personality traits: impulsiveness, rigidity, repression.
7. Perceptual-Motor Skill
   a. Perceptual speed/accuracy
   b. Spacial relations

Driver Behaviors (Dependent Variables)

1. Risk taking behaviors
   a. Excessive speed
   b. Improper maneuver
   c. Improper driving technique
   d. Improper defensive driving

2. Poor decision making behaviors
   a. Improper evasive action
   b. False assumption
3. Poor recognition behaviors
   a. Inattention
   b. Improper lookout
   c. View obstruction
   d. Internal distraction
4. Poor skill behaviors
   a. Overcompensation
   b. Inadequate directional control

The final materials required for "Study 5" are obviously not yet known. However, the following would be used as a starting point in the development of needed materials for "Study 4." For "Study 4," demographic information will be collected using a standard questionnaire (shown in Appendix C). Driving knowledge will be assessed using items from NHTSA's list of driver knowledge questions (see Table 2-11) and driver experience, exposure, familiarity and prior accident/violation record will be obtained from a standard questionnaire (Appendix D). Alcoholism and drug usage will be ascertained by means of a standard questionnaire (Appendix E), and, if necessary, the Michigan Alcoholism Screening Test (MAST). Personal adjustment will be assessed by a biographical questionnaire concerning life changes and stresses (Appendix F) and by selected items from anxiety, depression, or emotional unstability scales of existing standardized personality tests such as the California Psychological Inventory "Depression" Scale (Appendix G). Social adjustment will be assessed by a biographical questionnaire concerning conflicts with social agencies and institutions, social instability, social non-participation (Appendix H), and by selected items from socialization, hostility and psychopathic deviation scales of existing driver attitude inventories and standardized personality tests such as the MMPI's Pd Scale or CPI "Socialization" scale (Appendix I). Impulse control will be assessed by a biographic questionnaire concerning control of impulses and emotional release with cars, such as the Pelz-Schuman test (Appendix J), and by modifying scales from existing attitudinal and personality tests such as Rotter's Internal-External Control Scale or the CPI's "Impulsivity Scale" (Appendix K). Perceptual motor skill will be measured by the Dynamic Vision Tester, and paper-and-pencil tests of perceptual speed/accuracy such as the Minnesota Clerical and of spacial relations such as the Minnesota Paper Form Board (Appendix L).

Forms and procedures for determination of driver behaviors which cause or influence the severity of accidents have been developed as part of the present study (see Vol. I, Sec. 2.0).

Study Three

A pilot study will use in-depth accident data on file at the Institute for Research in Public Safety. These files contain some information concerning human characteristics of the **accident-involved** drivers, and a detailed assignment of causal factors for human errors committed by accident involved drivers. The objective of this study is to provide preliminary information concerning the relationship between driver traits and driver behaviors, with special focus on determining whether drivers with certain traits are more apt to engage in risk taking, or poor decision making, or poor perceptual and motor skill behaviors. The results of Study 3 will take advantage of existing data and help in designing details of further studies. Scales for each of the independent variables will be derived from questions on the In-Depth Human Factors Form, the Pelz-Schuman Test, the Driver Knowledge Test, and the Dynamic Vision Test (Appendix M).

Although there are no specific tests of personal adjustment, social adjustment, or impulse control, the following sets of questions may be used to form ad hoc scales for each: For personal adjustment, questions concerning emotional strain (#28), arguments (#29), manifest anxiety (#30-34), life problems (#35-38), smoking (#101), worry (#217), perceived pressure (#232-235), chronic illness (#12). For social adjustment, questions concerning job stability (#10-11), marital stability (#14-15), residence stability (#17-18), social participation (#39), completion of school (#203), anger (#220, #228-231). For impulsivity, social influences on risk taking (#204-206), dangerous driving (#210, 213), driving as emotional release (#222-227, #236-239), feelings of repression (#231-235), restraint use (#73). The dependent variables (driving behaviors) are coded in the data, thus allowing an analysis of the relationship between driver traits and type of driving behavior.

Study Four

A second study involves giving the entire, revised battery of questionnaires and tests described in the above section to a stratified, representative sample of the general driving population, while also collecting data concerning previous traffic crashes and violations. Drivers participating in this study should be paid for their cooperation, and the drivers selected should be stratified for age and sex to represent the general driving population. At least 50 to 100 drivers should take part in Study 4. Specific information concerning the **type** of accident, **type** of violation, and **type** of driver behaviors contributing to the crash or violation will be collected, following the format of dependent variables indicated above. The same type of analysis as above will be performed. One objective of this study is to provide a replication of Study 3 and to test (and revise) the questionnaires and tests which will be used in these studies. A second objective is to provide control group norms for Study 5.

Study Five

The fifth, and major study involves giving the entire revised battery to a representative sample of accident-involved drivers, as well as collecting the usual detailed in-depth analyses of the causal and severity-increasing factors attributable to the driver. Drivers participating in this study should be well paid for their cooperation, and at least 50 to 100 drivers should take part in Study 5. This study will provide the most detailed data available concerning whether different types of accident-causing behaviors are related to different basic human traits; or more specifically, whether, drivers who score high in personal maladjustment, social maladjustment, impulse non-control, perceptual-motor deficiency, etc., are over-represented in groups of drivers committing risk taking, poor decision making, poor perceptual or skilled driving errors. A further follow-up study would be to monitor the driving records of those involved in Study 5 for a future period (e.g., 24 months); this would provide data that could be used to determine the predictive validity of the measures used.

Implications of Studies

The proposed investigations would provide a level of analysis rarely achieved in the traffic safety field, and could generate the bases for useful tests of specific types of driving behaviors such as risk taking, poor decision making or poor perceptual-motor-skill. The development of tests for prediction of specific classes of problem drivers—rather than "the problem driver"—would have immediate implications for diagnosing, training, retraining, remedial and persuasion programs. Drivers tending to make different kinds of errors, for different kinds of reasons, could be reached by different instructional techniques, different persuasive arguments, and different remedial programs. The development of tests of specific kinds of driving propensities would also help advance the field of knowledge in the traffic safety area by clarifying questions raised by the extremely weak relations often obtained between theoretically interesting human factors and accident/violation rates. A better understanding of existing theories would also likely lead to improved remedial and training innovations in general.

2.3.6 Preliminary Study (Study No. 1)

Identification of the distinguishable and theoretically interesting characteristics of high risk drivers (e.g., drivers involved in three or more accidents in a three-year period) would yield an important first step in establishing countermeasures—possibly including recommendations for road and vehicle design and maintenance, and for driver training, licensing, and employment.

The present study was designed to provide information on four potentially important theories of accident causation which are suggested by the foregoing review of the literature: (1) the "social maladjustment theory" posits that poor driving is just one facet of a more general pattern of anti-social or irresponsible behavior and attitudes (e.g., Tillman & Hobbes, 1949); (2) the "personal maladjustment theory" posits that accident drivers are more likely to be people under personal stress going through difficult periods in their lives (Brown & Bohnert, 1968; Selzer, Rogers, & Kern, 1968); (3) the "impulse non-control theory" suggests that poor drivers are less able to cope with risk-taking impulses while driving and thus are more likely to allow driving to serve as an emotional release (Klein, 1974); (4) the "information processing defect theory" suggests that poor drivers lack efficient perceptual/motor speed and accuracy.

This preliminary study was conducted to compare a group of young accident repeaters with a matched group of non-accident drivers with respect to alcohol-drug use, personal adjustment, social adjustment, impulsivity and clerical ability. Based on the foregoing literature review and analyses, test scales were constructed which for theoretical reasons had been hypothesized to relate to recognition errors, decision errors, and risk-taking behaviors involved in traffic accidents. This study should be considered preliminary since its results and conclusions are based on a non-representative sample of the driving population, i.e., college students.

2.3.6.1 Methodology

Subjects and Design. Four hundred Indiana University freshman students who were licensed drivers between the ages of 18 and 19 inclusive served as subjects in order to fulfill a requirement for their Introductory Psychology course. Subjects who reported being involved (regardless of fault) in three or more traffic accidents as a driver during the prior three years were classified as the High Accident Group (N = 23), and a No-Accident Group (N = 23), matched for age, sex and average annual mileage, was selected from the pool of subjects who reported no accidents during the prior three years. There were 13 males and 10 females in each group.

Materials. A 24-page questionnaire was developed which consisted of two basic information sections, twenty short untimed test scales, and two timed tests of three minutes each. The tests are described below.

1. Basic Demographic Information: consisted of 12 questions concerning age, sex, marital status, income, education, etc.

2. Basic Driving Record: consisted of 10 questions concerning average annual mileage, total number of years as a licensed driver, traffic violation history, traffic accident history including description of driver's "errors", damage, configuration.

3. Alcohol and Drug Use: consisted of four questions concerning tranquilizer, cigarette and alcohol usage.

4. Manifest Anxiety: consisted of 11-item checklist of manifest anxiety, such as headaches, stomach aches, etc., adapted from Selzer and Vinokur (1974), and from items from the MMPI.

5. Citizenship: consisted of 6 questions concerning voting frequency, church attendance, club meeting attendance.

6. Social Participation: asked subjects to list all club or organizations they belonged to during past five years and the extent of their participation.

7. School Socialization: asked subjects to check "often", "sometimes", "rarely" or "never" for 15 such school-related events such as playing hooky, receiving awards, getting suspended, having conflicts with teachers, etc.

8. Juvenile Delinquency: 9-item checklist consisting of regular cigarette smoking before age 17, juvenile arrests and convictions, running away, full-time job during school year, school drop out, etc.

9. Life Changes: 23-item checklist of current changes involving getting married, trouble with parents, death of friend, school problems, financial change, etc., adapted from Selzer and Vinokur (1974).

10-13. Katz Adjustment Scales: asked subjects to check "almost never", "sometimes", "often", "almost always" to 44 behaviors occurring during the past six months; consisted of the following four scales adapted from Katz and Liverly (1963).

10. General Psychopathology: consisted of 24 questions such as "Felt people didn't care about me," "Had mood changes without reason," "Acted confused," "Behavior was childish," etc.

11. Belligerence: consisted of 4 questions such as "Got angry and broke things," "Got into fights with people," etc.

12. Negativism: consisted of 9 questions such as "Was stubborn" and "Did the opposite of what was asked."

13. Withdrawal: consisted of 6 questions such as "Was very slow to react" and "Was quiet."

14. Anti-Social Tendencies: consisted of 20 yes-no items selected from the Pd scale of the MMPI and Socialization scale of the CPI, such as "My parents often objected to the kind of people I went around with," or "My way of doing things is apt to be misunderstood by others."

15. Anxiety: consisted of 10 yes-no items selected from the MMPI and CPI such as "I find it hard to keep my mind on a task or job," or "I work under a great deal of tension."

16. Impulsivity: consisted of 10 yes-no items from the MMPI and CPI such as "I consider a matter from every standpoint before I make a decision," or "I do whatever makes me feel cheerful here and now."

17. Pro-Religious Attitudes: eight forced choice items adapted from the Allport-Lindsay Scale of Values Test, such as "I would prefer to be: mathematician or clergyman," or "Which is more important for mankind: mathematics or theology."

18. External Locus of Control: seven forced choice items adapted from Rotter's Internal-External Locus of Control Test, such as "Concerning inflation: We have means to handle

inflation or There's little we can do," or "People like myself can change the course of world events: I agree or I disagree."

19. Driver Attitudes for Risk Taking: consisted of 9 yes-no items adapted from the Pelz-Schuman Test, such as: "During the past few months I have gone driving to blow off steam after an argument at least once."

20. Driver Attitudes for Unsafe Driving: consisted of 10 yes-no items adapted from the Rommel Driver Attitude Scale, such as "I find driving a form of relaxation which I use to relieve my tension," or "I'd rather have an old car with plenty of guts than a newer model with less power."

21. Driver Attitudes for Competition: consisted of 6 yes-no items adapted from Goldstein (1962), such as "It's a thrill to outwit other drivers."

22. Driver Attitudes for Speed: consisted of 5 yes-no items adapted from Goldstein (1962) such as "Driving at high speeds gives you a sense of power."

23. Clerical Ability for Findings A's: gave subjects 3 minutes to circle each word in a 750-word list that contained a letter "a"; score based on total words correctly circled, adapted from French (1963).

24. Clerical Ability for Number Comparisons: gave subjects 3 minutes to check each pair of digit strings in a 96-pair list that were not the same, such as 34861890173-34861840173. Score based on number correct minus number wrong, adapted from French (1963).

A complete questionnaire is shown in Appendix N.

Procedure. The questionnaires were passed out to subjects during class. Instructions were read, but no mention was made of the true purpose of the study. Subjects were told not to sign their questionnaires and that their responses would be totally confidential. During class the two 3-minute timed tests—Finding A's and Number Comparison—were administered. Subjects were then allowed to take the questionnaire home and to return the completed questionnaire at the next class meeting.

Subjects without a driver's license and who were not either 18 or 19 years old were eliminated from the sample. Of the remaining group, test responses were scored for the 23 subjects who reported involvement in three or more accidents (High Accident Group) and for a more matched control group of 23 subjects (No Accident Group).

2.3.6.2 Results

The mean score for the two groups for each of the 22 short tests (or scales) is presented in Table 2-19. Individual t-tests indicated several reliable differences between means (see Table 2-19) and a discriminant analysis of the standardized scores revealed that the seven tests which discriminated best between the two groups were, in order of their discriminant function coefficients: General Psychopathology (.90), Anti-Social Tendencies (.64), Number

Table 2-19

Mean Score for High Accident and No Accident Groups on 22 Tests

Test	No Accident Group	High Accident Group	t Value (df=44)	p Value	Discriminant Function Coefficient
Alcohol-Drug Use (+)	3.74	5.26	-2.06	< .05	-.38
Personal Maladjustment					
Manifest Anxiety (+)	.78	.83	- .13	ns	.24
Life Changes (+)	3.35	4.96	-2.16	< .05	.04
Katz: General Psychopathology (+)	14.65	21.26	-3.24	< .01	.91
Katz: Withdrawal (+)	4.22	4.70	- .67	ns	-.43
Anxiety (+)	2.57	3.04	-1.14	ns	-.03
Social Maladjustment					
Citizenship (-)	9.04	7.83	.76	ns	-.53
Social Participation (-)	33.83	32.57	.14	ns	.08
Juvenile Delinquency (+)	.26	.91	-2.86	< .01	.27
School Socialization (-)	12.87	11.35	2.05	< .05	-.52
Katz: Negativism (+)	14.74	16.52	-2.17	< .05	.58
Pro-Religious Values (-)	4.09	3.74	.52	ns	.08
External Locus of Control (-)	3.26	2.26	2.05	< .05	-.57
Antisocial Tendencies (+)	6.74	9.13	-3.01	< .01	.64
Impulsivity					
Katz: Belligerence (+)	5.30	6.04	-1.60	< .12	-.41
Impulsivity (+)	3.87	5.17	-1.89	< .07	-.14
Pelz-Schuman: Risk Taking Attitudes (+)	3.17	4.04	-1.53	< .14	.24
Rommel: Unsafe Attitudes (+)	5.52	5.35	.29	ns	-.39
Goldstein: Pro-Competition Attitudes (+)	2.13	2.13	0	ns	.23
Goldstein: Pro-Speed Attitudes (+)	2.70	2.57	.44	ns	-.14
Clerical Speed Accuracy					
Finding A's (-)	42.13	38.09	1.32	< .20	.07
Number Comparison (-)	28.30	20.30	2.87	< .01	-.59

Note. Plus (+) indicates prediction that High Accident score is higher than No Accident score; minus (-) indicates prediction that High Accident score is lower. Out of 22 tests, 19 scores occurred in the predicted direction, 1 tied, and 2 occurred in the reverse direction.

Comparison (-.59), Negativism (.58), External Control (-.57), Citizenship (-.53), School Socialization (-.52).

A factor analysis revealed eight major factors with the following structure (loadings indicated in parenthesis):

1. Negativism (.78).

2. Social Participation (.41), Pro-Religious (.31).

3. Risk-taking Driving Attitudes (.19), Unsafe Driving Attitudes (.25), Pro-Speed Attitudes (.45).

4. School Socialization (.21), Belligerence (.18), Pro-Competitive Driving Attitudes (.47).

5. General Psychopathology (.65), Withdrawal (.27), Anxiety (.23), Citizenship (-.28).

6. Anti-Social Tendencies (.55), Alcohol-Drug Use (.28), Life Changes (.17).

7. Number Comparison (.41), Finding A's (.41).

8. External Control (-.31), Juvenile Delinquency (.24), Impulsivity (.23), Manifest Anxiety (.08).

Of these factors, #2 (Pro-Social Institutions) and #3 (Risk-taking Driver Attitudes) seem to be of little value in distinguishing the accident from the control group. Of the remaining six factors which may be important, #5 seems to correspond to the general factor of personal maladjustment, #6 seems to correspond to the general factor of social maladjustment with #8 (hostility), #1 (negativism) and #4 (competitiveness) closely related. Number 7 seems to measure general clerical ability.

The High Accident group scored reliably higher in alcohol-drug use; however, **the fact that the alcohol-drug scale did not play a strong role in the discriminant function suggests that it adds little information to other, more discriminating tests.** For example, factor analysis revealed that the alcohol-drug scale has its highest factor loading on the same factor as the Anti-Social Tendencies Scale's highest loading.

The High Accident group also scored higher on all five tests of personal maladjustment, revealing higher levels of manifest anxiety, anxiety, withdrawal, general psychopathology and life changes; however, only the latter two measures reached statistically reliable levels. Again the fact that only the general psychopathology scale achieved a high discriminant function coefficient suggests that the other tests add little information. This idea is supported by the results of a factor analysis which revealed that general psychopathology, withdrawal and anxiety all load most heavily on the same factors, while life changes loads most heavily on the same factor as anti-social tendencies, and manifest anxiety doesn't load heavily on any factor.

The High Accident group also scored reliably higher in social maladjustment as measured by juvenile delinquency, negativism, anti-social tendencies, and scored lower in social adjustment as measured by school socialization, external locus of control, citizenship, social participation, and pro-religious values, although the latter three failed to reach statistical significance. Five scales received high discriminant function coefficients indicating that each adds unique information in distinguishing the accident from the control group. None of these factors—citizenship, school socialization, negativism, external control and anti-social tendencies—has its highest loading on the same factor, while juvenile delinquency loads on the same factor as external control; in addition, pro-religious values and social participation share a common factor which apparently does not distinguish the accident from the control group. **Apparently social maladjustment is an important variable that has several unique components.**

The High Accident group also tended to score higher on personality measures of impulsivity and belligerence, but of the related driver attitude measures, only the adapted Pelz-Schuman test for risk taking driver attitudes produced large differences. Even in these cases, the differences among the groups reached only marginally reliable levels and none of these tests received a high discriminant function coefficient. The factor analysis revealed a mutual loading of the driver attitude scales on a single factor, apparently one that does not powerfully distinguish between the two accident groups, and the remaining factors do not seem to load highly on any of the eight factors. **These results suggest that impulsivity is only a mildly important factor,** and that the driver attitudes about risk may be tapping a different factor than personality measures of impulsivity.

Finally, the High Accident Group performed more poorly on the two clerical tasks, and these two tasks load neatly onto the same factor. **Thus, clerical ability seems to be a single factor mildly related to accident record,** with number comparison—by virtue of its high discriminant coefficient—the more useful measure.

2.3.7 Validation Study (Study No. 2)

In order to ascertain the predictive validity of the discriminant function established in the above study, the identical questionnaire was administered to 200 subjects with the same characteristics as the original study. From these, seven High Accident and seven matched No Accident drivers were obtained, as in the original study. The discriminant function of the original study correctly assigned over 90% of the original sample (i.e., 42 out of 46) and correctly predicted the actual group membership of over 85% of the validation sample (12 out of 14).

The discriminant function score and predicted group membership is given in Table 2-20 for the validation subjects. These results clearly indicate that it is possible to distinguish between very high risk drivers and no accident drivers on the basis of short tests not "directly relevant" to the driving task. The fact that the discriminant function established in the original sample was able to **predict** group membership of **new** cases in the validation sample indicates that **measures such as social and personal adjustment are relevant and valid measures of driving behavior.**

For purposes of further analysis, the original and validation samples were combined (Table 2-21). All the reliable differences noted with 46 drivers were retained at similar or smaller α levels, and two additional scales reached statistical significance: the High Accident Group scored higher than the No Accident Group on the 10-item personality measure of impulsivity ($t(58) = -2.61$, $p < .01$) and on the modified Pelz-Schuman test of driving attitudes related to

Table 2-20

Prediction of Group Membership of Validation Sample Based on Discriminant Function of Original Sample

Driver No.	Actual Membership	Predicted Membership	Discriminant Score
1	Control	Control	-3.86
2	Control	Control	- .78
3	Control	Control	-1.36
4	Control	Control	-1.10
5	Control	Accident	+1.46
6	Control	Control	-2.07
7	Control	Control	-1.40
8	Accident	Accident	+ .24
9	Accident	Accident	+ .04
10	Accident	Accident	+3.75
11	Accident	Control	- .93
12	Accident	Accident	+ .35
13	Accident	Accident	+2.31
14	Accident	Accident	+1.03

impulse control and risk-taking ($t(58) = -2.26, p < .05$). The scales which best distinguished the groups based on a discriminant were (coefficients in parentheses): Citizenship (-.87), Anti-social Tendencies (.80), General Psychopathology (.61), Number Comparison (-.56), Withdrawal (-.54), Negativism (.48), External Control (-.47), and School Socialization (-.37). This list is essentially similar to the one obtained earlier except that the Katz scale of Withdrawal has been added. A factor analysis based on the data for 60 drivers revealed the same general factor structure as with 46 drivers except that Belligerence now loads highest on factor 1, and factor 8 is eliminated with Impulsivity and Manifest Anxiety now loading on factor 4, External Control onto factor 5, and Juvenile Delinquency onto factor 6. It may be seen (Table 2-21) that results do not differ markedly between sexes; in fact, males and females displayed similar patterns for nearly every scale, rendering the number of reliable differences for the total (male and female) groups of particular interest.

Conclusions from Studies 1 and 2

Because these results are based on a small (N=60) and fairly limited sample (licensed college freshmen, ages 18 and 19), their generality is obviously limited. However, these findings provide modest support for the idea that high accident drivers do differ from no accident drivers, and are most promising in their support for several theoretical notions concerning the differences. **These results are overwhelmingly consistent with the idea that personal maladjustment (i.e., problems with one's self) and social maladjustment (e.g., problems with**

Table 2-21

Mean Score for Accident (3 or more) and Control (No Accidents) Groups on 22 Tests

Test	Males Control (N=18)	Males Accident (N=18)	Females Control (N=12)	Females Accident (N=12)	Total Control (N=30)	Total Accident (N=30)	Discriminant Function Coefficients
Alcohol-Drug Use (+)	4.44	6.11m	3.00	4.50m	3.87	5.47*	
Personal Maladjustment							
Manifest Anxiety (+)	1.00	0.72	1.00	1.25	1.00	0.93	
Life Changes (+)	3.44	5.00m	3.83	4.42	3.60	4.77m	
Katz: General Psychopathology (+)	15.78	21.00*	14.25	21.08*	15.17	21.03*	+0.61
Katz: Withdrawal (+)	4.44	4.94	3.50	3.25	4.06	4.27	
Anxiety (+)	2.78	3.00	2.58	3.58m	2.70	3.23	
Social Maladjustment							
Citizenship (-)	8.72	6.17m	9.67	8.75	9.10	7.20m	-0.87
Social Participation (-)	18.44	19.56	46.42	39.42	29.63	27.50	
Juvenile Delinquency (+)	0.39	1.22*	0.17	0.50m	0.30	0.93*	
School Socialization (-)	12.56	10.56*	13.25	12.75	12.83	11.43*	-0.37
Katz: Negativism (+)	14.88	17.22*	13.92	15.33	14.50	16.47*	+0.48
Pro-Religious Values (-)	3.78	3.89	4.92	3.75	4.23	3.83	
External Locus of Control (-)	3.61	2.28*	3.08	2.58	3.40	2.40*	-0.47
Anti-social Tendencies (+)	7.22	8.83m	6.50	9.75*m	6.93	9.20*	+0.80
Impulsivity							
Katz: Belligerence (+)	5.72	6.22	5.25	6.08	5.53	6.17m	
Impulsivity (+)	4.17	5.67*	3.75	5.17m	4.00	5.47*	
Pelz-Schuman: Risk Taking Attitudes (+)	2.94	4.56*	2.75	3.00	2.87	3.93*	
Rommel: Unsafe Attitudes (+)	5.39	5.78	4.75	4.25	5.13	5.17	
Goldstein: Pro-Competition Attitudes (+)	2.22	2.56	1.42	1.58	1.90	2.17	
Goldstein: Pro-Speed Attitudes (+)	2.83	2.78	2.25	2.50	2.60	2.67	
Clerical Speed Accuracy:							
Finding A's (-)	43.67	39.67	39.50	40.25	42.00	39.90	
Number Comparison (-)	31.78	22.50*	24.75	22.33	28.97	22.43*	-0.56

Note. Plus (+) indicates prediction that Accident score is higher than Control score; minus (-) indicates prediction that Accident score is lower. Asterisk (*) indicates significant difference between Accident and Control means at $p < 0.05$ by two-tailed t-test, and the letter "m" indicates a marginally significant difference at $p < 0.10$. Out of 22 tests, 18 differences occurred in the predicted direction for males, 19 for females, and 21 for total.

society) are related to higher accident rate; to a lesser extent cognitive abilities (e.g., clerical abilities) and impulsivity are related to accidents.

At this point in our understanding, the mechanisms underlying the relationships may only be hypothesized. Several reasonable interpretations of the fact that high accident drivers score higher in personal maladjustment are: (1) that such drivers are "mixed up" (e.g., their information processing system is cluttered with non-driving information), and thus they are more likely to miss important information or to misinterpret it; (2) that such drivers are depressed to the point of being mildly suicidal, and thus they are less likely to protect themselves from danger. Possible implications of these respective theories are that drivers scoring high in personal maladjustment should be more likely to commit perceptual errors, and decision errors, or to be involved in single vehicle accidents.

The fact that social maladjustment is higher in accident drivers than controls suggests a general sense of antisociability, negativism, and hostility that is manifested in the driving situation. This idea predicts that drivers would lash out against society by intentionally engaging in risk-taking behavior and thus be engaged in accidents involving high speed, etc.

Impulsivity and driver risk-taking attitude were only mildly important in this study. However, this may be due to the low number of subjects and very short attitude scales used. Impulsivity would be expected to result in risk-taking behaviors.

Finally, the fact that poor clerical ability was related to auto crashes is also consistent with the information processing idea that people who are poor at processing perceptual information are likely to make recognition errors while driving. Future research is needed to test these predictions.

In short, while the generality of these results is limited, we believe they are quite promising for future research aimed at developing a theory of human accident involvement. While our questionnaire is not intended to be, nor would it serve well as, a licensing criteria, this line of research can contribute modestly to our understanding of the mechanisms underlying human error in driving performance. The present results indicate that the same patterns exist for males and females, but differences in the absolute levels encourage separate norms, by sex, in future test development (Harrington, 1972).

2.3.8 Supplemental Study Using In-depth Interviews (Study No. 3)

2.3.8.1 Introduction

Although the pilot and validation studies described above encourage the idea that certain psychological, social and cognitive factors may be related to accident involvement, the findings are limited by the fact that self-reports of a small, young sample were used. To help overcome the problems inherent in self-reports and to expand the subject pool, the following analysis—based on accident-involved drivers already interviewed as part of IRPS' in-depth level of data collection (Level C)—was conducted. This approach also permitted a comparison of driver measures with "culpability" or specific type of error committed.

In order to initially evaluate the role of psychological factors in accident involvement, the responses of drivers on the In-Depth Human Factors Form were analyzed. Items were selected from the In-Depth Form to produce scales for six psychological-social and related factors which—based on the review and results of the section—might be related to driver risk-taking behaviors that result in accident involvement. The six scales, or profile scores, were personal adjustment, social adjustment, impulse control, alcohol-drug use, prior record and socio-economic status (SES). These scales include all the independent variables listed in Table 2-18 except information processing. Although selection of scale items was post-hoc in the present study, one purpose was to determine the usefulness of devising a new Human Factors Form specifically aimed at these factors.

2.3.8.2 Method

Subjects and Design. The data was based on 287 drivers who had been involved in traffic accidents and were given In-Depth Human Factors interviews. Of these, 110 drivers were found by a multidisciplinary team to have been not-at-fault, and 177 drivers were assigned one or more human errors based on the causal factors.

Materials. The six profile scales, based on items selected post-hoc from the In-Depth Human Factors Form, are as follows:

1. Personal Adjustment—10 questions concerning emotional strain, manifest anxiety, disagreements, etc. (Questions 12, 18, 19-24, 98 and 106 on the In-Depth Human Factors Form; see Appendix M).
2. Social Adjustment—3 questions concerning marital status, attitude towards police (Questions 9, 10, 135 on the Human Factors Form).
3. Socio-Economic Status (SES)—4 questions concerning income, education, occupation (Questions 5-8).
4. Impulse Control—5 questions concerning seat belt use, steering and braking habits, etc. (Questions 73, 74, 97, 98, 148).
5. Alcohol/Drug Usage—20 questions concerning frequency and amount of drug and alcohol consumption (Questions 28-32, 33-42).
6. Prior Record—9 questions concerning prior traffic citations and prior accident involvement (Questions 28-36).

Procedure. Accident-involved drivers provided spoken responses to questions read to them by IRPS interviewers as part of the in-depth human factors investigation.

2.3.8.3 Results and Discussion

Involvement Analysis. Table 2-22 shows the profile scores of drivers who were involved in accidents and were judged to have committed an error and those who did not commit an error. Higher scores indicate maladjustment, lower SES, poorer impulse control, more drug/alcohol usage and worse prior record. Separate analyses of variance revealed that drivers who committed errors tended to score higher in personal and in social maladjustment as compared with drivers who did not commit errors. A discriminant analysis performed on these data

Table 2-22

Average Profile Score for Drivers Who Did and Did Not Commit Human Errors

Profile Scale	No Error	Human Error	F	P
Personal Adjustment	2.34	2.76	3.47	.06
Social Adjustment	.69	.88	5.76	.02
Socio-Economic Status	1.66	1.64	<1	ns
Impulse Control	2.10	2.10	<1	ns
Alcohol/Drug Use	.67	.82	<1	ns
Prior Record	2.80	3.25	2.24	.14

NOTE: Higher scores indicate maladjustment, lower SES, poorer control, more alcohol use, poorer record. For each group the approximate number of drivers was 110 and 177 respectively.

revealed social adjustment, personal adjustment and alcohol use as the most important scales in discriminating the two groups; however, the discriminant function failed to reach statistical significance.

These results are encouraging for the idea, suggested by a review of the literature, that personal and social maladjustment are related to accident involvement. In order to determine whether these profile scales were related to specific types of driving errors, a subsequent analysis was performed.

Error Analysis. Table 2-23 gives the profile scores for drivers involved in accidents who committed a recognition error, other error, or no error. Accident-involved drivers who did not commit an error may be considered a control group with which drivers who commit errors may be compared. For personal and social adjustment, the no-error group scored lowest and the non-recognition error group scored slightly higher than the recognition error group. These differences were marginally reliable, based on separate analyses of variance.

Since the literature review (above) strongly suggested social and personal adjustment as the two most likely personality factors related to driving behavior, the present results are consistent. In the present case the differences in profile scores between at-fault drivers who committed recognition errors and those committing other types of errors are not great, although both are considerably higher than the not-at-fault group especially for social and personal adjustment. Thus, although our scales were not able to predict type of error, they do seem related to accident causation.

In order to further assess the relationship between our profile scores and type of driver error, the average scores for several non-mutually exclusive error groups were determined and are shown in Table 2-24.

For personal maladjustment, no error drivers scored lowest (best adjusted) and drivers who

Table 2-23

Average Profile Score by Type of Error Committed

Profile Scale	No Error	Recognition Error	Non-Recognition Error	F	P
	Type of Error				
Personal Adjustment	2.26	2.70	2.78	2.02	.14
Social Adjustment	.70	.84	.91	2.76	.07
Socio-Economic Status	1.62	1.62	1.70	.15	ns
Impulse Control	2.09	2.04	2.14	.38	ns
Alcohol/Drug Use	.70	.92	.84	.35	ns
Prior Record	2.86	3.59	3.16	1.72	.18

NOTE: Higher scores indicate maladjustment; lower SES, poorer control, more alcohol use, poor record. For each group the number of drivers was approximately 99, 69 and 88, respectively.

committed errors due to conditions and states (including alcohol) and inattention scored highest. Separate analyses of variance comparing each error group with the non-error group indicated reliable differences for inattention, alcohol and human conditions and states. These results are consistent with the idea that personal problems may distract and pre-occupy the driver.

For social maladjustment, the "no error" group and performance error group scored low, but the other error groups scored higher. Separate analyses of variance revealed significant differences from the no error group for decision and recognition error groups. Thus, anti-social drivers may share some of the problems of the above group, but also may commit decision errors presumably due to a conscious decision to drive recklessly.

For impulse control, only alcohol drivers scored reliably higher than the control group. For prior record of alcohol use, drivers committing inattention errors scored lowest, and as would be expected, drivers with alcohol-related errors scored highest. For prior driving record, alcohol drivers and drivers making decision errors scored highest, as compared with the control group. In our study, socio-economic status scores were equivalent for all error groups.

These results are consistent with the cluster analysis discussed in Section 4.0 of this volume. For example, the personal adjustment scores of cluster 2 (not-at-fault), cluster 1 (recognition error), cluster 4 (decision error), and cluster 5 (human conditions and states) were 1.5, 2.2, 2.8, and 3.5 respectively; the same scores for social adjustment were .50, .90, .70, and 1.1 respectively (where in each case, higher scores reflect **poorer** adjustment). Since both the cluster analysis and the present analysis are based on the same data, this correspondence is not surprising; however, together they encourage further research in this area.

Table 2-24

Average Profile Scores for Groups of Drivers Who Committed Specific Errors

Profile Scale	No Error (N=110)	Recognition Error (N=177)	Decision Error (N=89)	Performance Error (N=20)	Human Conditions and States (N=20)	Alcohol Error (N=5)	Inattention Error (N=23)
Personal Adjustment	2.34	2.70m	2.73m	3.05m	3.45**	4.80**	3.26**
Social Adjustment	.69	.84*	.86*	.65	.95m	1.00m	.87
Socio-Economic Status	1.66	1.62	1.58	1.35	1.67	1.60	1.50
Impulse Control	2.10	2.04	2.09	2.17	2.11	3.00**	2.27
Alcohol/Drug Use	.67	.92	1.02m	.33	.87	4.50**	.15*
Prior Record	2.80	3.59m	3.66**	3.56	2.79	4.25	3.45

Note: For each group the approximate number of subjects was approximately 110, 77, 89, 20, 5, 23 respectively. Asterisk (*) indicates score is significantly different from No Error group at p < .10, and double asterisk (**) indicates significant difference at p < .05, m indicates score is marginally different from No Error group at p < .20.

2.3.8.4 Conclusions

Taken together, these studies suggest that:

1. Personal maladjustment—including anxiety, personal problems, etc.—is related to accident involvement.
2. Social maladjustment—including anti-social attitudes, failures with social institutions, etc.—is related to accident involvement.
3. Drivers committing any error, especially alcohol, conditions and states and inattention errors are more personally maladjusted than controls. One hypothesis is that personal problems may pre-occupy or distract the driver.
4. Drivers committing almost any error, especially recognition and decision errors (and possibly alcohol errors) are more anti-social than controls. Socially maladjusted drivers may make a conscious decision to drive more recklessly.
5. Alcohol-error drivers tend to lack impulse control. These last three findings suggest that personal maladjustment, social maladjustment and lack of control may all be factors underlying the alcohol-erring driver. Further research is needed to clarify this point.

2.4 Driver Characteristics and Culpability

The purpose of this section is to investigate the relationships between accident-involved driver characteristics and driver culpability. Driver characteristics chosen for investigation are driver age, sex, driving experience, vehicle familiarity, annual mileage and road area familiarity. Culpability is decided by technician level investigators. Accident-involved drivers are classified as culpable if investigators determine driver behavior/physiological-psychological conditions or states have in some way caused or increased the severity of a motor vehicle accident — otherwise they are nonculpable.

The first subsection investigates the effects of accident-involved driver age and sex on driving experience, vehicle familiarity, annual mileage and road area familiarity. Information from this analysis is used in subsequent analyses to adjust driving experience, vehicle familiarity, annual mileage and road area familiarity for the effects of age and sex, allowing the assessment of culpability relationships after effects attributed to age and sex have been removed.

The second subsection discusses the procedures used to control driving experience, vehicle familiarity, annual mileage and road area familiarity for the effects of age and sex.

The third subsection analyzes the relationships between culpability and age, driving experience, vehicle familiarity, annual mileage and road area familiarity for male and female accident-involved driver groups. In addition, male and female, culpable and nonculpable drivers are compared on the basis of age-adjusted driving experience, vehicle familiarity and annual mileage.

Summary of Results

Female culpability is related to road area familiarity, age-adjusted driving experience, and age, but not to either vehicle familiarity or average mileage. Nonculpable accident-involved women are characterized as having high road area familiarity, more driving experience than would be expected for their age and either being over 54 or 35 to 44 years old. Culpable women drivers are characterized as having zero to moderate road area familiarity, moderate driving experience for their age and being under 25 or between the ages of 45 and 54.

Male culpability is related to road area familiarity, age-adjusted vehicle familiarity and "age/experience," but not to annual mileage. Nonculpable men are characterized as being more familiar with the road, having more familiarity with their vehicles than would be expected for their age and being between the ages of 35-54. Culpable men are characterized as having little road area familiarity, having less familiarity with their vehicles than would be expected for their age and being young (15-19) or old (over 64).

2.4.1 Relationships Between Age/Sex and Driving Experience, Vehicle Familiarity, Annual Mileage and Road Area Familiarity

In order to assess the effects of accident-involved driver age and sex on driving experience, vehicle familiarity, annual mileage and road area familiarity, a two-factor analysis of variance model was used. Drivers were divided into two sex groups (factor 1) and seven age groups (factor 2)—a 2x7 factorial design—with the criterion measures being driving experience, vehicle familiarity, annual mileage and road area familiarity. Results are presented in figures 2-1 through 2-4.

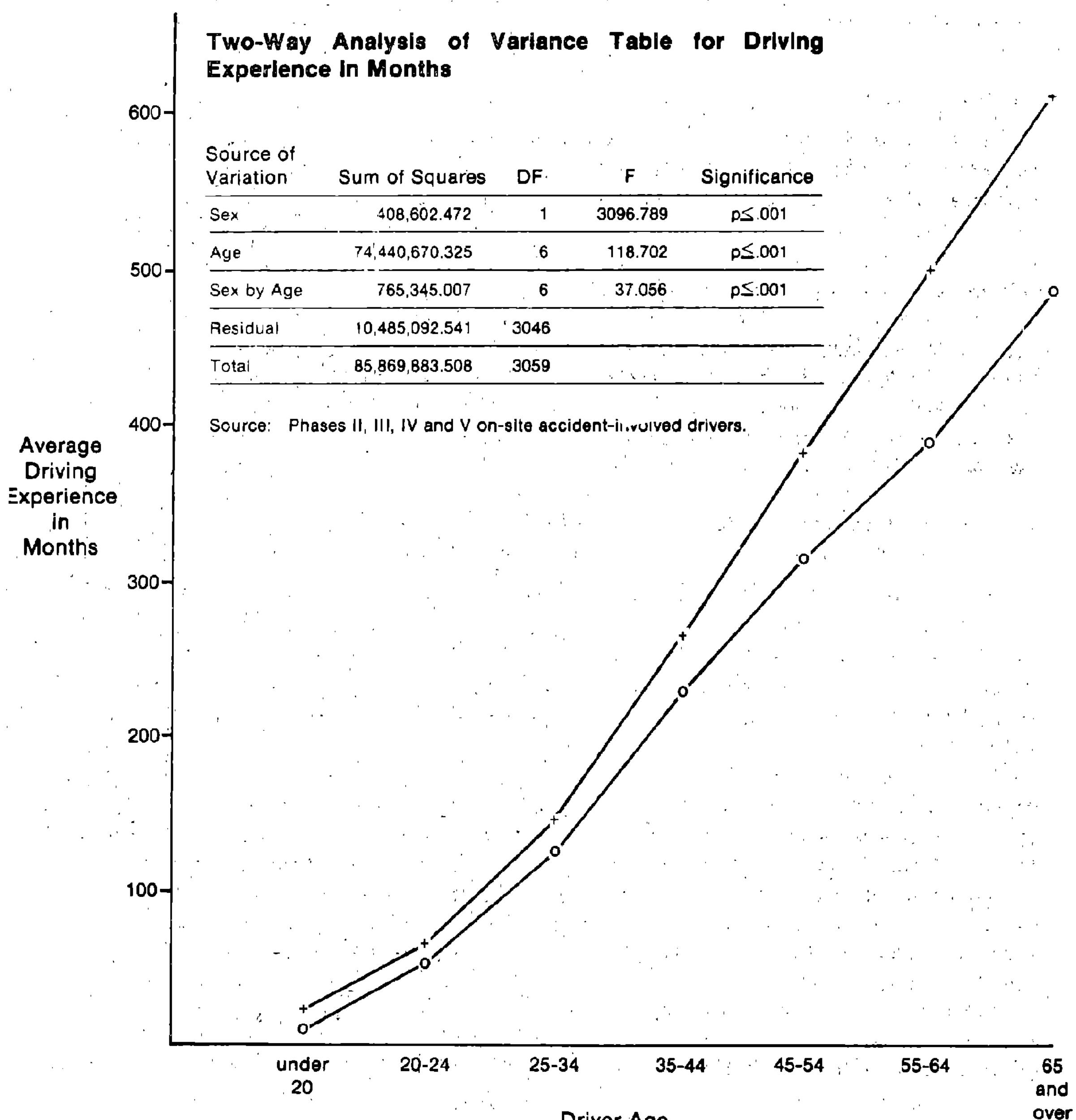
Two-way ANOVA results of driver age and sex on driving experience are presented in Figure 2-1. Results show that accident-involved men have significantly more driving experience than women (168.25 months for men and 152.11 months for women). In addition there is a large age main effect—younger drivers have less experience and older drivers more. An interesting interaction effect is also present. Men and women under 35 have about the same average driving experience while women over 35 have increasingly less experience than their male counterparts. This is probably because more women than men enter the licensed driving population at a later age.

Age and sex effects on vehicle familiarity are presented in Figure 2-2. Results show that accident-involved women are more familiar with their vehicles than accident-involved men (19.27 months for men and 23.62 months for women). Vehicle familiarity is also significantly related to age. Young accident-involved drivers have less vehicle familiarity than older drivers. There is no significant interaction effect.

Age and sex effects on exposure as measured in annual mileage are displayed in Figure 2-3.

Figure 2-1

Average Driving Experience (in Months) by Age and Sex for Accident-Involved Drivers



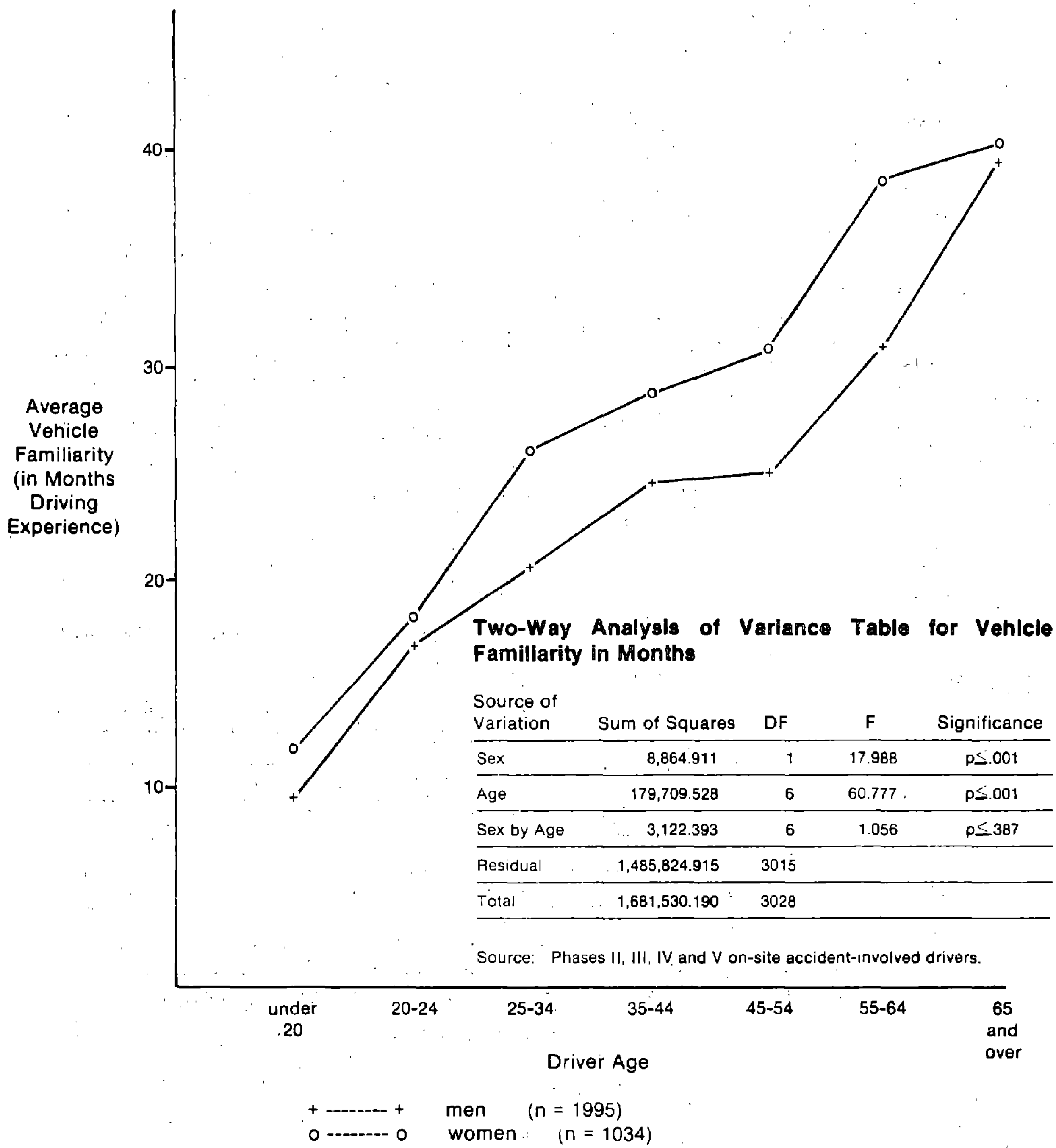
Two-Way Analysis of Variance Table for Driving Experience in Months

Source of Variation	Sum of Squares	DF	F	Significance
Sex	408,602.472	1	3096.789	p≤.001
Age	74,440,670.325	6	118.702	p≤.001
Sex by Age	765,345.007	6	37.056	p≤.001
Residual	10,485,092.541	3046		
Total	85,869,883.508	3059		

Source: Phases II, III, IV and V on-site accident-involved drivers.

Figure 2-2

Average Vehicle Familiarity (Months Driving Experience) by Age and Sex for Accident-Involved Drivers



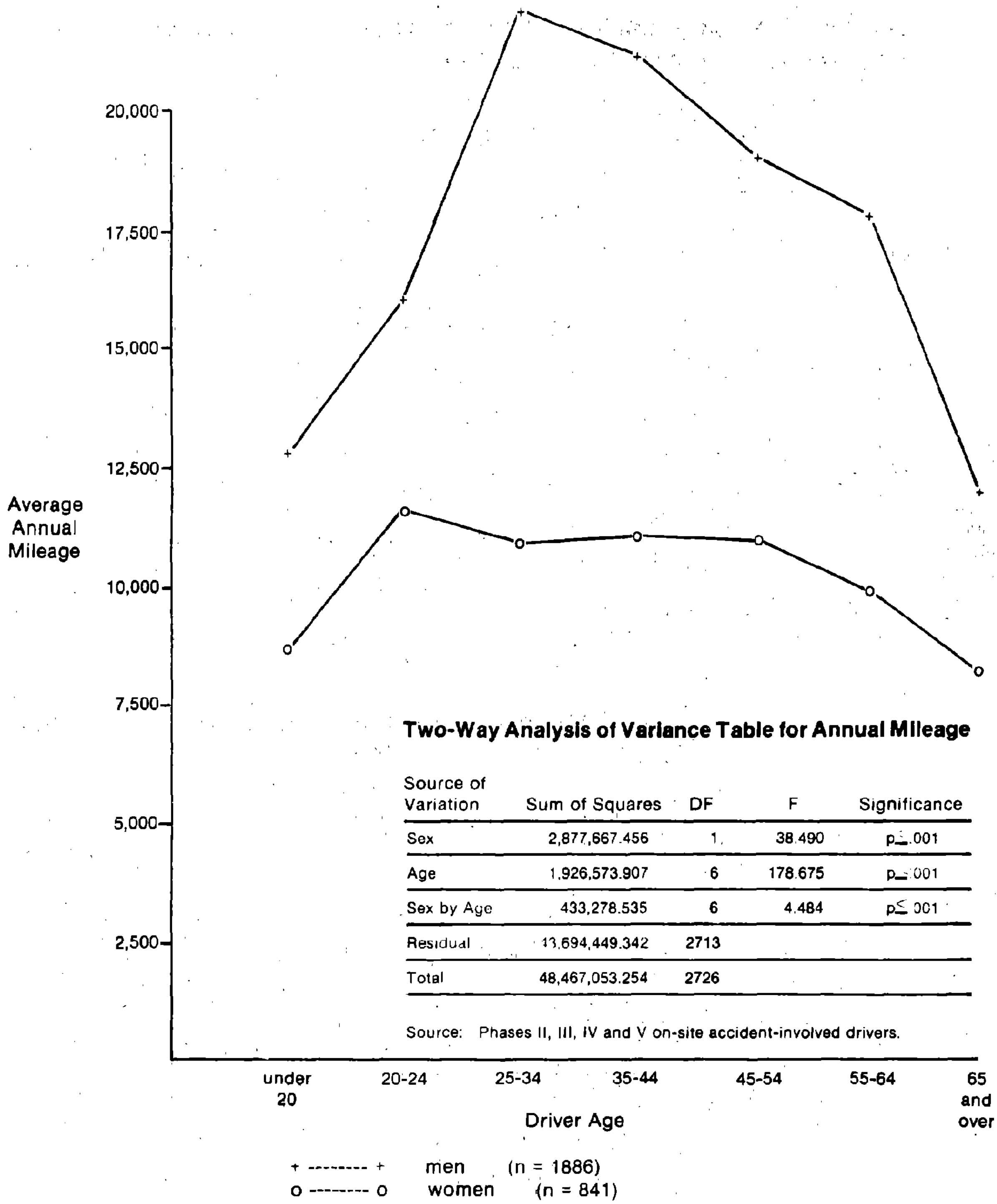
Two-Way Analysis of Variance Table for Vehicle Familiarity in Months

Source of Variation	Sum of Squares	DF	F	Significance
Sex	8,864.911	1	17.988	p≤.001
Age	179,709.528	6	60.777	p≤.001
Sex by Age	3,122.393	6	1.056	p≤.387
Residual	1,485,824.915	3015		
Total	1,681,530.190	3028		

Source: Phases II, III, IV and V on-site accident-involved drivers.

Figure 2-3

Average Annual Mileage by Age and Sex for Accident-Involved Drivers



Two-Way Analysis of Variance Table for Annual Mileage

Source of Variation	Sum of Squares	DF	F	Significance
Sex	2,877,667.456	1	38.490	$p \leq .001$
Age	1,926,573.907	6	178.675	$p \leq .001$
Sex by Age	433,278.535	6	4.484	$p \leq .001$
Residual	43,694,449.342	2713		
Total	48,467,053.254	2726		

Source: Phases II, III, IV and V on-site accident-involved drivers.

Accident-involved men drive more than accident-involved women (17,200 annually for men and 10,800 annually for women). Accident-involved drivers under 20 and over 64 drive significantly less than middle aged accident-involved drivers. A significant interaction effect exists between age and sex. This is because annual mileage for accident-involved women between the ages of 20 and 54 remains relatively constant (11,000 miles per year) while annual mileage for men in that age range first makes an initial dramatic increase (for 25-34 year olds) followed by a gradual decline during later years.

Age and sex of accident-involved drivers do not influence road area familiarity (see Figure 2-4). This is quite a surprising finding. One might expect young accident-involved drivers to be less familiar with the roads they drive than older drivers. Since this did not happen, it's possibly reflective of the highly mobile/transient nature of the study area driving population.

2.4.2 Adjusting Driving Experience, Vehicle Familiarity, Annual Mileage and Road Area Familiarity for Driver Age and Sex

In order to adjust driving experience, vehicle familiarity, annual mileage and road area familiarity for the effects of sex, drivers were divided into male and female groups and analyzed separately. This was done in lieu of numerical adjustments in order to simplify the interpretation of results.

Male and female groups were adjusted separately for the effects of age. Regression techniques were used to remove age effects from driving experience, vehicle familiarity and annual mileage distributions. (Road area familiarity was not adjusted for age because ANOVA results indicate no age effect exists). Drivers were divided into seven age classes (under 20, 20-24, 25-34, 35-44, 45-54, 55-64, 65 and over) and the residuals of dummy variable regression (age classes as dummy variates) of age on driving experience, vehicle familiarity and annual mileage used in subsequent analyses as "age-adjusted" driving experience, vehicle familiarity and annual mileage.

2.4.3 Differences Between Culpable and Nonculpable Drivers

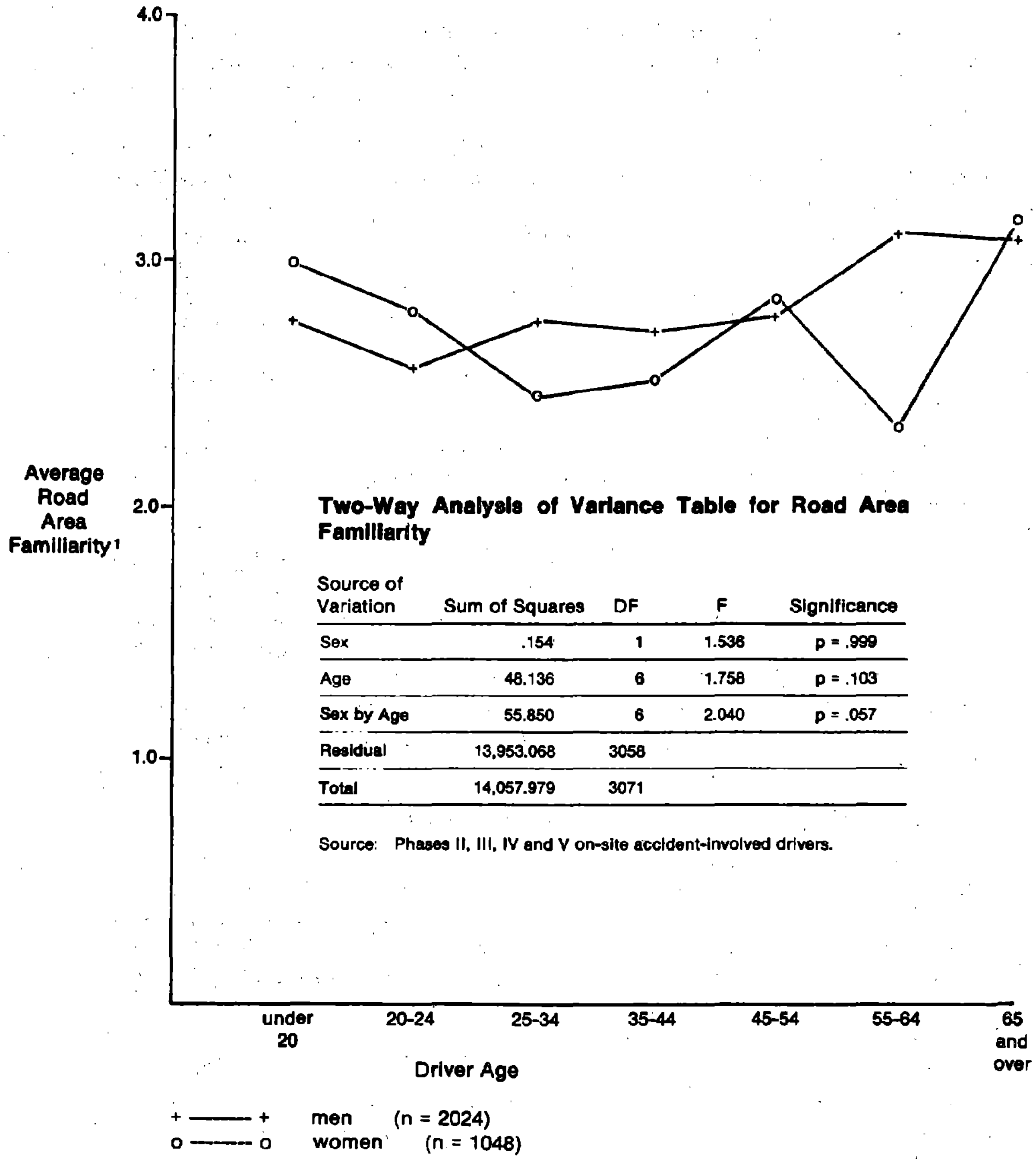
Culpable and nonculpable drivers were compared on the basis of driver age, driving experience, vehicle familiarity, annual mileage, road area familiarity, age-adjusted driving experience, age-adjusted vehicle familiarity and age-adjusted annual mileage. Median tests and Kolmogorov-Smirnov (K-S) tests were run for each comparison. Note: The K-S Z statistic was computed on raw ungrouped data. Results for females are presented in Table 2-25 and for males in Table 2-27.

Females

The best predictor of culpability for women is road area familiarity. Table 2-29 shows the distribution of road area familiarity for culpable and nonculpable drivers. A K-S Z of 3.07 ($p \leq .000$) indicates the two distributions are significantly different.

Figure 2-4

Average Road Area Familiarity[1] by Age and Sex for Accident-Involved Drivers



Two-Way Analysis of Variance Table for Road Area Familiarity

Source of Variation	Sum of Squares	DF	F	Significance
Sex	.154	1	1.536	p = .999
Age	48.136	6	1.758	p = .103
Sex by Age	55.850	6	2.040	p = .057
Residual	13,953.068	3058		
Total	14,057.979	3071		

Source: Phases II, III, IV and V on-site accident-involved drivers.

[1] **Higher Average Scores Indicate Less Road Area Familiarity**

Table 2-25

Comparison of Female, Culpable and Nonculpable Accident-Involved Driver Distributions Before and After Adjustment for Driver Age

	Before Age Adjustments				After Age Adjustments			
Driver Characteristic	Not Culpable Median	Culpable+ Median	Median Test	K-S° Test	Not Culpable Median	Culpable Median	Median Test	K-S Test
Driver Age	27.5	25.7	χ^2=6.20 n=1037 p=.0128	Z=1.54 n=1126 p=.0173				
Driving Experience (months)	114.3	92.5	χ^2=5.26 n=1037 p=.0218	Z=1.68 n=1037 p=.0072	160.2	149.1	χ^2=6.88 n=1034 p=.0087	Z=1.82 n=1034 p=.0026
Vehicle Familiarity (months)	18.1	14.5	χ^2=.95 n=1031 p=.3287	Z=.71 n=1031 p=7009	18.8	18.2	χ^2=.02 n=1028 p=.8818	Z=.79 n=1028 p=.5596
Annual Mileage in 100's of Miles	98.7	98.3	χ^2=2.10 n=840 p=.1470	Z=.95 n=840 p=.3302	95.9	95.9	χ^2=.00 n=837 p=.9513	Z=.85 n=837 p=.4609
Road Area Familiarity*	1.38	2.24	χ^2=38.52 n=1047 $p \leq .0000$	Z=3.07 n=1047 $p \leq .0000$				

* Larger median indicates less road area familiarity.

° Kolmogorov-Smirnov 2-sample test.

+ At the certain or probable, causal or severity-increasing levels of certainty and significance.

Table 2-26

Relative Importance of Variable Classes in Discriminating Between Culpable and Nonculpable Female Accident-Involved Drivers

Road Area Familiarity Class	Rank	Age-Adjusted Driving Experience in Months Class	Rank	Age Class	Rank
Driven Daily	1*	Under 54	7M	Under 20	7–
Twice a Week	2*	54-113	4M	20-24	6–
		114-137	3M	25-34	4M
Once Weekly	3–	138-161	8–	35-44	2*
Twice Monthly	6–	162-185	2*	45-54	5–
Once Monthly	4–	186-211	1*	55-64	3*
Very Infrequently	5–	212-233	6M	65 and over	1*
First Time on Roadway	7–	234-473	5M		

* Descriptive of nonculpable female drivers
– Descriptive of culpable female drivers
M Little discriminatory power

Table 2-29 indicates women who drive the road at least twice a week are less often culpable in accidents than those who drive the road less often. In addition to testing for distribution differences, the median test was run to check for differences in central tendency. The medians for nonculpable and culpable women are 1.38 and 2.24, respectively (the smaller medians indicates more road area familiarity). Culpable women are shown to be significantly ($p \leq .0000$) less familiar with the road area at the accident scene.

The second most powerful predicton of female culpability is age adjusted driving experience (K-S Z=1.82, p=.0026). The distribution of age-adjusted driving experience is presented in Table 2-34; culpable women are shown to have less driving experience than would be expected for their age. The median test (p=.0087) confirms this finding. After adjustment for age the median driving experience for nonculpable women is 160.2 months and the median for culpable women is 149.1 months (see Table 2-25).

Table 2-27

Comparison of Male, Culpable and Nonculpable Accident-Involved Driver Distributions Before and After Adjustment for Driver Age

Driver Characteristic	Before Age Adjustments				After Age Adjustments			
	Not Culpable Median	Culpable+ Median	Median Test	K-S° Test	Not Culpable Median	Culpable+ Median	Median Test	K-S Test
Driver Age	25.7	23.4	χ^2=14.27 n=2208 p=.0002	Z=2.12 n=2208 p=.0002				
Driving Experience (months)	109.5	82.6	χ^2=17.67 n=2010 p≤.0000	Z=2.22 n=2010 p=.0001	168.0	167.9	χ^2=.36 n=2006 p=.5495	Z=.93 n=2006 p=.3524
Vehicle Familiarity (months)	12.2	11.0	χ^2=14.98 n=1982 p=.0001	Z=2.28 n=1982 p=.0001	14.4	12.7	χ^2=4.02 n=1979 p=.0449	Z=1.59 n=1979 p=.0129
Annual Mileage in 100's of Miles	132.0	126.0	χ^2=.15 n=1873 p=.6957	Z=1.09 n=1873 p=.1850	133.9	144.1	χ^2=.92 n=1870 p=.3386	Z=.90 n=1870 p=.3942
Road Area Familiarity*	1.44	2.02	χ^2=30.09 n=2013 p≤.0000	Z=2.70 n=2013 p≤.0000				

* Larger median indicates less road area familiarity.

° Kolmogorov-Smirnov 2-sample test.

\+ At the certain or probable, causal or severity-increasing levels of certainty and significance.

Table 2-28

Relative Importance of Variable Classes in Discriminating Between Culpable and Nonculpable Male Accident-Involved Drivers

Road Area Familiarity		Age-Adjusted Vehicle Familiarity In Months		Age	
Class	Rank	Class	Rank	Class	Rank
Driven Daily	1*	Less than 3	7–	Under 20	7–
Twice a Week	2*	3-6	6M	20-24	5M
Once Weekly	3–	7-12	5M	25-34	3M
Twice Monthly	5–	13-24	3M	35-44	1*
Once Monthly	6–	25-36	1*	45-54	2*
Very Infrequently	4–	37-60	2*	55-64	4M
First Time on Roadway	7–	61 and over	4M	65 and over	6–

* Descriptive of nonculpable male drivers
\- Descriptive of culpable male drivers
M Little discriminatory power

Driver age ranks as the third best predictor of female culpability (K-S Z=1.54, p=.0173). Age distributions of culpable and nonculpable women are presented in Table 2-30. The most culpable age groups for women are 15-24 and 45-54. The median test (p=.0128) shows that culpable women (median=25.7 years) are younger than nonculpable women (median=27.5 years).

Neither vehicle familiarity nor annual mileage are related to female culpability (see Tables 2-32 and 2-35 for vehicle familiarity and Tables 2-33 and 2-36 for annual mileage).

In addition to the above analysis, road area familiarity, age-adjusted driving experience and age were used in a discriminant analysis to predict culpable and nonculpable group membership. In this analysis, classes of road area familiarity, age-adjusted driving experience and age were used as dummy variables to predict culpable and nonculpable group membership — thus allowing each class of road area familiarity, age-adjusted driving experience and age to be ranked by discriminatory power. Results of this analysis are presented in Table 2-26. Classes

Table 2-29

Comparison of Male and Female, Culpable and Nonculpable Accident-Involved Drivers by Road Area Familiarity

	Males				Females			
Road Area Familiarity	Non-Culpable		Culpable[1]		Non-Culpable		Culpable[1]	
	n	%	n	%	n	%	n	%
Driven Daily	453	53.4	499	42.9	245	56.6	253	41.2
Twice a Week	130	15.3	159	13.7	68	15.7	73	11.9
Once Weekly	68	8.0	100	8.6	38	8.8	66	10.7
Twice Monthly	28	3.3	45	3.9	11	2.5	28	4.6
Once Monthly	30	3.5	58	5.0	17	3.9	28	4.6
Very Infrequently	105	12.4	200	17.2	44	10.2	120	19.5
First Time on Roadway	35	4.1	103	8.8	10	2.3	46	7.5
Total	849	100.0	1164	100.0	433	100.0	614	100.0
	Kolmogorov-Smirnov Z=2.70, p=.0000				Kolmogorov-Smirnov Z=3.07, p=.0000			

Source: Phases II, III, IV and V on-site investigated accidents.

[1] At the certain or probable, causal or severity-increasing levels of certainty and significance.

with high rank, e.g., 1, are more descriptive of **nonculpable** drivers; classes with low rank are more descriptive of **culpable** drivers. To further clarify, classes have been marked with stars (*), minuses "-" or M's. "Starred" classes are descriptive of nonculpable drivers and "minused" classes are descriptive of culpable drivers. M's mark classes with little discriminatory power. Culpable accident-involved women are shown to have little road area familiarity, moderate driving experience for their age and are 15-24 or 45-54 years old. Nonculpable accident-involved women are familiar with the road area, have more than expected driving experience for their age and are 35-44 or over 54 years old.

Table 2-30

Comparison of Male and Female, Culpable and Nonculpable Accident-Involved Drivers by Age

Age	Males				Females			
	Non-Culpable		Culpable[1]		Non-Culpable		Culpable[1]	
	n	%	n	%	n	%	n	%
Under 20	157	17.3	318	24.5	60	13.0	127	19.1
20-24	266	29.3	395	30.4	115	24.9	184	27.7
25-34	194	21.4	252	19.4	121	26.2	143	21.5
35-44	103	11.3	100	7.7	81	17.5	84	12.7
45-54	91	10.0	83	6.4	45	9.7	74	11.1
55-64	55	6.1	64	4.9	22	4.8	28	4.2
65 and over	42	4.6	88	6.8	18	3.9	24	3.6
Total	908	100.0	1300	100.0	462	100.0	664	100.0
	Kolmogorov-Smirnov Z=2.12, p=.0002				Kolmogorov-Smirnov Z=1.54, p=.0173			

Source: Phases II, III, IV and V on-site investigated accidents.

[1] At the certain or probable, causal or severity-increasing levels of certainty and significance.

In summary, female culpability in accidents is highly related to road area familiarity, age-adjusted driving experience and age but not to either vehicle familiarity or annual mileage. Nonculpable women drivers are characterized as having high road area familiarity, more driving experience than would be expected for their age and either being over 54 or 35 to 44 years old. Culpable women drivers are characterized as having zero to moderate road area familiarity, moderate driving experience for their age and being under 25 or between the ages of 45 and 54.

Males

Results for males are presented in Table 2-27. The best predictor of culpability for men is

Table 2-31

Comparison of Male and Female, Culpable and Nonculpable Accident-Involved Drivers by Driving Experience

	Males				Females			
Months Driving Experience	Non-Culpable		Culpable[1]		Non-Culpable		Culpable[1]	
	n	%	n	%	n	%	n	%
Under 18	51	6.0	124	10.6	23	5.3	69	11.4
18-29	54	6.4	98	8.4	26	6.0	42	7.0
30-41	55	6.5	91	7.8	29	6.7	45	7.5
42-53	66	7.8	91	7.8	32	7.4	42	7.0
54-113	208	24.6	308	26.4	107	24.7	140	23.2
114-233	163	19.3	190	16.3	101	23.3	133	22.0
234-353	92	10.9	73	6.3	69	15.9	69	11.4
354-473	72	8.5	66	5.7	25	5.8	36	6.0
474-593	45	5.3	63	5.4	16	3.7	18	3.0
594 and over	38	4.5	62	5.3	5	1.2	10	1.7
Total	844	100.0	1166	100.0	433	100.0	604	100.0
	Kolmogorov-Smirnov Z=2.22, p=.0001				Kolmogorov-Smirnov Z=1.68, p=.0072			

Source: Phases II, III, IV and V on-site investigated accidents.

[1] At the certain or probable, causal or severity-increasing levels of certainty and significance.

road area familiarity (K-S Z=2.70, p $\leq$ .0000). Road area familiarity distributions are presented in Table 2-29. Accident-involved males who drive the road at least twice a week are less culpable than those who drive the road less frequently. The median test (p = .0000) indicates culpable males have significantly less road area familiarity than nonculpable males.

The second best predictor of male culpability is vehicle familiarity (K-S Z=2.28, p=.0001). After adjustment for age, results are still significant (K-S Z=1.59, p=.0129). This is important

Table 2-32

Comparison of Male and Female, Culpable and Nonculpable Accident-Involved Drivers by Vehicle Familiarity

	Males				Females			
Vehicle Familiarity	Non-Culpable		Culpable[1]		Non-Culpable		Culpable[1]	
	n	%	n	%	n	%	n	%
Less than 3	128	15.3	244	21.3	48	11.3	66	10.9
3-6	128	15.3	226	19.7	58	13.6	99	16.3
7-12	186	22.3	238	20.7	83	19.6	130	21.5
13-24	181	21.7	204	17.8	97	22.8	133	21.9
25-36	93	11.1	102	8.9	55	12.9	80	13.2
37-60	72	8.6	76	6.6	57	13.4	63	10.4
61 and over	47	5.6	57	5.0	27	6.4	35	5.8
Total	835	100.0	1147	100.0	425	100.0	606	100.0
	Kolmogorov-Smirnov Z=2.28, p=.0001				Kolmogorov-Smirnov Z=.71, p=.7009			

Source: Phases II, III, IV and V on-site investigated accidents.

[1] At the certain or probable, causal or severity-increasing levels of certainty and significance.

because it indicates that, for men, vehicle familiarity independent of age is related to culpability in accidents. The distribution of age-adjusted vehicle familiarity for culpable and nonculpable males is presented in Table 2-35. After adjustments for age, males with less than 25 months driving experience are more culpable; males who have 25 or more months driving experience are less culpable. The median test (p=.0489) shows that culpable males have less vehicle familiarity independent of the effect of age than nonculpable males—14.4 months for nonculpable males and 12.7 months for culpable males.

The next most predictive driver attribute for males is driving experience (K-S Z=2.22, p=.0001). However, after the effects of age are removed; this relationship disappears (K-S Z=.98, p=.3524) indicating the relationship between driving experience and culpability can be

Table 2-33

Comparison of Male and Female, Culpable and Nonculpable Accident-Involved Drivers by Annual Mileage

	Males				Females			
Annual Mileage	Non-Culpable		Culpable[1]		Non-Culpable		Culpable[1]	
	n	%	n	%	n	%	n	%
Less than 6,000	65	8.1	133	12.4	74	20.7	115	23.9
6,000 to 10,999	247	30.9	306	28.5	175	48.9	224	46.5
11,000 to 15,999	189	23.7	255	23.7	67	18.7	87	18.0
16,000 to 20,999	131	16.4	148	13.8	18	5.0	37	6.4
21,000 to 25,999	46	5.8	84	7.8	11	3.1	11	2.3
26,000 to 30,999	54	6.8	39	3.6	7	2.0	5	1.0
31,000 and over	67	8.4	109	10.1	6	1.7	9	1.9
Total	799	100.0	1074	100.0	358	100.0	482	100.0
	Kolmogorov-Smirnov Z=1.09, p=.1850				Kolmogorov-Smirnov Z=.95, p=.3302			

Source: Phases II, III, IV, and V on-site investigated accidents.

[1] At the certain or probable, causal or severity-increasing levels of certainty and significance.

accounted for by the effects of driver age. This does not mean an "experience" effect is nonexistent; it does mean that experience and age effects for males on overall culpability cannot be separated.

Driver age is the next best predictor of male culpability (K-S Z=2.2, p=.0002). Age distributions of culpable and nonculpable males are presented in Table 2-30. Accident-involved males 15-20 and over 64 are most culpable, while accident-involved males 35-64 are least culpable. The median test (p=.0002) shows that culpable drivers are younger than nonculpable drivers.

No significant relationship exists between culpability and annual mileage before or after adjustments for driver age (see Tables 2-33 and 2-36).

Table 2-34

Comparison of Male and Female, Culpable and Nonculpable Accident-Involved Drivers by Age-Adjusted Driving Experience

	Males				Females			
Age Adjusted Driving Experience in Months	Non-Culpable		Culpable[1]		Non-Culpable		Culpable[1]	
	n	%	n	%	n	%	n	%
Under 18	8	1.0	12	1.0	21	4.9	29	4.8
18-29	2	.2	0	0	3	.7	4	.7
30-41	8	1.0	5	.4	3	.7	5	.8
42-53	2	.2	4	.3	4	.9	6	1.0
54-113	23	2.7	28	2.4	29	6.7	41	6.8
114-137	56	6.7	81	7.0	66	15.3	92	15.3
138-161	218	25.9	316	27.1	105	24.4	203	33.7
162-185	278	33.0	418	35.9	90	20.9	100	16.6
186-211	150	17.8	179	15.4	48	11.1	39	6.5
212-233	52	6.2	64	5.5	25	5.8	31	5.1
234-353	44	5.2	54	4.6	36	8.4	52	8.6
354-473	1	.1	3	.3	1	.2	1	.2
Total	842	100.0	1164	100.0	431	100.0	603	100.0
	Kolmogorov-Smirnov Z=.93, p=.3524				Kolmogorov-Smirnov Z=1.82, p=.0026			

Source: Phases II, III, IV and V on-site investigated accidents.

[1] At the certain or probable, causal or severity-increasing levels of certainty and significance.

Table 2-35

Comparison of Male and Female, Culpable and Nonculpable Accident-Involved Drivers by Age-Adjusted Vehicle Familiarity

Age Adjusted Vehicle Familiarity in Months	Males				Females			
	Non-Culpable		Culpable[1]		Non-Culpable		Culpable[1]	
	n	%	n	%	n	%	n	%
Less than 3	130	15.6	183	16.0	64	15.1	71	11.7
3-6	113	13.6	164	14.3	35	8.3	46	7.6
7-12	142	17.1	238	20.7	52	12.3	93	15.4
13-24	196	23.6	279	24.3	109	25.8	184	30.4
25-36	123	14.8	137	11.9	74	17.5	93	15.4
37-60	84	10.1	88	7.7	62	14.7	83	13.7
61 and over	44	5.3	58	5.1	27	6.4	35	5.8
Total	832	100.0	1147	100.0	423	100.0	605	100.0
	Kolmogorov-Smirnov Z=1.59, p=.0129				Kolmogorov-Smirnov Z=.79, p=.5596			

Source: Phases II, III, IV, and V on-site investigated accidents.

[1] At the certain or probable, causal or severity-increasing levels of certainty and significance.

In addition to the above analysis, road area familiarity, age-adjusted vehicle familiarity and age were used in a discriminant analysis to predict culpable and nonculpable group membership. In this analysis, classes of road area familiarity, age-adjusted vehicle familiarity and age were used as dummy variables to predict culpable and nonculpable group membership. Each class of road area familiarity, age-adjusted vehicle familiarity and age was ranked by discriminatory power after taking into account the effects of other variable classes. Results of this analysis are displayed in Table 2-28. Classes with high rank, e.g., 1, are more descriptive of nonculpable drivers; classes with low rank are more descriptive of culpable drivers. To further clarify, classes have been marked with stars "*", minuses "-" and M's.

Table 2-36

Comparison of Male and Female, Culpable and Nonculpable Accident-Involved Drivers by Age-Adjusted Annual Mileage

	Males				Females			
Age Adjusted Annual Mileage	Non-Culpable		Culpable[1]		Non-Culpable		Culpable[1]	
	n	%	n	%	n	%	n	%
Less than 6,000	93	11.7	121	11.3	69	19.4	117	24.3
6,000 to 10,999	209	26.3	275	25.6	174	48.9	192	39.9
11,000 to 15,999	195	24.5	288	26.8	68	19.1	112	23.3
16,000 to 20,999	130	16.3	150	14.0	20	5.6	34	7.1
21,000 to 25,999	63	7.9	97	9.0	11	3.1	12	2.5
26,000 to 30,999	39	4.9	37	3.4	8	2.2	4	.8
31,000 and over	67	8.4	106	9.9	6	1.7	10	2.1
Total	796	100.0	1074	100.0	356	100.0	481	100.0
	Kolmogorov-Smirnov Z=.90, p=.394				Kolmogorov-Smirnov Z=.85, p=.4609			

Source: Phases II, III, IV, and V on-site investigated accidents.

[1] At the certain or probable, causal or severity-increasing levels of certainty and significance.

"Starred" classes are descriptive of nonculpable drivers and "minused" classes are descriptive of culpable drivers. M's indicate classes with little discriminatory power. Culpable accident-involved men are shown to have little road area familiarity, less than expected vehicle familiarity for their age and are young (15-20) or old (over 64). Nonculpable accident-involved men are familiar with the road area, are more familiar with their vehicles than would be expected for their age and are 35-54 years old.

In summary, male culpability is related to road area familiarity, age-adjusted vehicle familiarity and "age/experience" but not to annual mileage. Nonculpable men are characterized as being more familiar with the road, having more familiarity with their vehicles than would be expected for their age and being between the ages of 35-54. Culpable men are characterized as having little road area familiarity, having less familiarity with their vehicles than would be expected for their age and being young (15-19) or older (over 64).

3.0 Special Analyses: Human, Vehicular, and Environmental Characteristics and Accident Causation

In this section, results of separate analysis efforts employing cluster analytic and Automatic Interaction Detector (AID) procedures, are presented. The overall objective of these two efforts was to obtain a better understanding of **who** makes **what type** of errors, and under **what conditions.**

3.1 Cluster Analysis

3.1.1 Introduction

In an effort to arrive at a taxonomy of human involvement in accidents, causation data for traffic units (95% were drivers of passenger vehicles, the remaining 5% were bicyclists or motorcyclists) from the phase IV and V sample of in-depth accidents were used as input to a cluster analysis. The purpose of the analysis was to: 1) determine whether there were any natural groupings of traffic units in terms of human causation; and 2) assess if these natural groupings of drivers differed with respect to driver knowledge, vision, and psychological makeup.

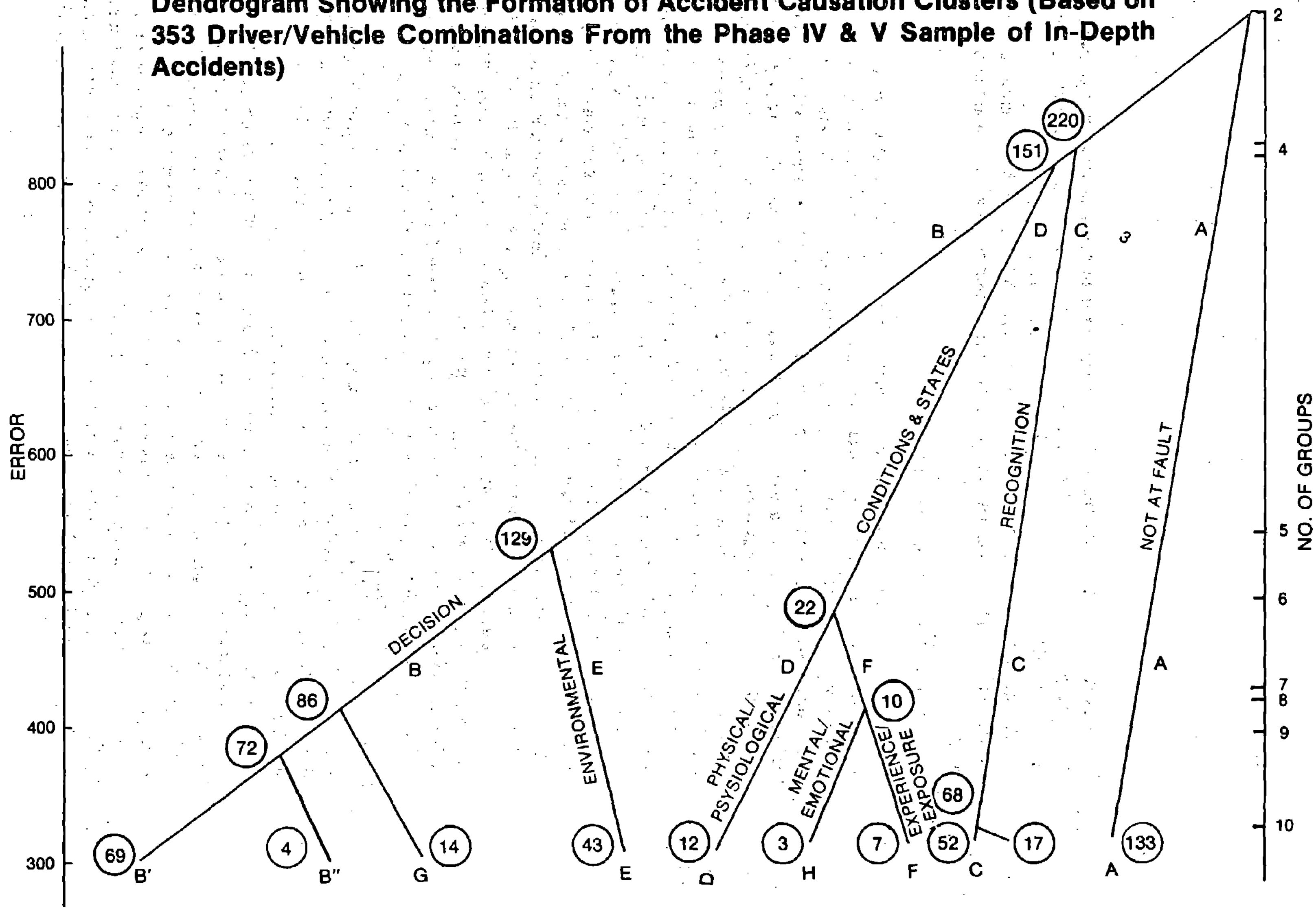
When performing the cluster analysis, the drivers which were most similar on the basis of causation variables were grouped together. As the clustering of variables continued, the groupings became larger, and the number of groups decreased until only two groups remained. It is always difficult to know exactly how many groups are sufficient to describe the data. As the number of groupings decreases, the error of classification increases. The increase in error and associated imprecision must be balanced against the parsimony of description provided by fewer groups.

Examination of the cluster analysis results for the in-depth data suggests that an optimal number of groups is somewhat less than ten. Figure 3-1 describes the results of the cluster analysis in terms of a dendrogram. At the base of the dendrogram, the clusters at the 10-cluster stage are shown. Below each cluster is listed the size of the cluster at that stage. It should be noted that the size of the clusters varies from 3 to 133.

As one moves up the dendrogram, the clusters collapse. The point at which two clusters join into a single cluster is called a node. It should be noted that the nodes do not occur at equal intervals along the vertical scale. This is because the vertical scale is an index of the relative error at each stage of the clustering. Since precision decreases as fewer groups are formed, the error index increases. The amount of increase when one goes from, say, 10 to 9 clusters is thus an indication of the incremental error associated with that particular grouping—a small increment is interpreted as a small increase in error (or small cost) when combining two particular clusters. Inspection of Figure 3-1 shows that the error associated with 10 groups is about 300 and that associated with two groups is about 800. Therefore, since the clustering

Figure 3-1

Dendrogram Showing the Formation of Accident Causation Clusters (Based on 353 Driver/Vehicle Combinations From the Phase IV & V Sample of In-Depth Accidents)



started with 353 traffic units, the *average* increase in error per clustering when going from 353 to 10 groups is approximately .*87* (300/343). On the other hand, the average increase per step in going from 10 to 2 groups is over *60* (500/8). Finally, because there was a very small increment in error associated with the move from 10 to 9 clusters, and because a very small cluster was lost when going from 9 to 8 clusters, the primary cluster description will begin at the eight-cluster stage.

3.1.2 Cluster Structure at 8 Groups

The initial description (and labeling) of the clusters will be on the basis of the causal hierarchy which was used to describe and record the involvement of human factors. The eight clusters vary in size from 3 to 133. The primary variables in the hierarchy which serve to define each cluster are listed in Table 3-1. The first cluster, A, (and the largest, n=133), consists of drivers for which no causal factors could be found at the probable level of confidence. (Note: When no causal factor was present, the factor was causal or severity-increasing in less than 10% of the cases in the cluster. On the other hand, a factor is said to be present when it was judged as causal or severity-increasing in 25% or more of the cases in the cluster.)

The second largest cluster (B) consisted of 72 drivers in which Decision errors were present 89% of the time. Also present, but at a much lower rate (35%), are Environmental factors. Associated with this cluster is Cluster G, which has only 14 drivers, but for which Decision errors, false assumption in particular, are present in all cases. A secondary characteristic of this small cluster is the presence of highway-related Environmental errors in 9 of the 14 cases (64%).

The third largest cluster (C) is a Recognition Cluster. In this cluster, Recognition errors (Delays in particular) were judged to be causal or severity-increasing for 100% of the drivers. Improper Lookout was a factor in 42%, and Internal Distraction was a factor in 25%. It should be noted that this cluster **does not** contain all of the Recognition errors in the total sample; rather, it contains those errors which were judged **most similar** at this particular stage of the clustering. Recognition errors, when coupled consistently with other factors, may be and are present in other clusters.

The next cluster, Cluster E, is a fairly large cluster of 43 cases in which Environmental factors were cited as causal or severity-increasing in 100% of the cases. Of these, 74% were highway-related, and 33% were ambience-related. A secondary characteristic of this cluster was Recognition errors, which were present in 30% of the cases.

In each of the final three clusters (Clusters D, F, and H) Human Conditions and States were indicated as causal or severity-increasing in 100% of the cases. In Cluster D, consisting of 12 cases, Physical Conditions were cited in all cases, and Alcohol in 42%. Secondary characteristics of this cluster were the presence of Decision and Recognition errors. In Cluster F, Experience-Exposure was cited as a factor in all 12 cases. Secondary characteristics were either Decision errors (primarily excessive speed) and Performance errors or Environmental factors. The smallest cluster (H) consisted of three cases in which Mental-Emotional States were cited and were coupled with Decision errors. As noted in the table, there were secondary

Table 3-1

Description of 8 Clusters in Terms of Causal Hierarchy

CLUSTER A (n = 133)	
Not at Fault	
CLUSTER B (n = 72)	
Decision	.89
Environmental	.35
CLUSTER E (n = 43)	
Environmental	1.00
Highway Related	.74
Ambience Related	.33
Recognition errors	.30
CLUSTER F (n = 7)	
Conditions or States	1.00
Experience-Exposure	1.00
Decision	.71
Excessive Speed	.43
Performance Errors	.43
Environmental	.29
Non-Slick	.29

CLUSTER C (n = 69)	
Recognition	1.00
Delays	1.00
Improper Lookout	.42
Internal Distraction	.25
CLUSTER G (n = 14)	
Decision	1.00
False Assumption	1.00
Environmental	.64
Highway Related	.64
CLUSTER D (n = 12)	
Conditions or States	1.00
Physical	1.00
Alcohol	.42
Decision	.42
Recognition	.33
Delays	.25
CLUSTER H (n = 3)	
Conditions or States	1.00
Mental-Emotional	1.00
Decision	1.00
Improper Driving Technique	.67
Excessive Speed	.67
Environmental Factors	.33
Slick	.33
Non-Slick	.33
Highway Related	.33
Ambience Related	.33

characteristics for this cluster; however, since the number of cases is so small, no firm inference may be drawn.

The Dendrogram Structure

It is often instructive to study the tree structure on which the clusters are based since it indicates the degree to which different clusters are linked with each other. This is especially important since the decision to describe the data in terms of a given number of different clusters is (as noted above) somewhat arbitrary.

As the eight clusters are reduced to seven, Clusters F and H are combined. The result is a Human Conditions and States Cluster comprised of drivers in which Experience-Exposure or Mental-Emotional aspects are present. At the next iteration, the two Decision error clusters (B and G) are combined. At the five-cluster stage, the Human Conditions and States (Clusters D, F, and H) have been combined into a single cluster (D) consisting of 22 cases.

To reach the four-cluster stage, the Decision and Environmental Clusters (B and E) are combined into a single cluster. At this stage the other clusters are a Human Conditions and States Cluster, a Recognition Error Cluster, and a Not-at-Fault (no error) Cluster.

At the next stage, the Decision Cluster and Conditions and States Cluster are combined. Finally, the Recognition Error Cluster is combined into the by now quite large cluster of At-Fault Drivers.

One implication to be drawn from the cluster analysis at this point is that Decision errors and Environmental factors are closely linked since the associated clusters were combined very early. To a lesser extent, Human Conditions and States and Decision Errors are linked. A more or less unitary concept is the Recognition error. Evidence for this is that this cluster remains intact and isolated from the other at-fault clusters until the last iteration.

It should be noted that the clustering, at the four-cluster stage, into Not-at-Fault, Recognition, Conditions and States, and Decision and Environmental factors is at least partially due to the human accident-causation model used in this study. The model views the driver as a real-time information processor in which information is first recognized, then evaluated (decision), and finally acted upon (response). In determining human direct causes, the search was typically for the first critical error. Thus, if a driver misperceived the situation, he would have been cited for a Recognition error but not a Decision error, whereas if a driver perceived the situation correctly but then made an inappropriate decision, he would be cited for a Decision, but not a Recognition, error. Thus, to the extent that only one of the two processes was a critical cause, the other would not be cited. The observed association between Decision errors and Environmental factors, however, and the independence of Conditions and States from the Direct Human errors cannot be attributed to the human factors model, but is rather a direct outcome of the cluster analysis.

3.1.3 The Dimensional Structure of the Eight Clusters

When there are eight distinguishable clusters, they may be completely represented by seven dimensions. As a part of the discriminant analysis, the dimensional structure of the clusters can be described. The successive dimensions account for successively less of the data, so that the first dimension is most important, and the seventh dimension is least important (in the statistical sense). It is possible to locate each cluster on each dimension and, as a result, to give the dimension substantive interpretation. A plot of each cluster across dimensions is represented in Figure 3-2. The following discussion will describe each dimension in order of its (statistical) salience.

Dimension 1. The first dimension appears to be a bipolar dimension with the Not-at-Fault Cluster (A) at one extreme and the Decision Clusters B, H, G, and F bunched together at the other extreme with D, also a Decision Cluster, located nearby. Although Clusters H, G, and F are Human Conditions and States Clusters, they do have Decision errors as secondary characteristics, as may be seen in Table 3-1. At the center of the dimension, Cluster E, the Environmental Cluster, is located toward the Not-at-Fault Cluster and the Recognition Cluster (C), located toward the Decision errors. Thus, this dimension appears to be a Not-at-Fault vs. Decision errors dimension.

Dimension 2. This is a Recognition vs. other error type dimension. All of the other clusters, with the exception of Cluster D (the Physical Conditions and States Cluster), are grouped very close together at the other end of the distribution.

Dimension 3. This dimension is an Environmental factor vs. other error dimension. While the other clusters are rather spread out, the Environmental Cluster is clearly isolated from the others.

Dimension 4. This dimension has all clusters grouped close together with the exception of Cluster D, which is a Human Conditions and States Cluster comprised of drivers for whom Physical Conditions were cited as causal.

Dimension 5. This dimension is a secondary Decision dimension. While Dimension 1 grouped all Decision clusters together, this cluster has Cluster G, a Decision and Environmental factor cluster, isolated at one extreme.

Dimension 6. Like Dimension 4, this dimension may be described as a Human Conditions and States dimension. This dimension, however, contrasts the Mental Condition Cluster against all other clusters.

Dimension 7. This dimension is also a Human Conditions and States dimension since at one extreme is located Cluster F, which is the Experience-Exposure Cluster. Midway between it and all of the other clusters is Cluster H, the Mental Conditions Cluster.

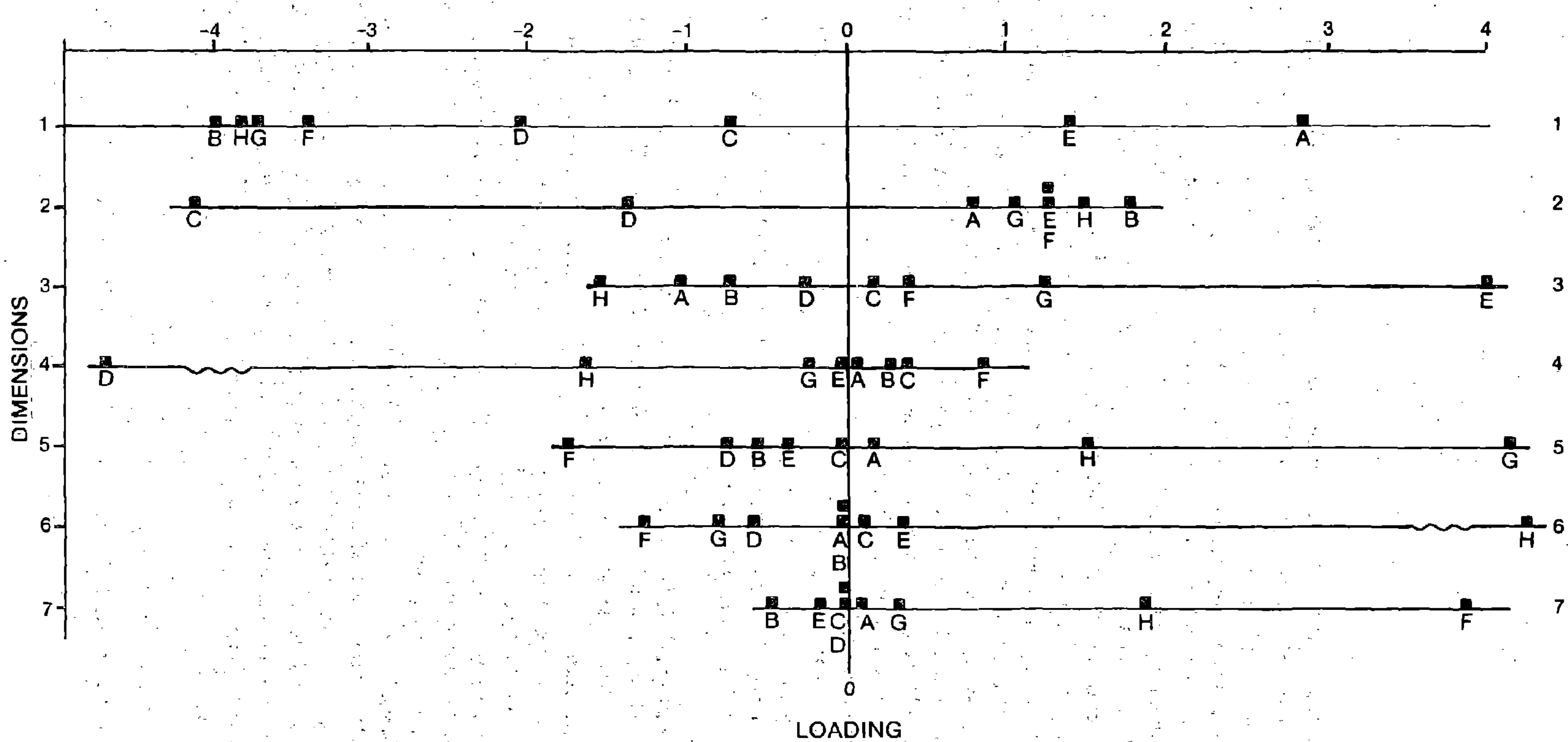
In summary, then, the seven dimensions may be characterized as a Not-at-Fault vs. Decision error dimension (1); a Recognition dimension (2); an Environmental dimension (3); a secondary Decision error dimension (5); and three Human Conditions and States dimensions (4, 6, and 7).

The Precision of the Clusters

Since the clusters were generated by means of clustering drivers on the basis of the causal

Figure 3-2

Location of Clusters on Each of 7 Dimensions



(see Table 3-1 for Cluster Labels)

hierarchy, and since it is not clear exactly how precise the clustering is at the eight-group stage, a discriminant analysis was performed on the eight groups using the 29 causal hierarchy variables. [In addition, 29 additional variables were used—the Driver Knowledge Test (DKT), the Driver Vision Test (DVT), and the Profile Scores (PS). The results of this analysis indicated that these 8 clusters can be distinguished on the basis of the variables used. It should be noted that the inclusion of 29 additional variables which were not used in the categorization actually may increase the errors of classification. In this analysis, however, the 8 clusters can be classified and reconstructed with very small error.] If the results of the discriminant analysis are summarized in terms of the accuracy of classification, we find that 95.8% of the cases are classified correctly. The results of this classification are summarized in Table 3-2. The patterns of misclassification should be noted. Of the 15 misclassifications, 11 are misclassifications **into** Clusters B and G, which are Decision Error Clusters, and 8 of those 11 are **from** clusters in which Decision errors are a factor. There are very few misclassifications **into or out of** Cluster C, which suggests the strength and cohesiveness of the Recognition factor. In addition, there were no misclassifications **into** the Human Conditions and States Clusters (D, F, and H). Also, there were no misclassifications **into** the Not-at-Fault Cluster.

3.1.4 Stability of the Cluster Structure Model—Comparison with On-Site Cluster Analysis

Before further analyses based on the eight-cluster structure can be judged as viable, it was decided to conduct a similar analysis on the on-site data base. The extent to which the on-site clusters would then correspond to the in-depth clusters would be an indication of the reproducibility of the results, i.e., a measure of the reliability of the clinical evaluation method.

Because of the large number of units involved in the on-site data file, and because of the expense of doing cluster analysis by computer, the procedure adopted was that of analyzing (by means of cluster analysis) random samples of 200 traffic units from the on-site data file. While such a random sampling procedure results in multiple descriptions, it is economical and has the advantage of providing a further indication of how stable the accident clusters are. That is, if the cluster descriptions are relatively consistent across samples, then it is reasonable to conclude that the resultant clusters indeed describe viable grouping of accidents.

Cluster analyses were performed on 14 random samples selected from the on-site file. A general dendrogram describing the structure found across all cluster runs is summarized in Figure 3-3. This result is similar to that for the in-depth cluster analysis and the more detailed analysis done in Interim Report II. Perhaps due to the smaller sample size, no consistent pattern emerged at cluster levels greater than five. Note that at the five-cluster level, the correspondence between the clusters in Figure 3-1 and Figure 3-3 is very good. Thus, for both in-depth and on-site data, the main groupings of cases are based on the categories Not-at-Fault, Conditions and States, Recognition, Environmental, and Decision, with the split between Decision errors and Environmental factors being the last.

Table 3-2

Summary of Classification Errors for 8 Clusters Using 58 Variables (Causal Hierarchy, Driver Knowledge Test, Driver Vision Test, and Profile Scores)

Actual Cluster Membership	N	Predicted Cluster Membership A	B	C	D	E	F	G	H
A	133	131	0	1	0	0	0	1	0
B	72	0	70	0	0	1	0	1	0
C	69	0	0	67	0	0	0	2	0
D	12	0	2	1	8	0	0	1	0
E	43	0	0	1	0	42	0	0	0
F	7	0	1	0	0	0	6	0	0
G	14	0	2	0	0	0	0	12	0
H	3	0	1	0	0	0	0	0	2

(95.8% of cases classified correctly)

3.1.5 The Distribution of Other Variables on the Clusters

At the eight-cluster stage, the scores on the driver knowledge test, driver vision test, and profile scores were computed for each cluster. The mean score on each of these variables within the eight clusters is summarized in Table 3-3. Also included in Table 3-3 is the grand mean on each variable for the 353 drivers. In order to see how well these variables characterize differences between the groups, a multivariate analysis of variance (MANOVA) was performed on the 29 dependent variables listed in Table 3-3. There were large and significant differences ($p < .001$) among the clusters of these variables. **It should be noted that none of these variables was used in the formation of the clusters.**

The results of the multivariate analysis are summarized in Table 3-4, which also contains the 29 variable names. Univariate ANOVA tests indicate that there are differences at beyond the .05 level for 14 of the 29 variables.

Inspection of Table 3-4 shows that there are overall differences among the clusters for the Driver Vision Test and the profile scores of Impulse Control, Alcohol-Drug Usage, and Prior Record. While there are large sex differences among the clusters, no significant age differences were found. For the Driver Vision Test, the results are complex: significant differences were

Table 3-3

Means Within Cluster Groupings on Driver Knowledge Test, Driver Vision Test, and Profile Scores

Cluster	A	B	C	D	E	F	G	H	Total
Number	133	72	69	12	43	7	14	3	353
Variable									
1	9.20	10.2	9.43	9.60	9.00	7.83	9.85	9.67	9.43
2	87.6	87.2	87.7	90.0	89.3	90.0	87.8	90.0	87.9
3	87.8	87.6	88.4	90.0	89.6	86.8	88.9	90.0	88.2
4	77.1	76.3	73.7	76.3	76.3	66.7	83.3	70.0	76.1
5	74.6	76.0	74.3	81.3	75.2	76.7	80.0	70.0	75.3
6	33.6	33.2	33.4	33.9	33.9	33.3	33.3	35.0	33.5
7	33.0	32.7	33.5	32.8	32.8	31.7	32.8	32.5	33.0
8	22.6	21.3	21.6	20.6	21.8	25.0	20.0	22.5	21.9
9	80.1	86.7	84.1	91.7	92.6	86.7	85.6	77.5	84.5
10	60.7	57.3	66.3	66.1	67.7	60.0	55.7	70.0	62.0
11	38.2	39.4	43.1	33.1	46.2	45.0	31.4	30.0	40.0
12	9.84	7.50	10.3	9.33	8.50	6.67	9.78	34.0	9.41
13	4.16	3.78	3.80	5.33	5.04	2.00	3.78	17.0	4.21
14	10.9	9.94	9.90	9.00	10.4	5.33	7.11	12.0	10.1
15	26.6	20.6	25.7	31.1	22.5	13.3	21.8	18.0	24.3
16	42.3	29.1	18.0	27.3	22.2	18.7	17.5	7.00	30.2
17	23.1	10.8	15.0	14.3	28.1	34.0	5.75	9.00	18.7
18	31.6	32.3	32.5	34.2	31.8	29.0	36.3	33.5	32.2
19	43.6	47.1	45.8	46.7	48.1	53.3	50.0	50.0	45.9
20	47.3	45.7	47.8	48.7	47.0	52.7	44.4	50.0	47.1
21	56.0	56.4	58.5	58.3	54.9	64.7	50.2	53.5	56.5
22	1.61	1.54	1.84	1.91	1.68	1.43	1.50	1.33	1.65
23	2.40	2.48	2.79	3.64	2.54	3.17	2.45	3.33	2.58
24	.71	.80	.89	1.00	.76	.86	1.00	1.00	.80
25	2.54	2.20	2.27	2.78	2.22	2.16	2.09	1.67	2.35
26	.70	1.05	.68	2.00	.80	0	.14	.33	.78
27	3.04	3.84	2.74	3.40	2.41	2.29	3.57	1.50	3.07
28	.50	.25	.41	.08	.35	.43	.29	.67	.39
29	30.3	28.9	29.4	29.6	29.9	23.7	23.4	29.7	29.3

found for 10 of the 20 DVT variables used in the analysis. Differences were found in Field of Vision variables and the Peripheral Movement In-Depth Thresholds. Finally, large differences were found in both simple and complex reaction time.

The results summarized in Table 3-4 indicate the variables for which there are differences between the clusters, but fail to specify which clusters differ. In an effort to specify differences among the clusters more precisely, ordered planned comparison analyses were performed. These tests examined differences between At-Fault and Not-at-Fault drivers (Comparison I), and among the At-Fault Clusters. These comparisons were (II) Human Conditions and States versus Other At-Fault (Clusters B+C+E+G vs. Clusters D+F+H); (III) for the Human Conditions and States Clusters, Physical vs. Mental and Experience/Exposure (Cluster D vs. F+H); (IV) Mental vs. Experience/Exposure (Clusters F vs. H); (V) Decision Clusters (B+E+G) vs. the Recognition Cluster (C); (VI) comparison of the two Decision Error Clusters (B+G) against the Environmental Factor Cluster (E); and finally, (VII) comparison of the two Decision Error Clusters (B vs. G). The results of these comparisons are summarized in Table 3-5. Each comparison will be discussed in turn.

I. Comparison of At-Fault vs. Not-at-Fault Clusters

In the comparison of the clusters of Not-at-Fault drivers (Cluster A) with all other drivers, the seven At-Fault Clusters were pooled.

The multivariate analysis of variance resulted in large differences between the two groups. The multivariate F was 3.846 with 29 and 317 degrees of freedom ($P < .001$). The univariate F tests on each of the 29 dependent variables are summarized in Table 3-5. There were significant differences found between these two groups on 9 of the 29 variables. There was no significant difference between At-Fault and Not-at-Fault drivers on the Driver Knowledge Test. For the Driver Vision Test, there were differences in Static Acuity among the two groups. For acuity, the Not-at-Fault drivers scored poorer (higher) on the no-glare/normal condition and considerably better on the no-glare/low level condition. In addition, there were large differences in Peripheral Movement In-Depth Threshold, and Dynamic Visual Acuity. The Peripheral Movement In-Depth Threshold scores were significantly poorer (higher) for the Not-at-Fault drivers. The size of this difference is 29 arc minutes/second for variable 16 and 7 arc minutes/second for variable 17 (see Table 3-3 for means). This result is counter-intuitive since it indicates that the Not-at-Fault drivers had **poorer** peripheral movement detection ability than the At-Fault Drivers. On the other hand, the Dynamic Visual Acuity Scores are significantly better for the Not-at-Fault drivers (20/44 vs. 20/48). There was no difference found between the two classes of drivers in terms of either simple or complex reaction time.

For the Profile Scores, there were no differences between the At-Fault and Not-at-Fault drivers in socio-economic status, personal adjustment, alcohol-drug usage, and prior record. Differences were significant for social adjustment and impulse control where the Not-at-Fault drivers scored better (i.e., lower) on social adjustment and poorer (i.e., higher) on impulse control. While the Not-at-Fault drivers were on the average 1.5 years older than the At-Fault

Figure 3-3
Median Cluster
Structure
On-Site

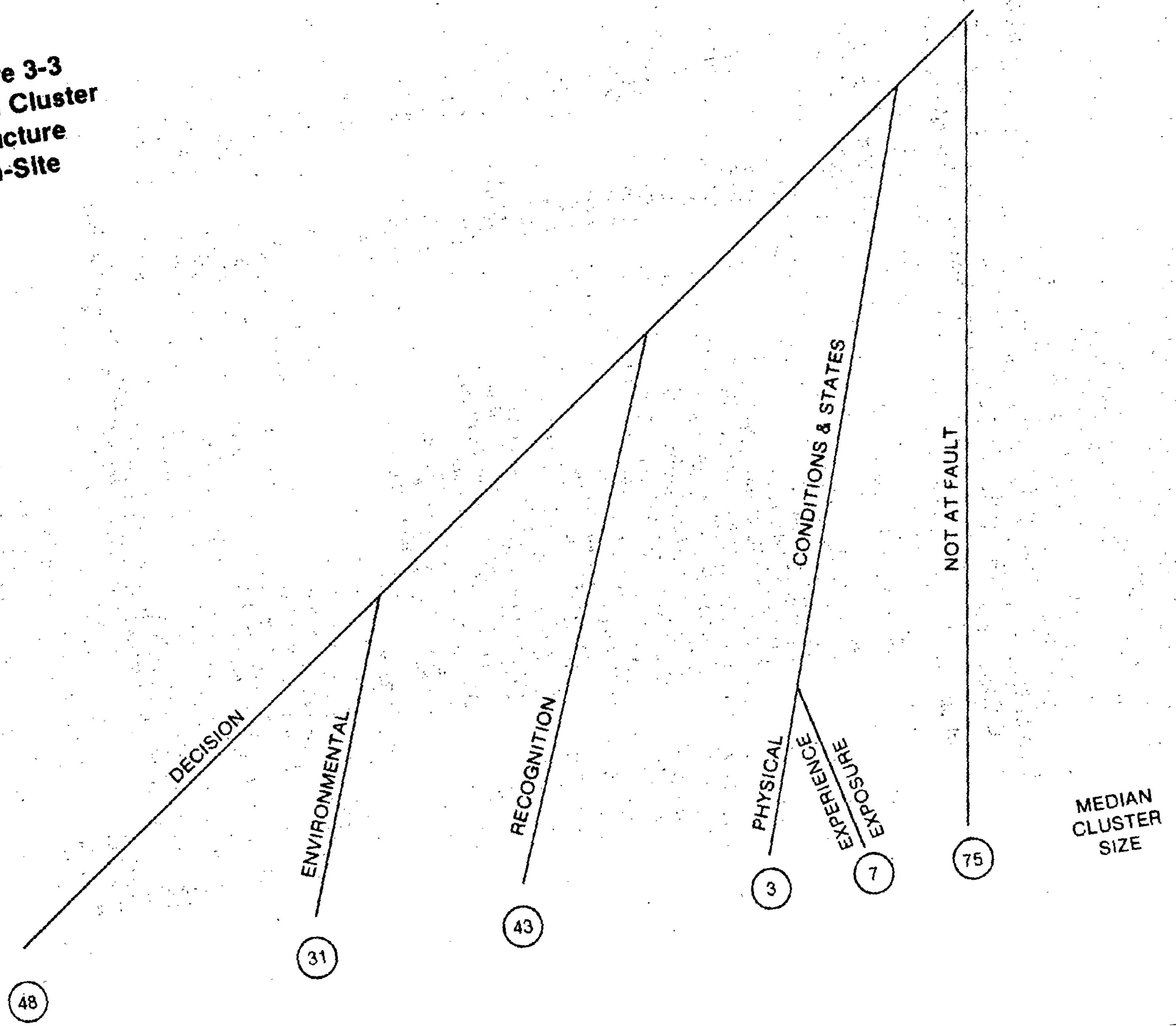


Table 3-4

Summary Results of Analysis of Variance on 29 Variables From Driver Knowledge Test, Driver Vision Test, and Profile Scores for the 8 Clusters

Variable		F-value	P less than
1	Driver Knowledge Test Score	2.007	.054
	Driver Vision Test		
2	DVT-Field of Vision-Right	2.043	.049*
3	DVT-Field of Vision-Left	2.513	.016*
4	DVT-Detect Acqu+Interpret 90'Angle-Left	3.376	.002**
5	DVT-Detect Acqu+Interpret 90 Angle-Right	1.506	.164
6	DVT-Detect Acqu+Interpret 30 Angle-Left	.487	.844
7	DVT-Detect Acqu+Interpret 30 Angle-Right	.825	.567
8	DVT-Static Acuity-No Glare-Normal	2.105	.042*
9	DVT-Static Acuity-No Glare-Low Level	1.478	.174
10	DVT-Static Acuity-Veiling Glare	1.569	.143
11	DVT-Static Acuity-Spot Glare	1.707	.106
12	DVT-Central Angular Movement-Threshold	3.861	.001***
13	DVT-Central Movement In-depth Threshold S	4.823	.001***
14	DVT-Central Movement In-depth Threshold L	.668	.700
15	DVT-Peripheral Angular Memnt-Threshold	.686	.684
16	DVT-Peripheral Memnt In-depth-Threshold S	5.499	.001***
17	DVT-Peripheral Memnt In-depth-Threshold L	4.666	.001***
18	DVT-Peripheral Movement—Tone	2.704	.010**
19	DVT-Dynamic Visual Acuity 120 Angle	1.520	.159
20	Average Simple Reaction Time	2.071	.046*
21	Average Complex Reaction Time	3.593	.001***
	Profile Scores		
22	Socio-Economic Status	.699	.673
23	Personal Adjustment	1.298	.250
24	Social Adjustment	.992	.437
25	Impulse Control	1.815	.083
26	Alcohol-Drug Usage	1.960	.060
27	Prior Record	2.134	.040*
28	Sex	3.182	.003**
29	Age	.830	.563

NOTE: All entries are Univariate F tests with 7 and 345 Degrees of Freedom. The overall Multivariate F is 2.421 with 203 and 2175 Degrees of Freedom ($p < .001$).

* $p \leq .05$
** $p \leq .01$
*** $p \leq .001$

Table 3-5

Results of Comparisons of Clusters and Cluster Groupings (Table entries are significance probabilities)

Variable		I	II	III	IV	V	VI	VII
		Comparison						
	Overall Significance:	.001	.001	.007	.001	.003	.001	.022
1	Driver Knowledge Test Score	.14	.26	.22	.25	.35	.01**	.63
	<u>Driver Vision Test</u>							
2	DVT-Field of Vision-Right	.21	.02*	.99	.99	.62	.01**	.68
3	DVT-Field of Vision-Left	.11	.48	.11	.16	.96	.004**	.19
4	DVT-Detect Acqu+Interpret 90 Angle-Left	.12	.09	.03*	.60	.01**	.51	.01**
5	DVT-Detect Acqu+Interpret 90 Angle-Right	.27	.21	.12	.32	.20	.43	.16
6	DVT-Detect Acqu+Interpret 35 Angle-Left	.77	.47	.96	.36	.98	.17	.85
7	DVT-Detect Acqu+Interpret 35 Angle-Right	.85	.30	.46	.66	.05*	.91	.93
8	DVT-Detect Acuity-No Glare-Normal	.02*	.37	.03*	.36	.67	.37	.42
9	DVT-Static Acuity-No Glare-Low Level	.01**	.84	.48	.60	.24	.20	.87
10	DVT-Static Acuity-Veiling Glare	.39	.67	.74	.52	.09	.01**	.80
11	DVT-Static Acuity-Spot Glare	.20	.26	.39	.28	.46	.03*	.17
12	DVT-Central Angular Movement-Threshold	.50	.15	.16	.001***	.10	.71	.39
13	DVT-Central Movement In-depth Threshold S	.87	.06	.52	.001***	.52	.11	.99
14	DVT-Central Movement In-depth Threshold L	.23	.45	.67	.30	.92	.60	.30
15	DVT-Peripheral Angular Memnt-Threshold	.23	.90	.16	.80	.29	.73	.89
16	DVT-Peripheral Memnt In-depth-Threshold S	.001***	.87	.37	.59	.11	.39	.20
17	DVT-Peripheral Memnt In-depth-Threshold L	.005**	.40	.20	.11	.78	.001***	.44
18	DVT-Peripheral Movement—Tone	.06	.91	.06	.17	.84	.19	.005**
19	DVT-Dynamic Visual Acuity 120 Angle	.01**	.44	.29	.70	.30	.80	.43
20	Average Simple Reaction Time	.62	.01**	.24	.53	.05*	.18	.50
21	Average Complex Reaction Time	.43	.06	.36	.04*	.005**	.74	.007**
	<u>Profile Scores</u>							
22	Socio-Economic Status	.61	.98	.25	.89	.10	.44	.90
23	Personal Adjustment	.13	.03*	.56	.89	.25	.85	.95
24	Social Adjustment	.05*	.42	.72	.75	.36	.57	.28
25	Impulse Control	.007**	.34	.07	.47	.58	.83	.70
26	Alcohol-Drug Usage	.46	.35	.006**	.76	.42	.74	.05*
27	Prior Record	.83	.53	.19	.63	.09	.002**	.70
28	Sex	.001***	.60	.04*	.45	.08	.26	.77
29	Age	.25	.68	.44	.48	.67	.40	.13

* $p \leq .05$
** $p \leq .01$

drivers (30.3 years vs. 28.8 years), the difference was not significant. There was a significant sex difference between the Not-at-Fault drivers and the At-Fault drivers (50% males vs. 68% males, respectively). These age and sex differences could account for vision and profile score differences noted above.

II. Human Conditions and States Cluster versus All Human Direct Errors Clusters

There is a significant difference between these two cluster groups (multivariate $F = 2.212$, with 29 and 317 degrees of freedom, $p < .001$. These differences are largely confined to some of the Driver Vision Tests, but primarily simple reaction time ($p < .01$), which was slightly longer for the drivers classified as impaired (Cluster D). There is a difference on the Personal Adjustment Profile Score ($p < .03$), the drivers in the Human Conditions and States Clusters having higher scores on personal adjustment, indicating **poorer** personal adjustment.

III. Human Conditions and States Clusters: Physical versus Mental/Environmental and Experience/Exposure

In this comparison within the Human Conditions and States Clusters, there are highly significant differences ($p < .007$) on the Driver Vision Test (see Table 3-5), but not on the Driver Knowledge Test. Drivers classified as physically impaired had better static acuity, and were apparently better at time-sharing different tasks (based on Variable 18—tone count) than those classified into the Mental and Experience-related Conditions and States. On the Profile Scores, there are significant differences on impulse control, and alcohol-drug usage, the members of the Physical Condition Cluster having poorer impulse control and greater alcohol-drug usage. Some of these effects may be due to confounding with sex since there are significantly more males in Cluster D.

IV. Human Conditions and States Clusters: Mental (F) versus Experience/Exposure (H)

Although there are significant differences between these two clusters, the small sample sizes tend to render the differences not meaningful. The differences found were on the Driver Vision Test and complex reaction time.

V. Decision versus Recognition Clusters

In the comparison of the Decision Clusters (B, E, G) with the Recognition Cluster (C), an overall significant difference was found ($p < .003$). These differences were found on five Driver Vision Test items, and in particular, both reaction time measures. Both simple and choice reaction times were slightly longer for the drivers in the Recognition Cluster. These drivers also had poorer acuity in the presence of veiling glare. There were no differences on the Profile Scores although there is a slight difference in prior record, with those drivers making Decision errors having a slightly poorer record. In addition, there are significantly more females in the Recognition Cluster.

VI. Decision Cluster versus Environmental Error Clusters

There is a large difference between these two cluster types ($p < .001$). There is a significant Driver Knowledge Test difference, with the scores of those drivers in the Environmental Error Cluster scoring significantly lower on the test than those in the Decision Clusters. There were five differences on the Driver Vision Test (see Table 3-5). Drivers classified into the Decision Cluster had a slightly narrower visual field, had worse peripheral movement detection ability (PMD-L: 28 minutes of arc/second vs. 9 minutes of arc/second), but had better acuity under veiling glare (20/57 vs. 20/68). There were no sex and age differences, although there was a significant difference between the clusters in terms of prior record, the Environmental Error group having a significantly "better" prior record.

VII. Within Decision Clusters Comparisons, Cluster B versus Cluster G

There is a slight, but significant, difference between these two clusters. These differences are largely confined to the Driver Vision Test and complex reaction time. There was a difference in terms of the Profile Score on alcohol-drug usage, the smaller cluster (G) evincing virtually no alcohol-drug usage, compared with a fairly high rate for the drivers within the other cluster (B), i.e., drivers making Decision errors **other** than False Assumption.

3.1.6 Summary

The results of the cluster analysis of the causal hierarchy indicate that the hierarchy is consistent, in that there are clear groupings or clusters of traffic units. These "natural" groupings are on the basis of Decision errors, Recognition errors, Environmental factors, Human Conditions and States, and no errors. This pattern is consistent with the causal factor hierarchy and suggests that the accident investigators were in fact able to use it properly. The groupings also appear to be highly stable since they were obtained for both the in-depth data as well as random-sample analyses of on-site data.

The grouping of drivers into the above clusters also appears to be meaningful in terms of other driver attributes (vision, knowledge, personality, and reaction time) which were **not used** in the process of deriving the clusters. These results indicate that the causal hierarchy is a useful system for a taxonomy of accident-involved drivers. In particular, analyses of the accident-involved driver vision (Section 2.1) and personality (Section 2.3) results also support the usefulness of the hierarchy's classification code.

3.2 AID Analysis

3.2.1 Introduction

In the development of hypotheses related to the design of models of the driver role in traffic accidents it is advantageous to know the characteristics of drivers who are most likely to commit errors of any kind, the errors they are most likely to commit, and the characteristics of drivers most likely to commit each type of error. It might be of interest, for example, to know the particular characteristics of people who were involved in accidents because they improperly entered a travel lane, or to have a description of the most error-prone type of driver. Such information, confirmed by subsequent hypothesis testing, would permit the tailoring of educational programs to specific types of students, thereby maximizing the effectiveness of instruction; it could be used in the design and targeting of public information programs; and it should lead to hypotheses which would inform the design of future accident causation studies. This section represents an exploratory attempt to develop profiles of accident-involved drivers for a number of error types drawn from the IRPS causal hierarchy.

3.2.2 Methodology

With a typology of errors defined by the IRPS causal hierarchy (1), and with a large number of driver and accident situation characteristics collected, the problem is to choose a technique which can best utilize all available information. One obvious approach is through some form of index construction, but construction of indices from the type of data available on accident errors would require the ability to assign differential weights to possible predictors. Since there are no a priori criteria for the assignment of weights, some form of analysis which would allow the computation of weights based on available data is necessary. The ultimate choice of technique was dictated by the nature of the problem, as already stated, and the nature of the data. Taking error type as the dependent variable, four related techniques present themselves as obvious choices for the solution of this problem: discriminant function analysis, multiple regression, multiple classification analysis, and the Automatic Interaction Detector (AID). Since (1) most of the predictor variables involved are either categorical or crude ordinal scale variables; (2) there is every reason to expect nonlinear relationships between certain predictors and most of the dependent variables; (3) there is also every reason to expect nonadditive, i.e., interactive, relationships between sets of predictors and dependent variables; and (4) it was not possible to specify the precise nature of those relationships; the first three techniques were clearly not suitable. AID, because of its use of nominal and ordinal level predictors and because of its lack of restrictive assumptions concerning linearity and additivity, was the best available technique to permit the "discovery" of patterns of relationships that might otherwise not have been detected.

The Automatic Interaction Detector (AID), a technique developed principally by Sonquist and Morgan (2, 3) and tested by Sonquist (4), is designed for use as an exploratory device to discover patterns of relationships between a continuous dependent variable and one or more predictors. Utilizing principles of analysis of variance (ANOVA) to repeatedly subdivide a sample, AID generates a hierarchical "tree" of the type presented in section 3.2.3. Each split is decided by finding the predictor (independent variable) that accounts for the greatest proportion of the variation in the dependent variable in each group. In analysis of variance terms, a split is made on the predictor which maximizes the correlation ratio (E^2), which is the ratio of the between (explained) sum of squares to the total sum of squares (BSS/TSS) (5). A group is not split if the total variation within it is too small by arbitrary criteria; the group size is too small, defined as less than 20 for purposes of this study; or if E^2 is less than .006, i.e., the split would not account for at least 0.6% of the variation in the dependent variable. These quite liberal criteria are useful for exploratory research even though they present a risk of allowing some spurious splits, a relatively minor risk with the 2,433 cases analyzed. The ultimate test of a split must therefore be a judgment by the analyst that the results are reasonable and substantively explicable (4).

The analysis using 2,433 complete cases from the on-site traffic unit level data from Phases II, III, IV and V was performed in three stages: once with only those predictors which define driver characteristics, once with both driver-related and accident situation-related predictors, and, finally, with a subset of the larger group that most frequently appeared to have some relationship to human errors. The results of the third set of analyses are presented here. The dependent variables used in the analysis, all drawn from the IRPS causal hierarchy described in a previous IRPS report (1), are presented in Table 3-6. All dependent variables were collapsed into dichotomous categories coded as follows:

0—Not identified at the probable or certain level as a causal or severity-increasing factor, and

1—Identified at the probable or certain level as a causal or severity-increasing factor.

Hence, the mean on any independent variable is also the proportion of ones, i.e., the proportion of cases identified. That proportion is the expected value of the dependent variable, given no other information, and is the prior probability that any case will have been identified as having committed that error. The mean of any subgroup defined in the AID tree is the posterior probability that a case in that group will have been so identified.

The set of analyses reported here tests the proposition that driver errors can be classified according to the ten selected driver demographic and environmental characteristics described in Table 3-7.

3.2.3 Findings

Figures 3-4 through 3-17 are the AID trees for the causal factors that split on at least one of the dependent variables used in the analyses. Table 3-8 is the summary table of the 13 AID runs showing not only the splits that occurred in the trees, but the competition between different predictor variables which could have split the sample at the same point but which were overshadowed by a more powerful predictor.

Reading

Figure 3-4 can be read as follows. The box on the left represents the entire sample before

Figure 3-4
Human Factors

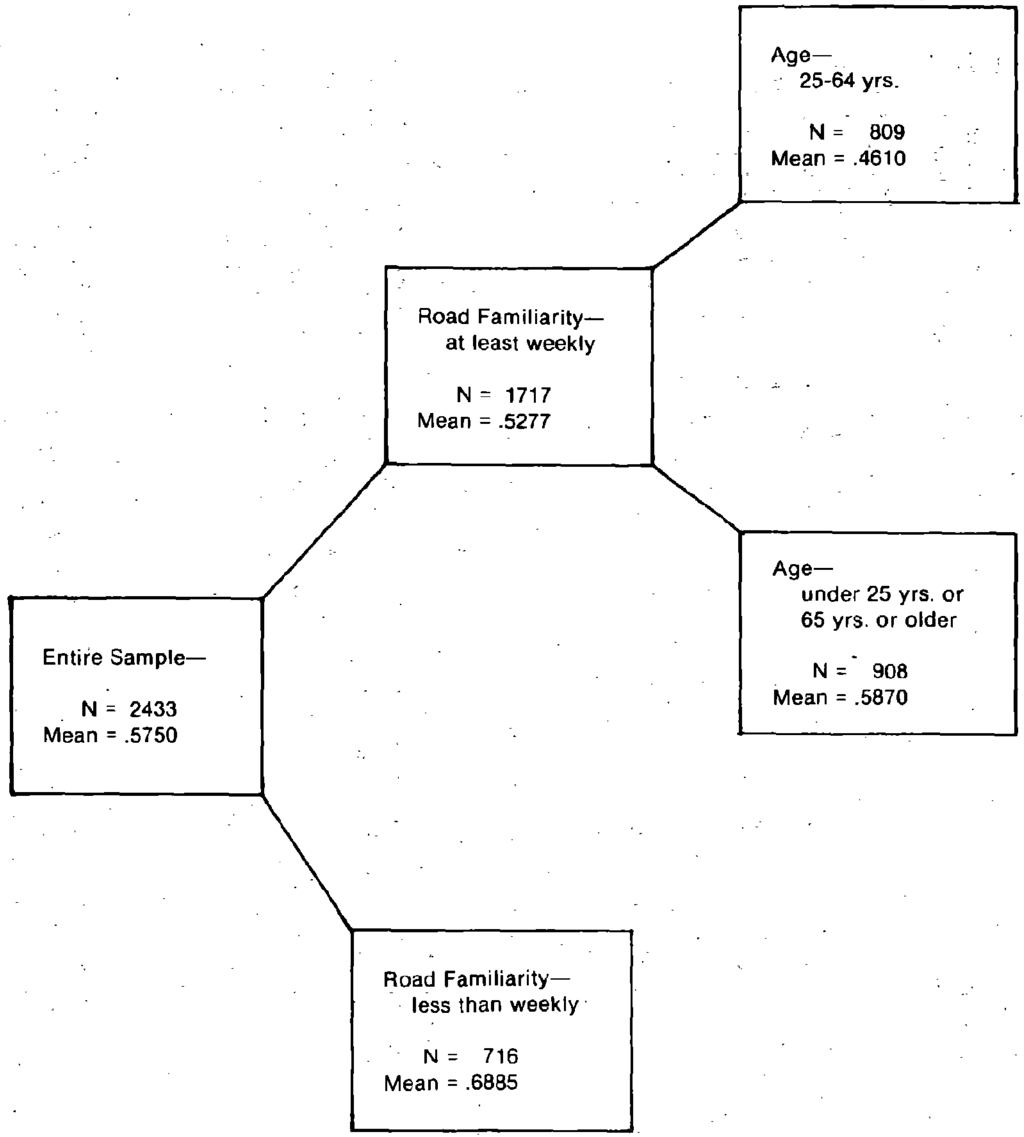


Table 3-6

Causal Factors Employed In Analysis

Causal Factors Producing Splits

Human Factors (Summary)
Direct Human Causes
Internal Distraction
External Distraction
Recognition Errors (Summary)
Delays in Recognition
Improper Lookout
Improper Lookout while Entering Travel Lane from Intersecting Street or Alley
Improper Lookout Prior to Changing Lanes or Passing
Improper Maneuver
Decision Errors
Excessive Speed
Human Conditions or States
Vehicular Causal Factors

Causal Factors Which Would Not Split

Inattention
—to Traffic Stopped or Slowing
Improper Lookout while Pulling Out from Parking Space
Delays in Perception
Driving Technique Inadequately Defensive
Tailgating
Improper Evasive Action
—Locked Brakes
Improper Driving Technique
False Assumption
Physical/Physiological Factors
—Alcohol Impairment
Driver In Hurry

any splits. N, the total number of cases employed, is 2,433. The mean of the human factors summary variable is .575, indicating that 57.5% of all drivers involved in on-site cases were adjudged by the investigators to have committed some kind of human error.[1] At the first stage, the sample was split into two groups on the basis of road familiarity, with those drivers who claimed to drive the road on which the accident occurred at least weekly exhibiting a somewhat lower human error rate than did those less familiar with the road. The group more familiar with the road split again on age, with drivers under 25 years of age and those 65 or older having a human factor identification rate substantially greater than that of drivers between the ages of

[1] At the certain or probable, causal or severity-increasing level.

Table 3-7

Predictor Variables Employed in AID Analysis

Variable Name	Code	Values	Frequency	%
Sex	1	Male	1682	69.13
	2	Female	751	30.87
Age	1	Under 20 years	451	18.54
	2	20-24 years	729	29.96
	3	25-34 years	523	21.50
	4	35-44 years	263	10.81
	5	45-54 years	214	8.80
	6	55-64 years	124	5.10
	7	65 years or older	129	5.30
Driving Experience	1	2 months or less	17	.70
	2	3-6 months	45	1.85
	3	7-12 months	100	4.11
	4	13-24 months	175	7.19
	5	25-60 months	533	21.91
	6	61-120 months	544	22.77
	7	Over 120 months	1009	41.47
Exposure	1	0-6000 miles/year	402	16.52
	2	6001-12,000 miles/year	984	40.44
	3	12,001-18,000 miles/year	413	16.97
	4	18,001-24,000 miles/year	259	10.64
	5	Over 24,000 miles/year	375	15.41
Vehicle Familiarity	1	2 months or less	376	15.45
	2	3-6 months	400	16.44
	3	7-12 months	526	21.62
	4	13-18 months	172	7.07
	5	19-24 months	339	13.93
	6	Over 24 months	620	25.48
Road Familiarity	1	Daily	1145	47.06
	2	Twice weekly	343	14.10
	3	Once weekly	229	9.41
	4	Twice monthly	88	3.62
	5	Once monthly	105	4.32
	6	Very infrequently	372	15.29
	7	First time on road	151	6.21

Table 3-7 continued

Variable Name	Code	Values	Frequency	%
Precipitation Intensity	1	None	2017	82.90
	2	Light	316	12.99
	3	Moderate	90	3.70
	4	Heavy	10	.41
Visibility	1	Clear	2114	86.89
	2	Hazy	297	12.21
	3	Fog	22	.90
Traffic Volume	1	Light	803	33.00
	2	Moderate	1147	47.14
	3	Heavy	483	19.85
Pavement Condition	1	Dry	1731	71.15
	2	Damp	634	26.06
	3	Wet	31	1.27
	4	Slush	37	1.52

25 and 64. The 809 drivers between 25 and 64 years of age who drove the road of accident at least weekly had a human factor identification rate of slightly more than 46%, compared to almost 69% for drivers who drove the same road less than once weekly. As these trees are drawn, the group with the highest identification rate will normally appear in the lower right hand corner of the page, and the group with the lowest identification rate, i.e., the safest group with respect to that particular factor, will appear in or near the upper right hand corner.

Reading the Summary Table

Table 3-8 is designed to show the step-by-step process that the AID algorithm employs in the determination of which variable to use in splitting a sample. The predictor variable showing the largest between sum of squares to total sum of squares ratio for a split between a program-determined dichotomous grouping of codes on that variable is used to split the sample into two groups. It is frequently possible that a split could be made on more than one predictor, and in many cases, predictor variables are in fairly close competition with each other for the privilege of making a particular split. For the purpose of examining the impact of different predictors on the error rates, or identification rates, on different causal factors, it is as important to examine the competitor variables as it is to observe the splits that actually did occur. In the summary table column one shows the dependent variable, the causal factor under analysis. Column two defines the group to be split at that stage, beginning with the entire sample and proceeding through each box in the AID tree that is in fact split. The third column shows the predictors that meet the minimum criterion for splitting a sample, i.e., those having a

Figure 3-5
Direct Human Causes

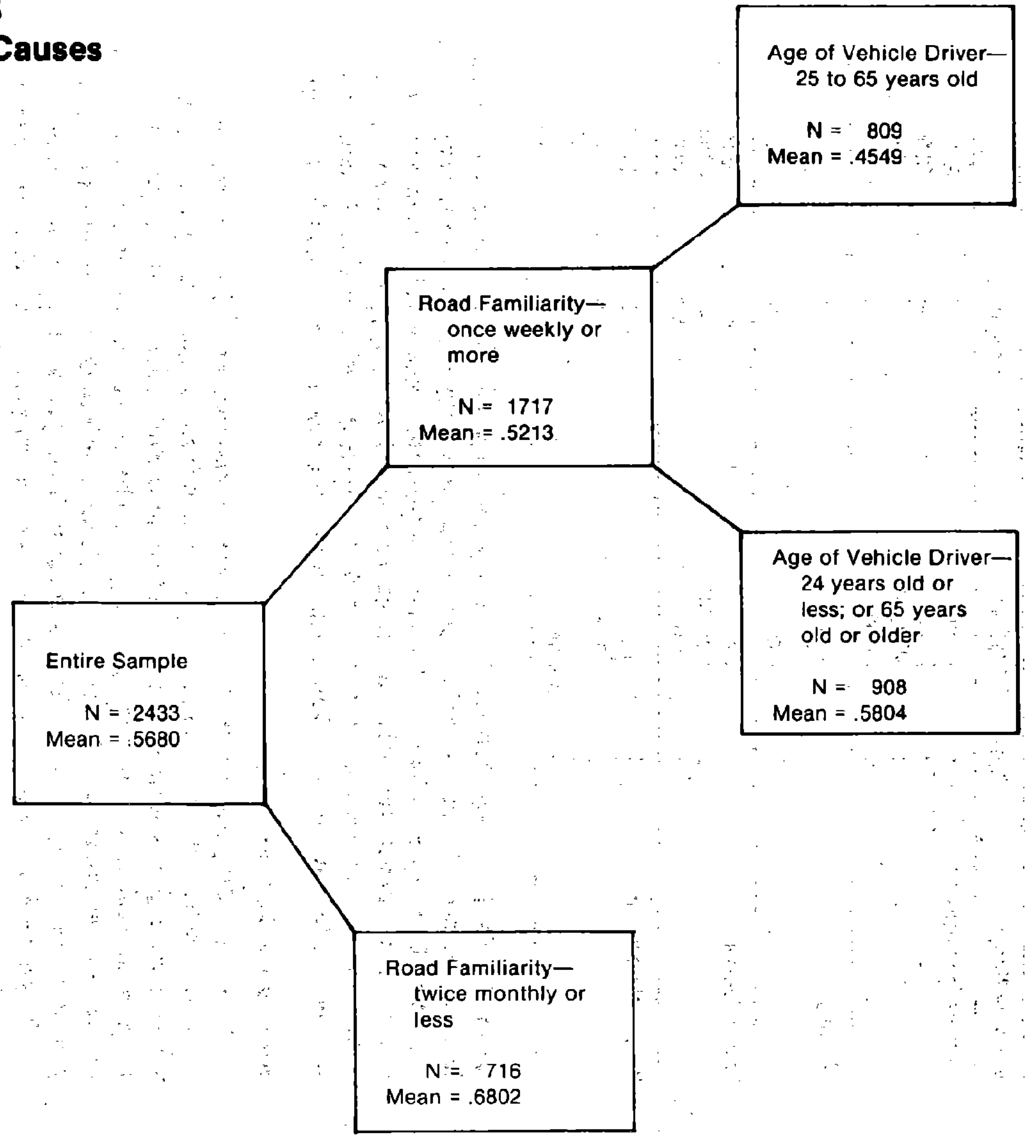


Figure 3-6
Internal Distraction

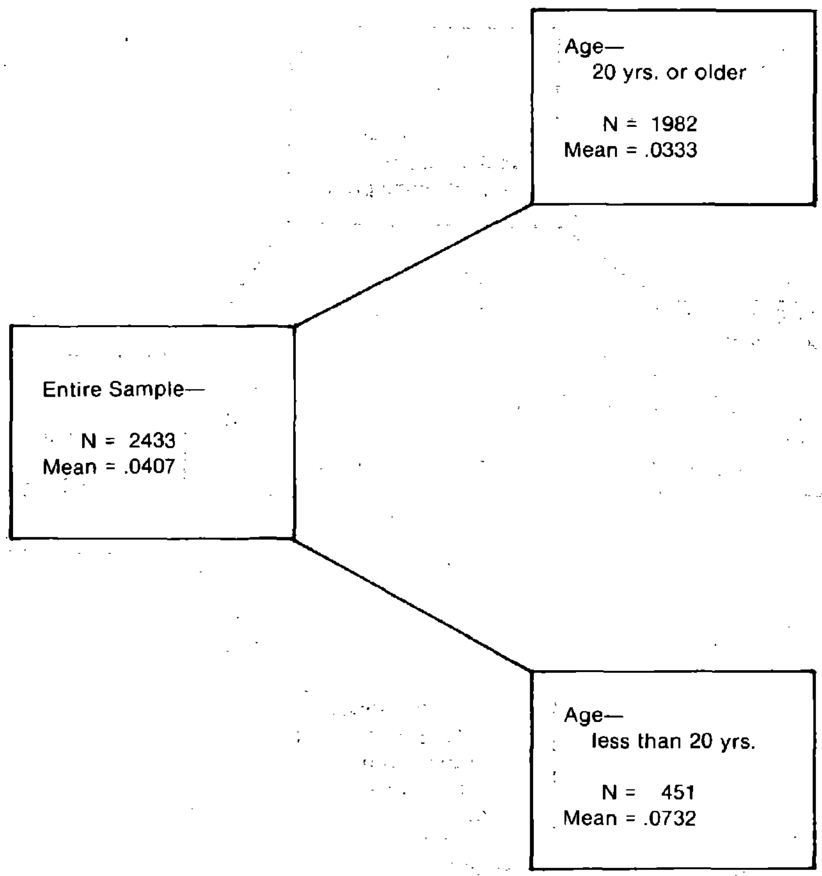


Figure 3-7
External Distraction

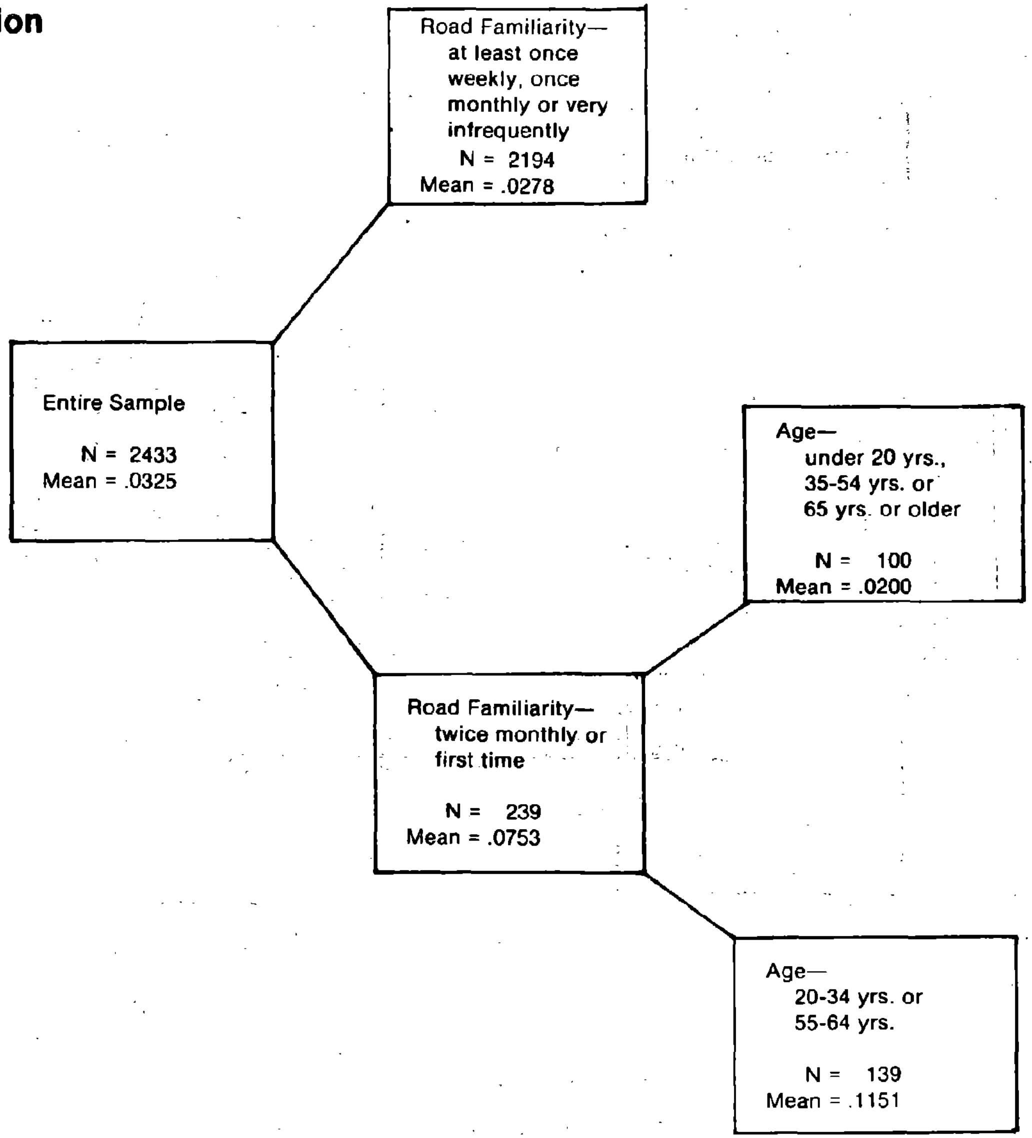


Figure 3-8
Recognition Errors

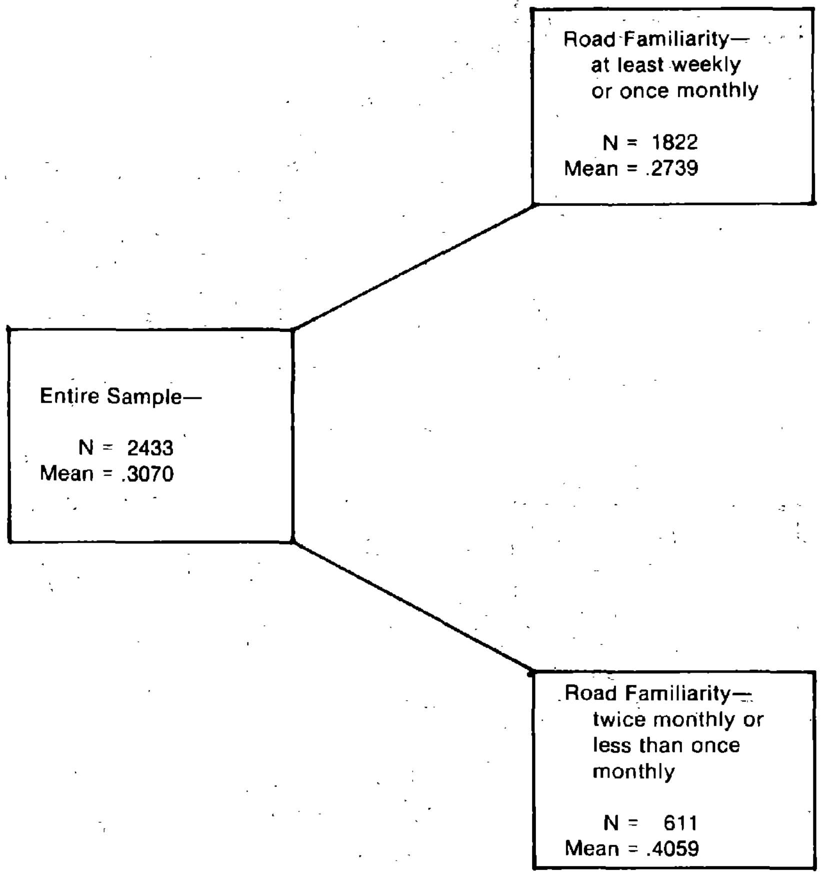


Figure 3-9
Delays in Recognition

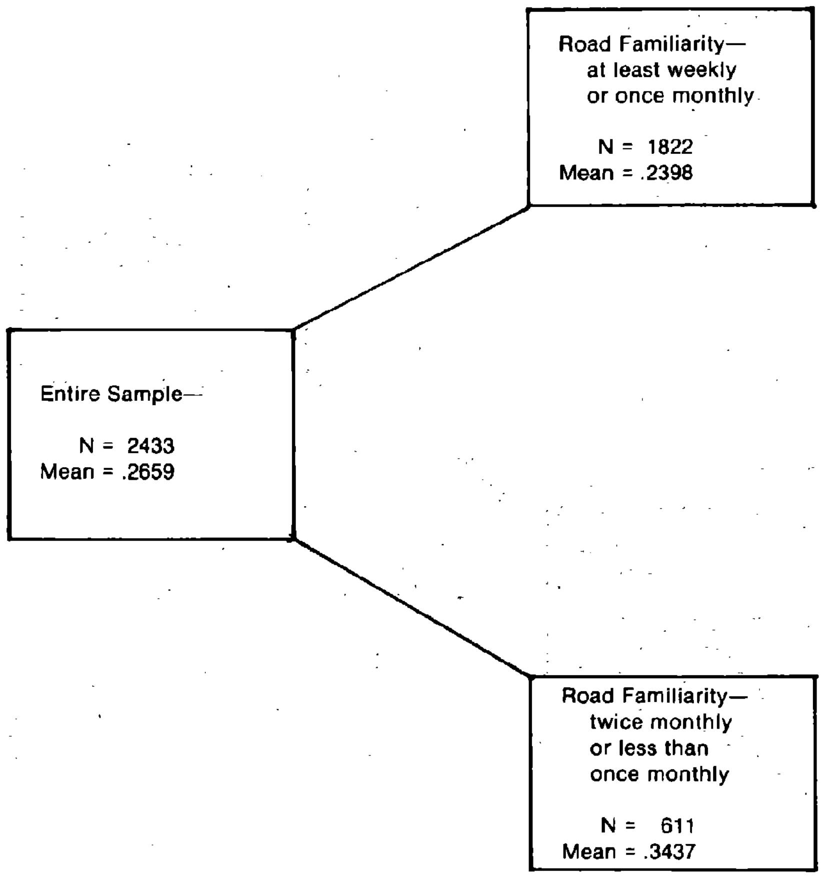


Figure 3-10
Improper Lookout

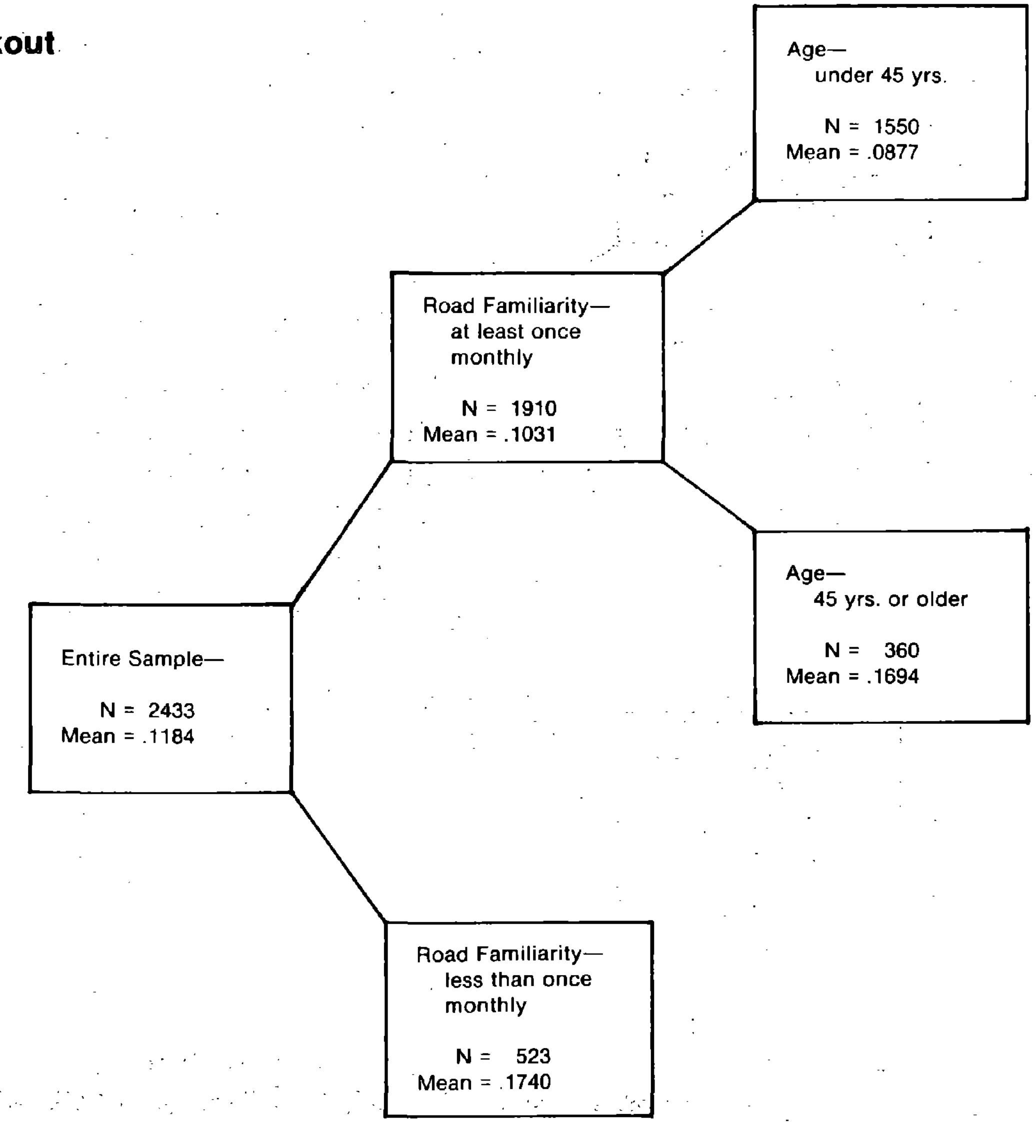


Figure 3-11
Improper Lookout While Entering Travel Lane from Alley or Intersection

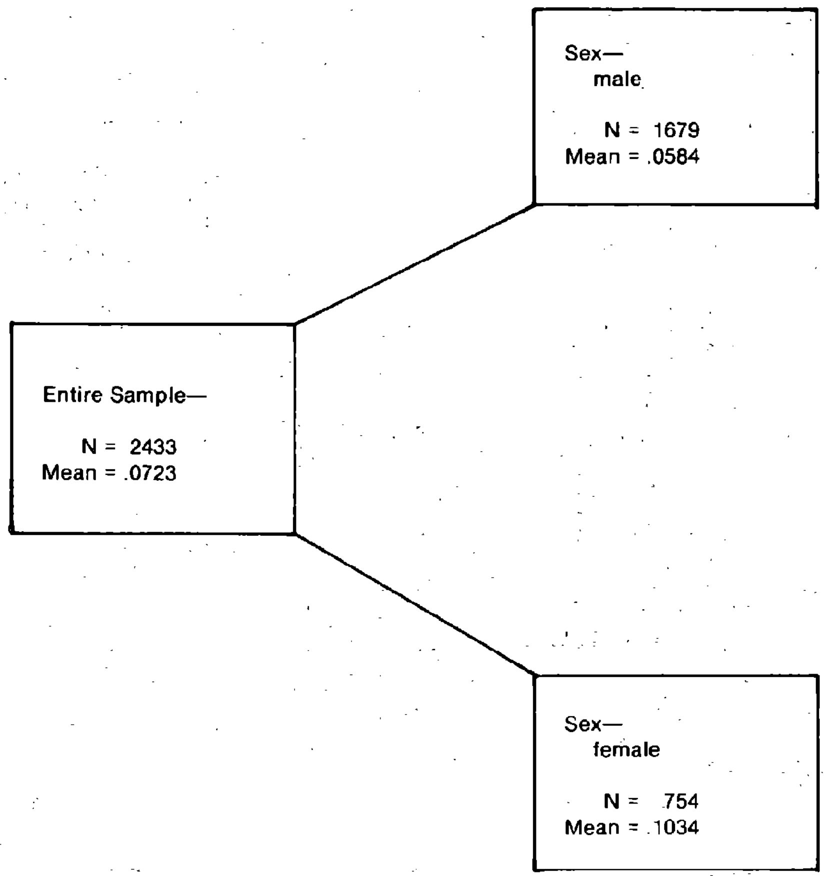


Figure 3-12
Improper Lookout Prior to Changing Lanes or Passing

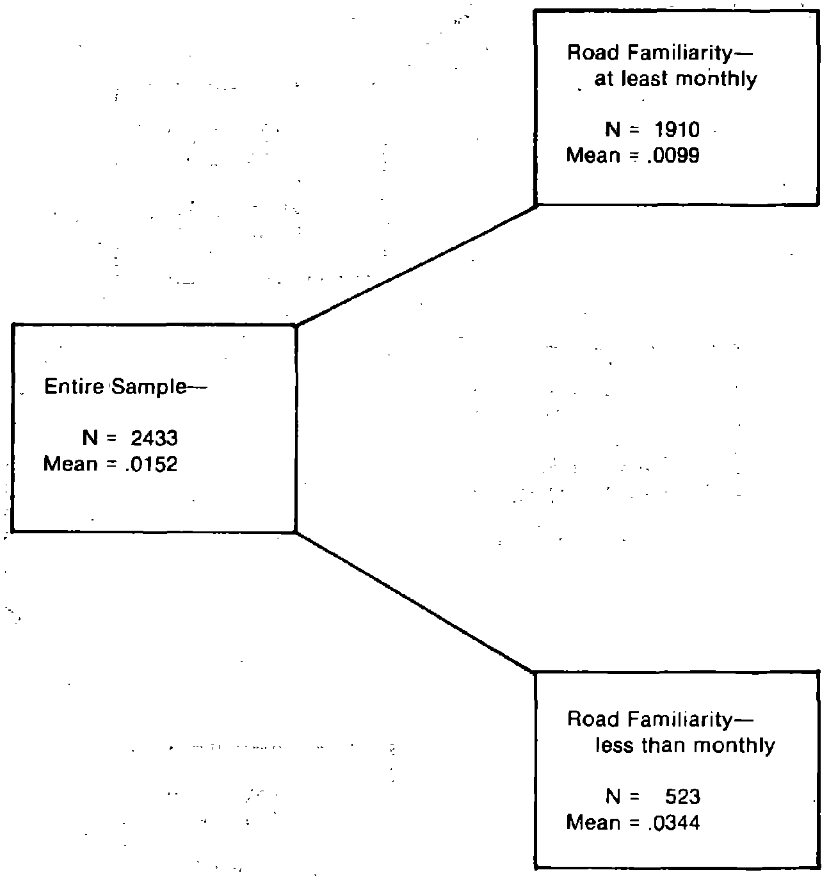


Figure 3-13
Improper Maneuver

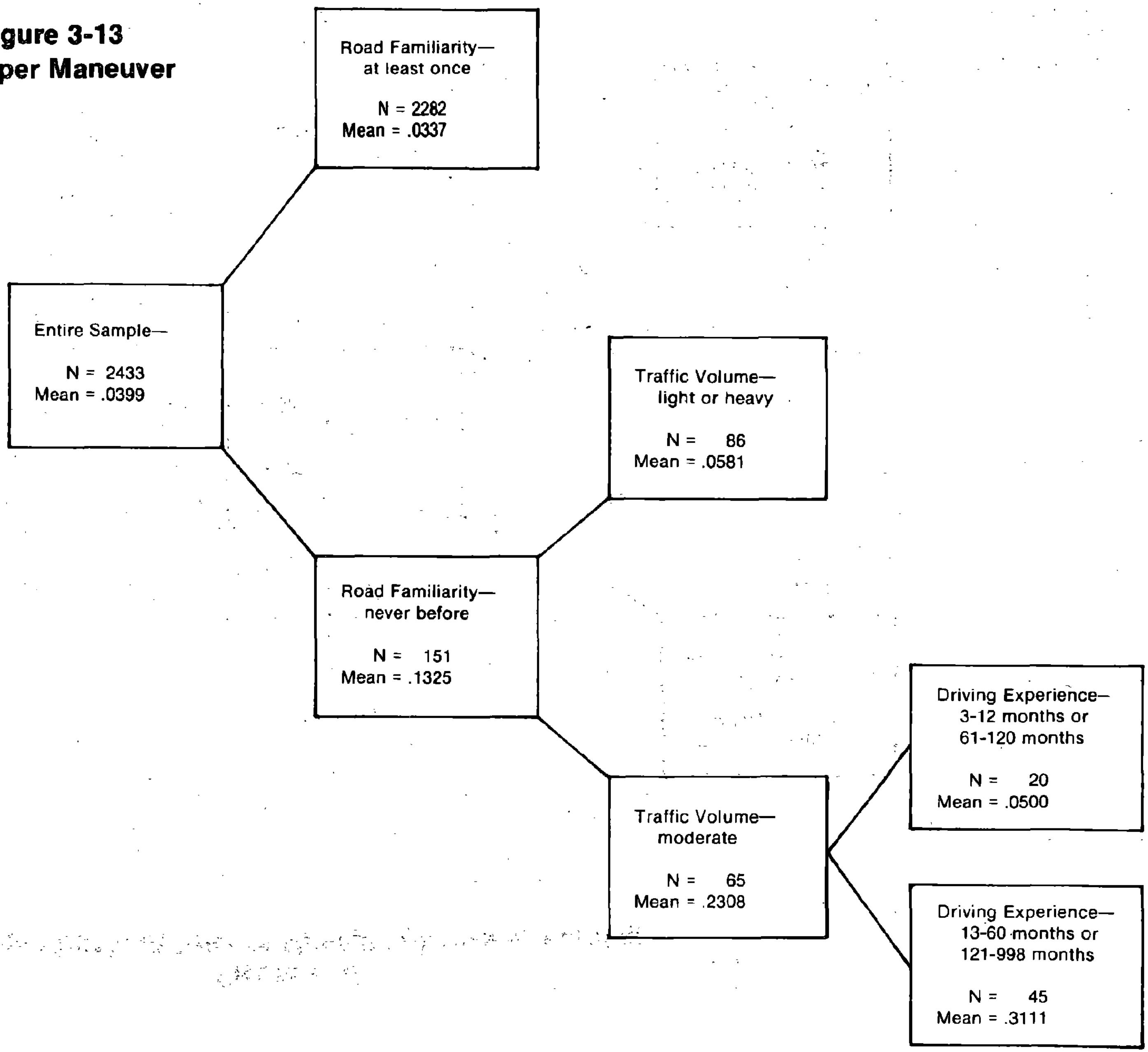


Figure 3-14
Decision Errors

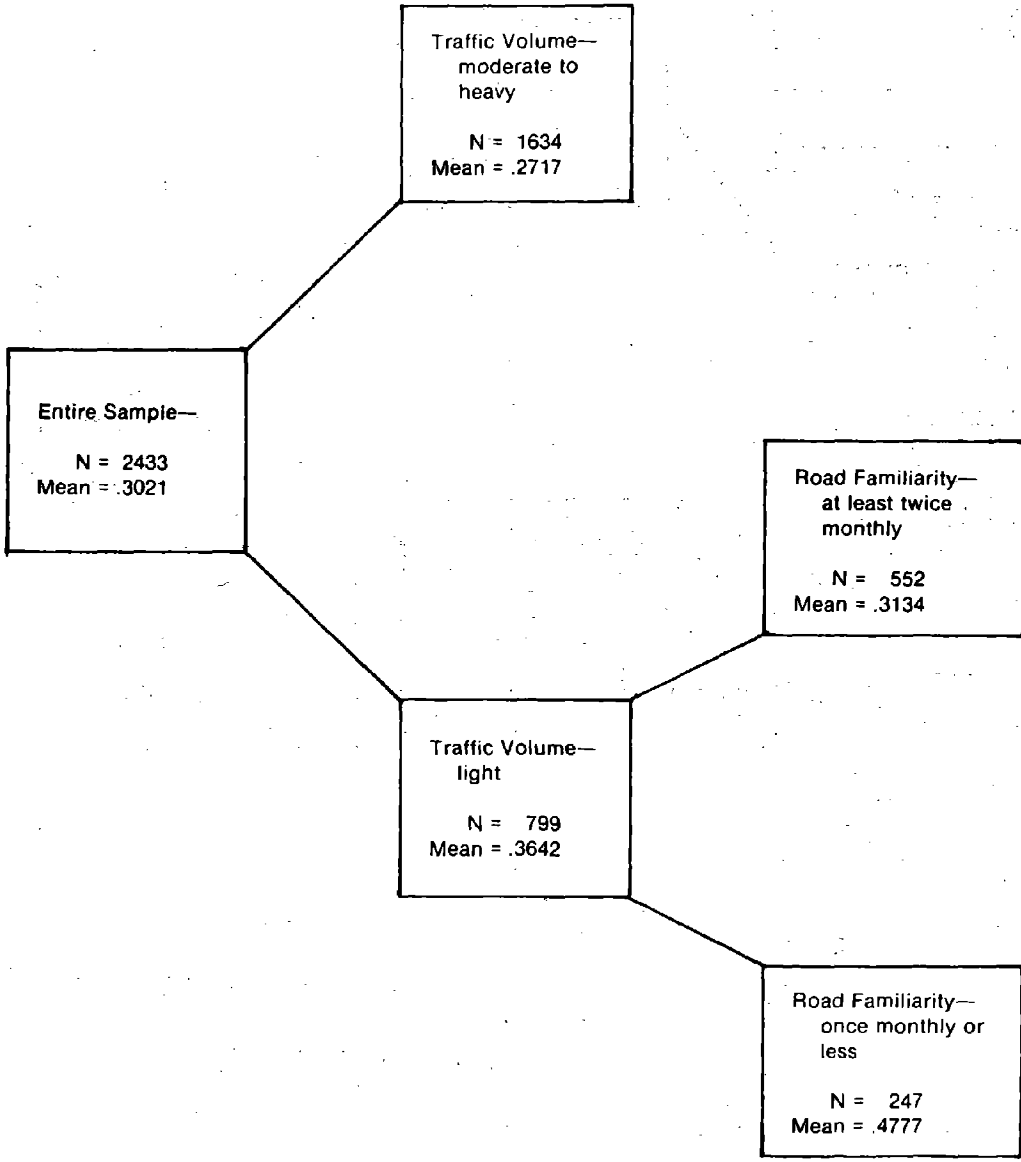


Figure 3-15
Excessive Speed

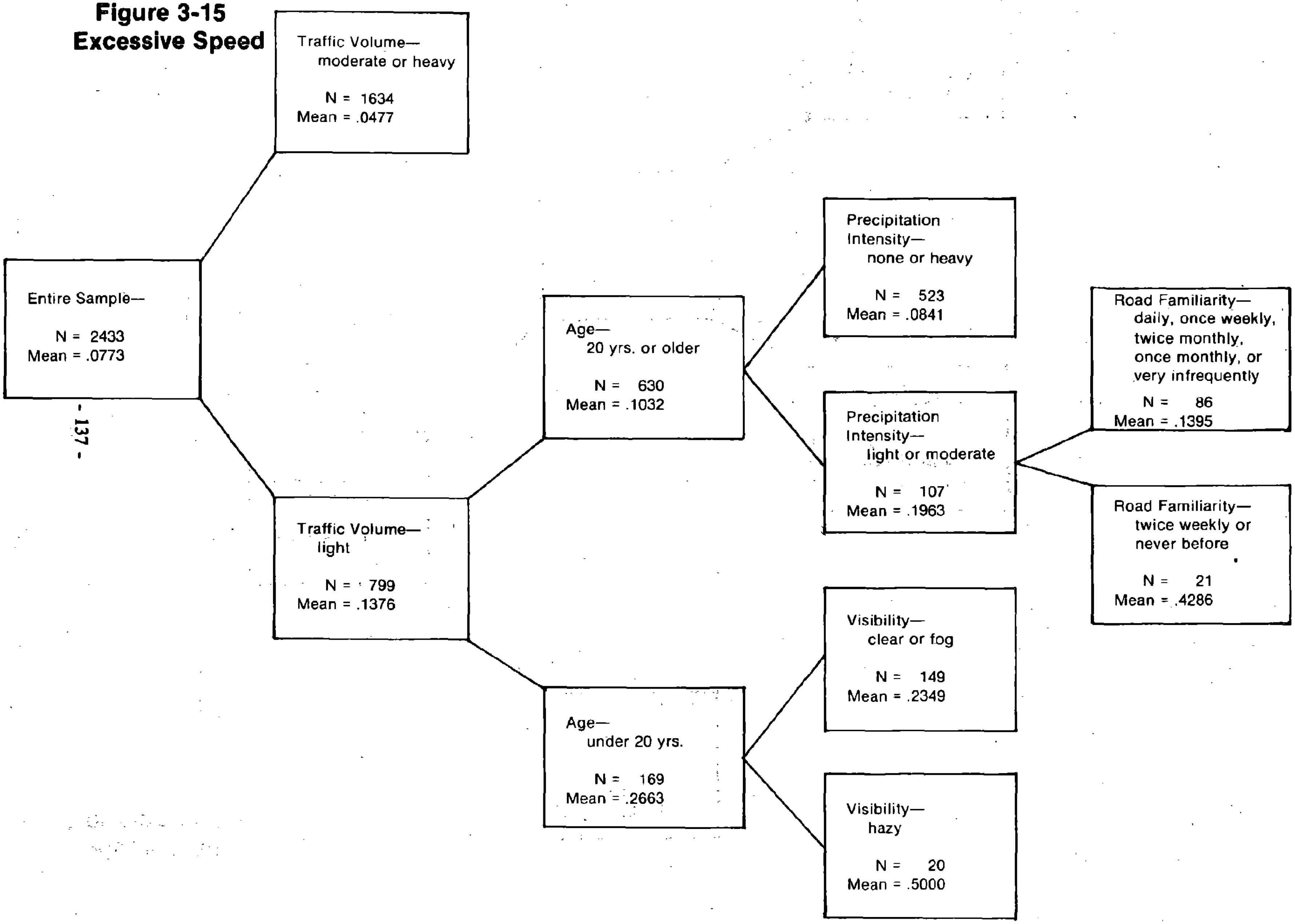


Figure 3-16
Human Conditions or States

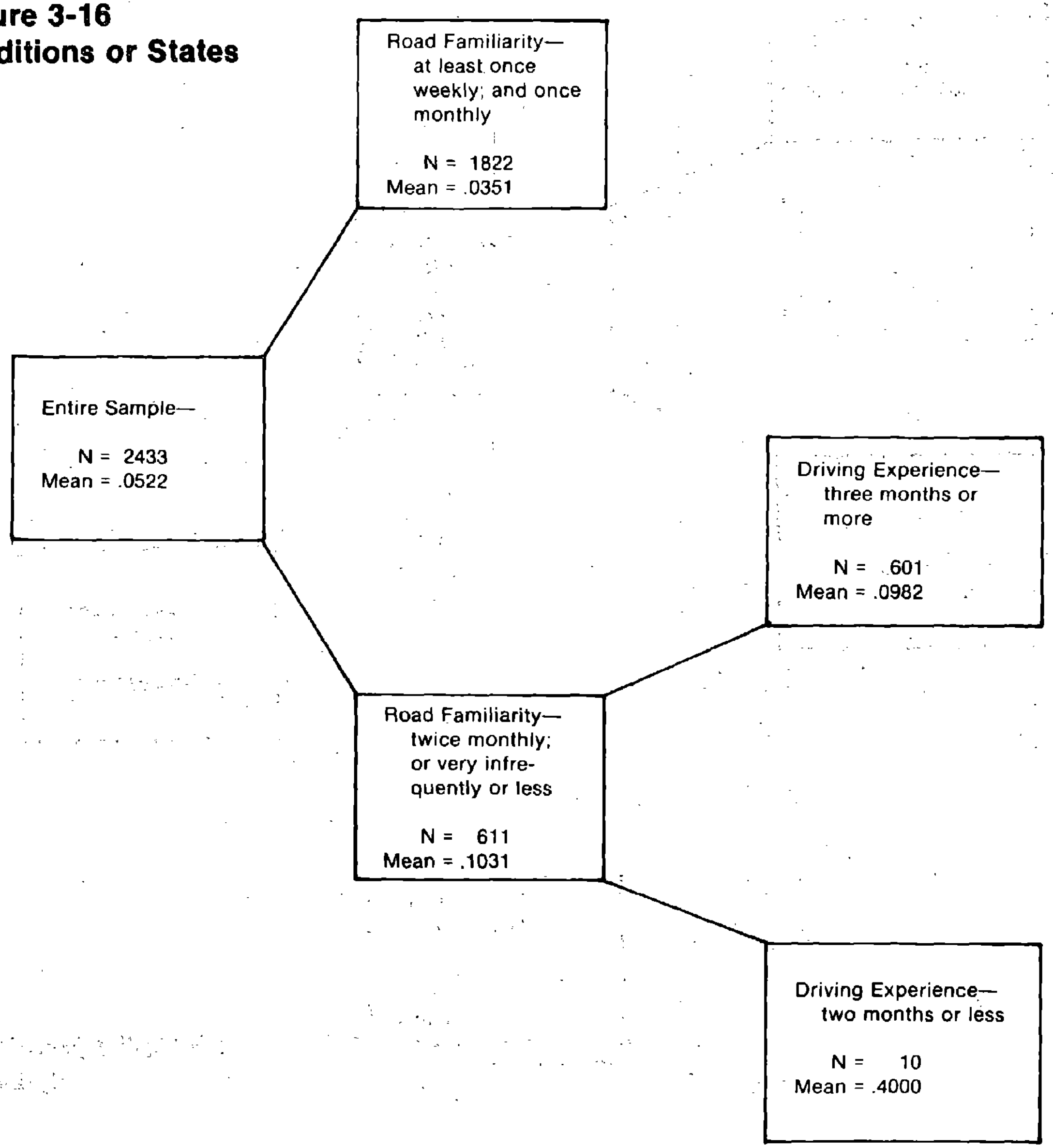


Figure 3-17
Vehicular Causal Factors

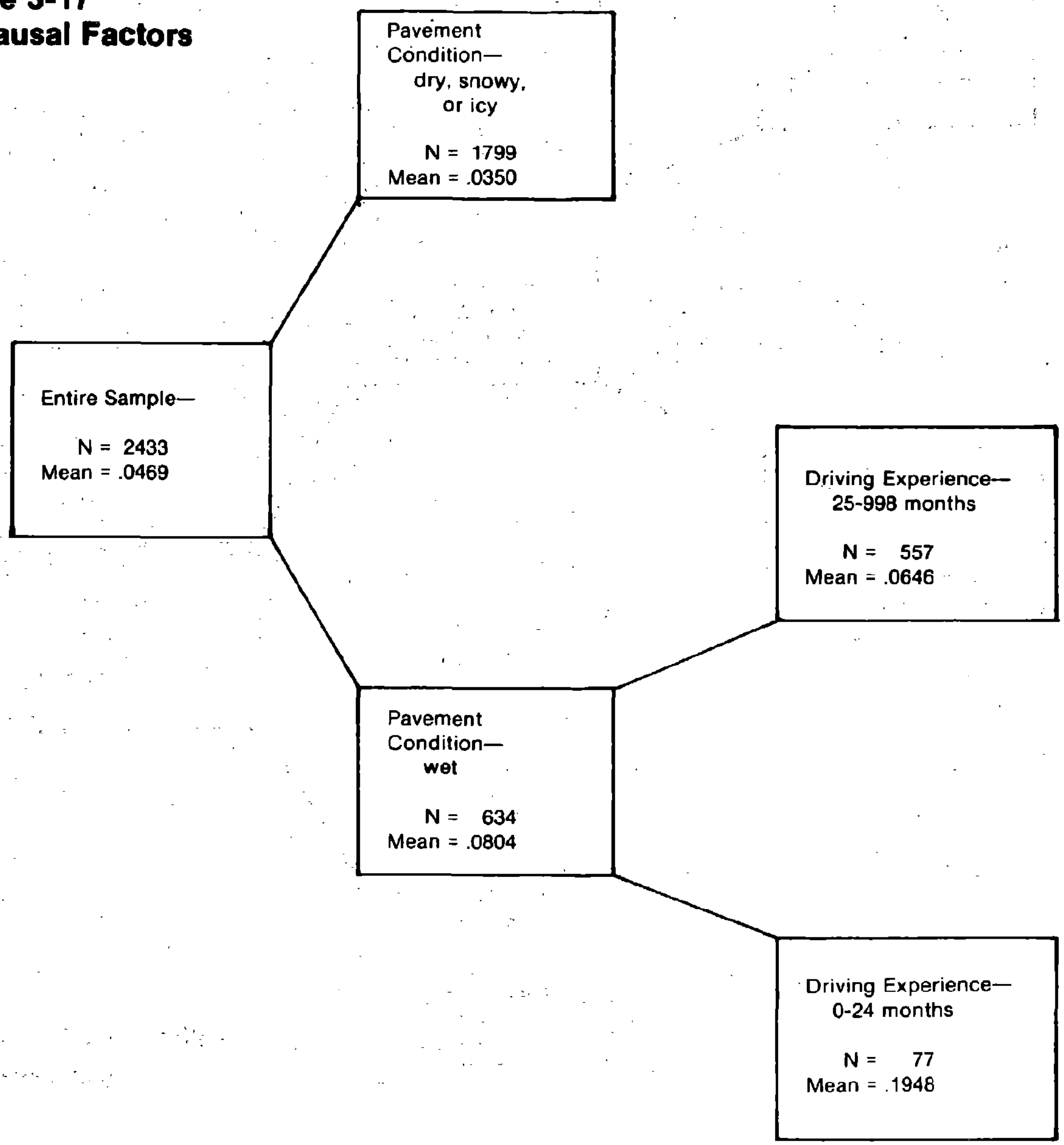


Table 3-8

AID Summary Table

Dependent Variable	Group to Be Split	Predictor	BSS/TSS E^2	Resultant Groups	Probability of Having Committed Error
Human Factors (Summary)	Entire Sample	Road familiarity	.02200	Once a week or more	.5277
				Less often than once a week	.6885
		Age	.01336	25-64	.5133
				Under 25; 65 and older	.6280
		Driving Experience	.00836	More than 10 years	.5213
				10 years or less	.6131
		Vehicle Familiarity	.00639	One year or more	.5480
				Less than one year	.6327
	Drivers who drive road of accident at least once a week	Age	.01586	25-64	.4611
				Under 25; 65 and older	.5870
		Driving Experience	.00941	More than 10 years	.4711
				10 years or less	.5691
		Vehicle Familiarity	.00709	6 months or less	.4991
				More than 6 months	.5896
Direct Human Causes	Entire Sample	Road Familiarity	.02137	Once a week or more	.5213
				Less often than once a week	.6802
		Age	.01260	25-64	.5080
				Under 25; 65 or older	.6196
		Driving Experience	.00801	More than 10 years	.5154
				10 years or less	.6053
	Drivers who drive road of accident at least once a week	Age	.01573	25-64	.4549
				Under 25; 65 and older	.5804
		Driving Experience	.00956	More than 10 years	.4642
				10 years or less	.5631
		Vehicle Familiarity	.00640	More than one year	.4791
				1 year or less	.5591

Table 3-8 continued

Dependent Variable	Group to Be Split	Predictor	BSS/TSS (E^2)	Resultant Groups	Probability of Having Committed Error
Internal Distraction	Entire Sample	Age	.00615	20 and over	.0333
				Under 20	.0732
External Distraction	Entire Sample	Road Familiarity	.00636	At least once monthly; Very infrequently	.0278
				Twice monthly; Never before	.0753
	Drivers who drive the road of accident twice monthly or who have never driven it before	Age	.03161	Under 20; 35-54 65 and older	.0200
				20-44; 55-64	.1151
		Vehicle Familiarity	.03018	2 mos. or less; 7-12 mos.; more than 2 yrs.	.0400
				3-6 mos.; 13-24 mos.	.1348
		Driving Experience	.01588	2 years or less	0
				More than 2 years	.0900
		Exposure	.01534	18,000 miles or less	.0562
				More than 18,000 miles	.1311
		Road Familiarity	.00608	First time on road	.0596
				Twice monthly	.1023
	Drivers who drive the road of accident twice monthly or never before and who are of ages 20-34 or 55-64	Experience in Vehicle	.03684	2 mos. or less; 7-12 mos.; more than 2 yrs.	.0625
				3-6 mos.; 13-24 mos.	.1864
		Exposure	.01587	18,000 miles or less	.0900
				More than 18,000 miles	.1795
		Age	.01355	20-34	.1032
				55-64	.2308
		Road Familiarity	.01128	Never before	.0864
				Twice monthly	.1552
		Driving Experience	.00912	3 months through 10 yrs.	.0971
				More than 10 yrs.	.1667

Table 3-8 continued

Dependent Variable	Group to Be Split	Predictor	BSS/TSS (E^2)	Resultant Groups	Probability of Having Committed Error
External Distraction continued		Traffic Volume	.00822	Light or moderate	.1026
				Heavy	.1818
Recognition Errors	Entire Sample	Road Familiarity	.01541	At least weekly; monthly	.2739
				Twice monthly; very infrequently; never before	.4059
Delays in Recognition	Entire Sample	Road Familiarity	.01039	Daily; Once weekly; Once monthly	.2398
				Twice monthly; Very infrequently; Never before	.3437
Improper Lookout	Entire Sample	Road Familiarity	.00812	Once monthly or more often	.1031
				Less often than once monthly or never before	.1740
		Age	.00798	Under 65	.1115
				65 and older	.2403
	Drivers who drive road of accident at least monthly	Age	.01104	Under 45	.0877
				45 and older	.1694
Improper Lookout while entering travel lane from intersecting street or alley	Entire Sample	Sex	.00648	Male	.0584
				Female	.1034
Improper Lookout prior to changing lanes or passing	Entire Sample	Road Familiarity	.00675	At least monthly	.0099
				Infrequently or never before	.0344
Improper Maneuver	Entire Sample	Road Familiarity	.01482	Has driven road before	.0337
				Has never driven road	.1325
	Driver has never driven road of accident	Traffic Volume	.00238	Light or heavy	.0581
				Moderate	.0048

Table 3-8 continued

Dependent Variable	Group to Be Split	Predictor	BSS/TSS (E^2)	Resultant Groups	Probability of Having Committed Error
Improper Maneuver continued	Driver has never driven road of accident continued.	Driving Experience	.06076	A year or less; 2-10 yrs.	.0588
				One to 2 yrs.; greater than 10 yrs.	.2273
		Precipitation	.02331	Wet	.1233
				Dry	.4000
		Exposure	.02046	Less than 12,000 miles; 19,000 through 24,000 miles	.1019
				13,000 through 18,000 miles; more than 24,000 miles	.2093
		Age	.01784	Under 35	.1062
				35 and older	.2105
		Vehicle Familiarity	.01166	2 months or less; 7 through 12 months	.0909
				3 through 6 months; more than 1 year	.1647
Decision Errors	Entire Sample	Traffic Volume	.00895	Moderate or heavy	.2717
				Light	.3642
		Road Familiarity	.00858	At least twice monthly	.2770
				Less often than twice monthly	.3742
		Age	.00792	25 through 64	.2580
				Under 25 or over 64	.3400
	Light Traffic	Road Familiarity	.02491	At least twice monthly	.3134
				Less often than twice monthly	.4777
		Age	.01500	Under 25; 45-54	.4136
				25-44; 55 or older	.2939
		Precipitation	.01200	Dry or Ice	.4786
				Rain or snow	.3399

Table 3-8 continued

Dependent Variable	Group to Be Split	Predictor	BSS/TSS (E^2)	Resultant Groups	Probability of Having Committed Error
Decision Errors continued	Light Traffic continued	Vehicle Familiarity	.00742	More than one year	.3133
				One year or less	.3920
		Driving Experience	.00717	More than one year	.3520
				One year or less	.5000
		Exposure	.00693	0-6000 miles; 13,000-18,000 miles	.4182
				7,000-12,000 miles; More than 18,000 miles	.3346
		Pavement Condition (Striking Vehicle)	.00648	Dry	.3347
				Not dry	.4150
Excessive Speed	Entire Sample	Traffic Volume	.02502	Moderate or heavy	.0477
				Light	.1377
		Age	.02051	20 or older	.0590
				Under 20	.1574
		Driving Experience	.01782	More than two years	.0630
				Two years or less	.1662
		Sex	.00696	Female	.0439
				Male	.0917
		Pavement Condition	.00651	Dry	.0636
				Not dry	.1111
		Vehicle Familiarity	.00614	More than one year	.0548
				One year or less	.0968
	Light Traffic Volume	Age	.03737	20 or older	.1032
				Under 20	.2663
		Driving Experience	.02962	More than two years	.1118
				Two years or less	.2734

Table 3-8 continued

Dependent Variable	Group to Be Split	Predictor	BSS/TSS (E^2)	Resultant Groups	Probability of Having Committed Error
Excessive Speed continued	Light Traffic Volume continued	Vehicle Familiarity	.01324	More than one year	.0932
				One year or less	.1730
		Precipitation Intensity	.01050	None	.1214
				Light or moderate	.2143
		Sex	.00955	Female	.0841
				Male	.1573
		Road Familiarity	.00940	Daily, weekly or twice monthly	.1084
				Twice weekly or once monthly or less	.1758
		Pavement Condition	.00764	Dry	.1160
				Not dry	.1795
		Visibility	.00671	Clear	.1278
				Hazy or foggy	.2184
	Drivers age 20 or older in light traffic	Precipitation Intensity	.01916	None	.0841
				Light or moderate	.1963
		Pavement Condition	.00705	Dry, wet, or icy	.0992
				Slushy or snowy	.2667
		Road Familiarity	.00649	Infrequently or at least twice monthly	.0940
				Once monthly or never before	.1688
	Drivers age 20 or older in light traffic in precipitation	Road Familiarity	.08354	Daily; weekly; once or twice monthly	.1395
				Twice weekly or never before	.4286
		Sex	.02559	Female	.0968
				Male	.2267
		Pavement Condition	.02409	Wet, icy	.1685
				Dry, snowy	.3333

Table 3-8 continued

Dependent Variable	Group to Be Split	Predictor	BSS/TSS (E^2)	Resultant Groups	Probability of Having Committed Error
Excessive Speed continued	Drivers age 20 or older in light traffic in precipitation continued	Vehicle Familiarity	.01252	3-6 months; 19-24 mos.	.1351
				2 months or less; 7-18 months, more than 2 yrs	.2286
		Driving Experience	.00725	Five years or less; more than 10 years	.1786
				5-10 years	.2609
		Exposure	.00715	6000 miles or less; more than 24,000 miles	.1471
				6,100-23,900 miles	.2192
	Drivers under 20 in light traffic	Visibility	.03753	Clear, foggy	.2350
				Hazy	.5000
		Driving Experience	.02288	More than 6 months through 10 years	.2378
				6 months or less; more than 10 years	.3885
		Sex	.01941	Female	.1538
				Male	.3000
		Vehicle Familiarity	.01691	13-24 months	.1250
				12 months or less; more than 2 years	.2897
		Road Familiarity	.01529	Weekly	.0769
				Less often or more often than weekly	.2821
		Pavement Condition	.01097	Dry, icy	.2315
				Wet, snowy	.3279
		Exposure	.01024	7000-12,000 miles; more than 24,000 miles	.2179
				0-6000 miles; 13,000-24,000 miles	.3077

Table 3-8 continued

Dependent Variable	Group to Be Split	Predictor	BSS/TSS (E^2)	Resultant Groups	Probability of Having Committed Error
Human Conditions or States	Entire Sample	Road Familiarity	.01757	At least weekly or monthly	.0351
				Twice monthly; infrequently; or never before	.1031
		Driving Experience	.00832	3 months or more	.0505
				Less than three months	.2941
		Traffic Volume	.00753	Moderate or heavy	.0387
				Light	.0797
	Drives road twice monthly; infrequently or has never driven it before	Driving Experience	.01586	3 months or more	.0982
				Less than three months	.4000
		Exposure	.01342	More than 12,000 miles	.0605
				12,000 miles or less	.1322
		Road Familiarity	.01106	Has driven road before	.0848
				Never before been on road	.1589
Vehicular Causal Factors	Entire Sample	Pavement Condition	.00890	Dry, snowy, or icy	.0350
				Wet	.0804
		Precipitation Intensity	.00727	None	.0387
				Any precipitation	.0865
		Driving Experience	.00723	Less than 3 or more than 6 months	.0444
				3-6 months	.1778
		Age	.00631	20 or older	.0389
				Under 20	.0820
	Wet Pavement	Driving Experience	.02444	More than 2 years	.0646
				2 years or less	.1948
		Age	.01398	20 or older	.0654
				Under 20	.1491

Table 3-8 continued

Dependent Variable	Group to Be Split	Predictor	BSS/TSS (E^2)	Resultant Groups	Probability of Having Committed Error
Vehicular Causal Factors continued	Wet Pavement continued	Road Familiarity	.01101	Less often than daily	.0536
				Daily	.1107
		Vehicle Familiarity	.00976	More than one year	.0514
				One year or less	.1053
		Sex	.00691	Female	.0481
				Male	.0962

BSS/TSS ratio of at least .006, ranked in order of the BSS/TSS ratio. The fifth column defines the group that did result or would have resulted from the split in question, and the last column gives the identification rates for each subgroup. Note that the first predictor listed for each group is the one on which that group was in fact split.

Human Factors

The human factors summary, a variable that indicates whether or not a particular driver was identified as having committed any given error, split first on road familiarity, with an identification rate of .53 among those who were relatively familiar with the road (those who drove it at least once a week), and .69 among those who were relatively unfamiliar with it. The sample could also have been split on the basis of age, driving experience, or vehicle familiarity, with the age split being relatively strong. Note that the probability of identification for the subgroups produced by splits on either age or driving experience would be roughly the same, and that these two variables are close competitors for splitting the sample at that point.

The high road familiarity group was further split on the basis of age, with drivers between the ages of 25 and 64 being less likely to have committed an error than those either under 25, or 65 or older. Again, driving experience split at the 10-year experience point is a close competitor with age.

Direct Human Causes

This variable is closely related to the human factors summary above, but excludes errors related to a driver's physiological or psychological state (including alcohol and drug usage). The results are essentially the same as for the human factors summary except that the entire sample for direct human causes could not have been split on the basis of vehicle familiarity. Since the vehicle familiarity split for the human factors summary was so close to the rejection point, this difference is not considered to have any important interpretation.

Internal Distraction

The only possible split on this variable occurs on the basis of age, with drivers under 20 more than twice as likely to have an accident caused by internal distraction.

External Distraction

The only predictor that could split the entire sample is road familiarity, with drivers who drove the road at least once weekly, or who said they drove it very infrequently, being much less frequently identified than other drivers. This split is not as neat as one would like, and, combined with other similar splits in previous analyses, appears to result from a problem in reporting on this particular variable. Briefly, drivers appeared to rank the response "very infrequently" at radically different places in the group of possible responses, thereby producing a response category that is extremely difficult to interpret, and which behaves erratically in this kind of analysis.

Drivers who drive the road of the accident twice monthly and those who had never driven it before produced a fairly strong split on age, but the nature of the split is not theoretically interpretable. The same group could have split on vehicle familiarity, driving experience, exposure, and road familiarity. Results of this type are presented for the benefit of other analysts who may find them useful, but no attempt here is being made to interpret them. It should be noted that the very low identification rate in these groups, i.e., the extreme skewness in the dependent variable, tends to produce unreliable splits in AID, and any interpretation that is made on this particular dependent variable should be made very cautiously with the understanding that the results may be an artifact of the skewness problem.

Recognition Errors

The only possible split of the sample of recognition errors was made on road familiarity, with drivers more familiar with the road less likely to have committed a recognition error.

Delays in Recognition

This causal factor, a subset of the recognition errors factor mentioned above, produced similar results.

Improper Lookout

Road familiarity and age proved to be close competitors to split the overall sample, with road familiarity producing the actual split. Based on the identification rates, it appears that drivers who are unfamiliar with the road or who are 65 years of age or older are substantially more likely than other drivers to commit some kind of improper lookout. The high familiarity drivers then split on age, with drivers 45 years of age or older, who are relatively familiar with the road, being twice as likely to commit an improper lookout than younger drivers equally familiar.

Improper Lookout While Entering Travel Lane from Intersecting Street or Alley

The only possible split of this group came on sex, with women being roughly twice as likely as men to commit this type of error.

Improper Lookout Prior to Changing Lanes or Passing

The only possible split on this factor came on road familiarity, with the probability of identification for drivers who drove the road of the accident at least monthly being roughly 1%, and that for other drivers being roughly 3.5%. It may be that citation of this particular error is an indication of misjudgment of distance between vehicles, or misjudgment of visibility.

Improper Maneuver While Entering a Travel Lane Prior to Changing Lanes or Passing

The overall sample could only be split on road familiarity between drivers who had been on the road and those who had not. Apparently, any prior experience with the roadway in question gives a driver a tremendous advantage where this maneuver is concerned, with the identification rates being 3% and 13% respectively.

The group of drivers who had never before been on the road of the accident split on traffic volume, with moderate traffic volume producing an error probability of 23%, as opposed to 5.8% for either light or heavy traffic volume. Apparently, light traffic volume presents few maneuver problems, and heavy volume restricts vehicle activity sufficiently to make maneuvering relatively unimportant, while a moderate traffic volume provides the potential hazards and obstacles of heavy volume without its concomitant restrictions on vehicle movement. This group could also have been split on driving experience, precipitation, exposure, age, and vehicle familiarity. One might speculate that the split between drivers having a year or less, or two through ten years of experience, and those with one to two years, or greater than ten years experience is explicable on the grounds of insufficient skills at one extreme and excessive exposure to risk occasioned by the size of the group and the time and experience span covered at the other. The precipitation split can be explained in much the same terms as the traffic volume split, with wet pavement imposing restrictions and engendering a certain amount of caution that reduced the probability of an improper maneuver. No interpretation is offered of the possible splits on exposure, age, or vehicle familiarity.

Decision Errors

The sample split on traffic volume, with an identification rate of 27% in moderate or heavy traffic and 36% in light traffic. Apparently, the greater the traffic volume, the greater the propensity of drivers to commit decision errors, or at least the propensity for those decision errors to result in traffic accidents. As one might expect, decision errors are more commonly committed by drivers on unfamiliar roads than on roads with which they are familiar. Drivers between the ages of 25 and 64 are much less likely to be cited for decision errors than either young drivers or old drivers.

The light traffic group split further on road familiarity, with drivers who drove the road of the accident at least twice monthly being identified as having committed decision errors at a rate of 31%, as opposed to 48% for drivers less familiar with the road. This same group could have been split on age, with young drivers and middle aged drivers (those between 45 and 54) being more frequently identified than drivers of other ages. In light traffic, decision errors were most likely to occur or result in accidents on either dry pavement or on ice than on either rain or snow, indicating a possible caution factor at play again in this case. Vehicle familiarity also appears to be a determinant of decision errors in light traffic, with drivers with one year or less time in their vehicles being somewhat more likely than those with more than a year to commit a decision error. The same is true of driving experience in general. No interpretation is offered for the apparently erratic split on exposure.

Excessive Speed

As might be expected, excessive speed split first on traffic volume, with an identification rate of slightly under 5% in moderate or heavy traffic and one of almost 14% in light traffic. This result is consistent with conditions that provide an opportunity to speed. Young drivers were almost three times as likely as drivers 20 or older to be cited for excessive speed; males were twice as likely as females; less experienced drivers (those with two years or less driving experience) were roughly two and a half times as likely as more experienced drivers; and those who are relatively unfamiliar with their vehicles were roughly twice as likely as those who were more familiar. It is possible that great familiarity with the vehicle permits a driver to gain a superior ability to control it, thereby increasing the probability of avoidance in accident situations in which excessive speed might become a factor. Excessive speed was cited almost twice as often on wet, snowy, or icy pavement than on dry pavement, probably related to the driver's ability to control the vehicle, to maneuver, and to stop.

The light traffic volume group split on age, with an identification rate of .27 for drivers under 20 and .10 for those 20 or older. This subgroup could have been split on the same other variables as the entire sample with roughly the same results. Additionally, when traffic volume is light, the probability of an accident being caused by excessive speed appears to be related to precipitation intensity, road familiarity, and visibility. Accidents caused by excessive speed in light traffic are more likely to occur in hazy or foggy conditions on pavement that is not dry and when there is some kind of precipitation. They are more likely to involve drivers under 20, those who are relatively inexperienced, those who are unfamiliar with their vehicle, males, or those who are unfamiliar with the road.

Drivers age 20 or older who were involved in accidents in light traffic are almost two and one half times as likely to be cited for excessive speed if there is some kind of precipitation. The 20% rate in this group indicates apparently strong need for countermeasures related to instruction in the assessment of safe speeds in wet weather. The possible split on pavement conditions separating slushy or snowy pavement conditions from dry, wet, or icy pavements again highlights the need for some way to teach drivers to properly assess the maximum speed at which they can safely operate their vehicles under certain environmental conditions. Road familiarity is also a factor, as might be expected, since ignorance of certain hazards or certain hazardous locations on a particular roadway might lead the driver to set an unsafe speed.

Drivers age 20 or older in light traffic in precipitation split on road familiarity, but the split is obviously unstable, possibly due to the small size of the group being split. Results in this category should be interpreted by readers with great caution.

Drivers less than 20 years of age driving in light traffic have a probability of committing an excessive speed error of 50% if visibility conditions are hazy. This same group is more likely to be identified as having committed an excessive speed error if they have been driving for 6 months or less, or more than 10 years; if they are male; if they have a year or less, or more than 2 years experience with the accident vehicle; or if they are driving on wet or snowy pavement. No interpretation of the road familiarity or exposure splits is offered.

Human Conditions or States

Many traffic accidents are certain to be attributable to different human psychological or physical conditions, especially alcohol and drug use. This factor split first on road familiarity, leading to the hypothesis that some kind of physical or psychological impairment is compounded by a lack of familiarity of surroundings in such a way that some other errors may not be. The possible splits on driving experience and traffic volume are consistent with the interpretation that an impairment of the type that would lead to identification of a human condition or state factor might be compounded by any other potential disadvantage (such as road familiarity, driver inexperience, or traffic volume patterns of the type that permit excessive speed). Drivers who drove the road of the accident twice monthly, infrequently, or never before (which we are interpreting here as being an unfamiliar group) are 4 times as likely to be identified as having some relevant human condition or state if they have less than 3 months driving experience; if their exposure rate is 12,000 miles annually or less; or if they are on the road of the accident for the first time.

Vehicular Causal Factors

The possible first splits on this factor were pavement condition, precipitation intensity, driving experience, and age. The high identification rates for wet pavement and precipitation are consistent with the fact that a majority of the vehicular factors are related to tires and brakes — problems which would be greatly intensified by environmental factors that might increase stopping distances or degrade vehicle handling. The two driver characteristic variables are consistent with the widely held belief, in part confirmed by other analyses presented in this report, that inexperienced drivers and young drivers are more likely than others to drive defective vehicles.

Drivers involved in accidents on wet pavement are more likely than others to be cited for some vehicular factor if they have been driving two years or less, they are under 20 years of age, they drive the road of the accident daily, have one year or less experience with the accident vehicle, or are male.

3.2.4 Conclusions and Recommendations for Future Research

The exploratory analyses presented here indicate that it is possible to identify subgroups of accident-involved drivers that exhibit a particularly high probability to commit a particular type of error that leads to traffic accidents, given knowledge of a few basic characteristics of the drivers and of the environmental circumstances under which their accidents occurred. Particularly important in discriminating between drivers who committed human causal or severity-increasing errors are variables related to the driver's experience with the driving task, measured in terms of the number of years of driving experience and annual exposure; familiarity with the road on which the accident occurred, measured in terms of the frequency with which he travels it; familiarity with the accident vehicle, measured in terms of the length of time he has been driving it; and driver age and sex, which are presumed to be related to experience, risk-taking behavior, type of exposure, and, at the high end of the spectrum, deterioration in motor skills and attention span. The commission of certain errors — those related to distractions, maneuvering, evasive actions, and speed — are also related to certain environmental characteristics of the accident scene such as traffic volume, precipitation, pavement condition, and visibility. For the most part these latter variables appear to affect the probability that some kind of driving error on the part of the driver will actually result in an accident, e.g., speeding is more likely to be cited as a causal factor in accidents on wet pavement than on dry, presumably because the potential for loss of control at unsafe speeds is greater on wet pavement than on dry.

Lack of familiarity with the road is apparently related to the commission of a broad range of human errors, and research should be conducted into the possibility of finding ways to alleviate that problem. While it is obvious that familiarity with a road can only be gained by driving on it, it might be profitable to explore the possibility of designing research which would identify the discrete components of familiarity in perceptual and behavioral terms and to design training programs that would teach drivers to more rapidly learn the relevant information from a new road. If a generally usable driver education program component could be developed to shorten and steepen the learning curve with respect to roadways, vehicles, and driving in general, it could ultimately have the effect of reducing that portion of traffic accidents attributable to driver inexperience.

Some of the potential splits on sex which turned up in this analysis are of interest. It is frequently assumed that the higher involvement rates and high error rates of male drivers are in part attributable to the substantially greater exposure that the average male driver has over the average female driver. The presence of a number of possible splits on sex (always showing higher identification rates for men) in situations in which a split on exposure was not possible, raises the question of whether there is some other characteristic of male drivers that leads them to commit certain types of errors. In the case of speed-related errors, it is commonly agreed that men are more likely to exhibit risk-taking behavior which may manifest itself in speeding, but this kind of explanation is somewhat weaker when applied to the apparent propensity of men to be driving relatively more defective vehicles. Of special interest in this subject is the finding that accident-involved women are twice as likely as accident-involved men to have pulled out into traffic with looking adequately.

Finally, this kind of exploratory assessment is greatly hampered by the relatively small subsample sizes with which it was necessary to deal. Even with the 2,433 complete cases available from the IRPS on-site investigations, the decomposition of a sample into subparts quickly produced relatively small groups of interest that cannot be adequately studied or further decomposed due to their small size. It is clear that future studies of accident causation will continue to refine both the definitions of causation and the human factors data collected. They should increase the ability of researchers to analyze relatively large subgroups by providing a longitudinal data set of cases currently available and those to be subsequently collected in a form consistent with previous work. Of course, this problem could be solved if NHTSA could develop a relatively simple causal assessment scheme that could be applied by the NASS level B teams.

4.0 Motorcycle Accidents and Causes

The purpose of this section is to provide information useful in the development of motorcycle operator training and other programs aimed at reducing the frequency and severity of motorcycle accidents. The following discussion is divided into three main sections.

The **first** assesses differences between the characteristics of accidents involving motorcycles and accidents involving other types of vehicles. Motorcycle and other accidents reported to the Indiana State Police in 1973 are compared on the basis of accident configuration [as developed by Reiss, Berger and Vallette (1)]; severity; place of occurrence; month; day of week; time of day; road surface condition; light condition; sex, age and alcohol presence of motorcyclist/driver.

Second, characteristics of IRPS motorcycle accidents are compared with 1973 Indiana State Police motorcycle data to determine the representativeness of the IRPS motorcycle sample.

Third, the IRPS motorcycle sample is analyzed on the basis of accident causation. Errors of accident-involved motorcyclists and errors of other vehicle drivers involved in motorcycle accidents are described and compared to error rates of all IRPS accident-involved drivers.

4.1 Summary of Results

4.1.1 Differences Between Motorcycle Accidents and Other Traffic Accidents (1973 Indiana State Police data)

Motorcycle accidents and other motor vehicle accidents take place in different situations. Motorcycle accidents when compared with other traffic accidents are more frequently single vehicle, rural, non-intersection; while other traffic accidents are more frequently multi-vehicle, urban.

Motorcycle accidents in Indiana occur at different times of the year. Motorcycle accidents happen more frequently in May, June, July, August and September; while accidents involving other motor vehicles occur more frequently in October through April.

Motorcycle and other motor vehicle accidents happen on different days of the week. Motorcycle accidents occur on the weekend and other motor vehicle accidents occur more often during the week.

Motorcycle accidents happen at different times of day. Motorcycle accidents occur more frequently between the hours 1:00 P.M. to 1:59 A.M. while other motor vehicle accidents occur more often between 2:00 A.M. and 12:59 P.M.

Motorcycle accidents happen more frequently in rural settings than accidents involving other motor vehicles.

Motorcycle accidents are more injury producing than accidents involving other motor vehicles.

Motorcycle accidents occur more often on dry road surfaces while other accidents happen more frequently on wet or snowy/icy road surfaces.

There is no difference between motorcycle accidents and other accidents with respect to light conditions at the time of the accident.

Accident-involved motorcyclists are younger than drivers of other accident-involved vehicles.

Accident-involved motorcyclists are more frequently male than drivers of other accident-involved vehicles.

There is no difference between motorcyclists and other drivers with respect to the presence of alcohol.

4.1.2 Representativeness of IRPS Motorcycle Sample

IRPS investigated 52 motorcycle accidents during the 5 yearly study phases (11/1/70 to 5/31/75). These accidents are representative of all 1973 ISP reported motorcycle accidents with respect to accident configuration, severity, place of occurrence, month, day of week, time of day, road surface condition and light conditions. IRPS accident-involved motorcyclists are representative with respect to sex and presence of alcohol but not with respect to age. The IRPS sample is overrepresented with 20-34 year-olds and underrepresented with motorcyclists less than 20.

4.1.3 Motorcycle Accident Causes

Accident-involved motorcyclists cause accidents primarily because of poor decision making and by not responding appropriately to environmental hazards. The most frequent decision making error is excessive speed, followed by false assumption (e.g., assumed other driver was required to stop or yield at intersection) and improper driver technique (e.g., should have adjusted speed). The most frequent environmental hazard for motorcyclists is view obstructions (e.g., hillcrests and sags) followed by slick roads and special hazards (e.g., non-contact vehicle).

Other motorists involved in motorcycle accidents are at-fault because they fail to recognize the presence of motorcycles, make poor decisions and respond improperly to environmental hazards. The primary recognition error is inattention to other traffic, improper lookout or other delays in perception when entering a travel lane from an intersecting street or alley. The second most frequent recognition error is internal distraction (e.g., conversation). The most prevalent decision error is improper maneuver (e.g., turn from wrong lane). The most frequent environmental hazard is view obstructions (e.g., parked traffic).

When compared with other accident-involved drivers motorcyclists make fewer human errors, make significantly fewer recognition errors ($p \leq .001$) and have fewer accident causing vehicle malfunctions. On the other hand, other vehicle drivers involved in motorcycle accidents are more culpable, make significantly more recognition errors ($p = .016$), make significantly fewer decision errors ($p = .044$) and are less likely to be affected by adverse physiological/psychological states (e.g., alcohol or drug impairment).

4.2 Detailed Discussion

4.2.1 Differences Between Motorcycle Accidents and Other Traffic Accidents (1973 Indiana State Police Data)

In order to compare the characteristics of motorcycle accidents and other motor vehicle accidents, it was necessary to access the 1973 Indiana State Police Accident file. By using this data, information from 4,326 motorcycle accidents was available for summarization.

All 1973 Indiana motorcycle accident data and a 1.15% systematic sample of crashes involving other motor vehicles were extracted from this file and saved for further analysis. This resultant motorcycle/other vehicle accident file (M/O file) contained information from 4,326 motorcycle accidents and 4,181 accidents involving other motor vehicles. The M/O file was then used to analyze the differences between characteristics of motorcycle accidents (M/A) and other motor vehicle accidents (OMV/A), accident-involved motorcyclists and other accident-involved drivers. M/As and OMV/As were compared on the basis of accident typology, severity, place of occurrence, month, day of week, time of day, road surface condition and light conditions. Motorcyclists and other accident-involved drivers were compared by age, sex and alcohol presence. Two-sample chi-square tests and significance levels were computed on the M/A and OMV/A distributions; results are presented at the bottom of the first two columns of Tables 4-1 through 4-11. M/A and OMV/A distributions are significantly different at the $p \leq .001$ level of significance for the following accident characteristics: accident typology, severity, place of occurrence, month, day of week, time of day, road surface condition, motorcyclists/driver age and sex.

Note: When significant differences do exist between M/A and OMV/A distributions, accurate explanations are at times difficult to make without the added information provided by exposure and causation statistics. When M/As are shown to happen more frequently at particular times, situations, etc. it is impracticable to judge if it is because motorcyclists log more mileage during those times — are exposed to a situation more frequently, or if particular times, situations, etc. are more dangerous for motorcyclists. Even in the absence of exposure and causation data, comparisons of this type are useful in describing M/A phenomena and in showing how they differ from OMV/As.

Accident typology distributions for M/As and OMV/As are presented in Table 4-1. Accident typology is defined in terms of the scheme developed by Reiss, Berger and Vallette (1). M/As are shown to differ from OMV/As in that they are more frequently single vehicle, rural, non-intersection and less frequently urban, multi-vehicle. This is probably because motorcyclists drive more in rural than in urban areas. There is however an over-involvement of single vehicle motorcycle accidents at urban intersections (.7% of OMV/As are single vehicle, urban, intersection accidents while 2.4% of M/As are in this class). If motorcyclists drive more in rural than urban areas, as is hypothesized, an over-involvement of single vehicle M/As at urban intersections indicates urban intersections are a particularly dangerous situation for motorcyclists.

When M/As and OMV/As are compared by month of occurrence, M/As are shown to be more prevalent in summer months. This is probably because of exposure — motorcyclists drive more during fair weather. Results are presented in Table 4-2.

M/A's take place on weekends. 35.7% of M/As happen on the weekend compared to 27.7% for OMV/As. There is also a slight over-involvement of M/As on Thursdays. Again this weekend over-involvement is probably because of exposure. Results are presented in Table 4-3.

When M/As and OMV/As are compared by time of day (Table 4-4), M/As are shown to occur more frequently between the hours of 1:00 P.M. and 2:00 A.M. It is probably true again that the over-involvement of M/As in afternoons and evenings is primarily due to overexposure at these times.

Results for M/A and OMV/A comparison by urban and rural places are presented in Table 4-5. The overrepresentation of rural M/As is, as stated earlier, probably a function of exposure.

Table 4-6, **Comparison of M/As and OMV/As by Accident Severity,** shows that Indiana Police reported M/As are more injury producing than OMV/As. 2.3% of M/As are fatalities compared to .5% for OMV/As. 75.9% of M/As are injury producing compared to 22.4% for OMV/As. One contributing factor to this large difference is the tendency for minor M/As to not be reported to police agencies thus making ISP estimates of less severe M/A accidents too small.

When comparing M/As and OMV/As by road surface condition (Table 4-7), results show more M/As take place on dry road surfaces (93.4% for M/As and 68.5% for OMV/As) and proportionally fewer M/As happen on wet or snowy/icy roads. Again this is probably because motorcyclists drive less during rainy, snowy or icy conditions.

Light condition comparisons are presented in Table 4-8. No statistically significant difference exists between M/As and OMV/As with respect to light conditions. There is a slight over-involvement of daylight M/As and corresponding under-involvement of night M/As.

Comparisons of accident-involved motorcyclists and other vehicle drivers are presented in Tables 4-9 through 4-11. Motorcyclists are shown to be younger, are usually male (96.4% male) and are no different with respect to alcohol presence. Again the over-involvement of young males in M/As is primarily due to the over-exposure of younger, male motorcyclists.

4.2.2 Representativeness of the IRPS Motorcycle Accident Sample

Fifty-two M/As were investigated by the IRPS on-site investigation team during the period November 1, 1970 to May 31, 1975. M/A characteristic distributions of the IRPS sample were compared with the distributions for all 1973 ISP M/As. One-sample chi-square statistics and significance levels were computed. ISP and IRPS distributions/chi-square one-sample tests for each characteristic are displayed at the bottom of columns two and three of Tables 4-1 through 4-11.

Generally, the IRPS sample is representative of 1973 ISP reported M/As. Only one

Table 4-1

Comparison of Motorcycle Accidents and other Motor Vehicle Accidents by Accident Configuration

Accident Configuration	1973 Indiana Accidents Involving Other Motor Vehicles		1973 Indiana Accidents Involving Motorcycles		Phases I thru V On-Site Accidents Involving Motorcycles	
	n	%	n	%	n	%
Multi-vehicle Urban Intersection	1271	30.4	1079	24.9	19	36.5
Multi-vehicle Urban Non-Intersection	858	20.5	655	15.1	7	13.5
Multi-vehicle Rural Intersection	442	10.6	498	11.5	4	7.7
Multi-vehicle Rural Non-Intersection	560	13.4	589	13.6	5	9.6
Single Vehicle Urban Intersection	28	.7	102	2.4	1	.9
Single Vehicle Urban Non-Intersection	549	13.1	511	11.8	7	13.5
Single Vehicle Rural Intersection	20	.5	72	1.7	-	-
Single Vehicle Rural Non-Intersection	453	10.8	820	19.0	9	17.3
Total	4181	100.0	4326	100.0	52	100.0

$\overline{X}^2 = 223.27$ with 7 d.f.***

$\overline{X}^2 = 5.317$ with 7 d.f. NS

Sources: Indiana—1973 ISP statistics; IRPS—Phases I thru V on-site accidents
NS—Not Significant

* $p \leq .05$
** $p \leq .01$
*** $p \leq .001$

Table 4-2

Comparison of Motorcycle Accidents and other Motor Vehicle Accidents by Month of Accident

Month of Accident	1973 Indiana Accidents Involving Other Motor Vehicles		1973 Indiana Accidents Involving Motorcycles		Phases I thru V On-Site Accidents Involving Motorcycles	
	n	%	n	%	n	%
January	313	7.5	50	1.2	2	3.8
February	326	7.8	40	.9	-	-
March	351	8.4	193	4.5	5	9.6
April	338	8.1	342	7.9	8	15.4
May	367	8.8	478	11.0	7	13.5
June	350	8.4	758	17.5	4	7.7
July	330	7.9	718	16.6	4	7.7
August	342	8.2	700	16.2	8	15.4
September	328	7.8	524	12.1	6	11.5
October	380	9.1	335	7.7	5	9.6
November	326	7.8	134	3.1	2	3.8
December	430	10.3	54	1.2	1	1.9
Total	4181	100.0	4326	100.0	52	100.0

$\overline{X}^2$ = 1309.48 with 11 d.f.***

$\overline{X}^2$ = 16.446 with 11 d.f. NS

Sources: Indiana—1973 ISP statistics; IRPS—Phases I thru V on-site accidents
NS—Not Significant

* $p \leq .05$
** $p \leq .01$
*** $p \leq .001$

Table 4-3

Comparison of Motorcycle Accidents and other Motor Vehicle Accidents by Day of Week

Day of Week	1973 Indiana Accidents Involving Other Motor Vehicles		1973 Indiana Accidents Involving Motorcycles		Phases I thru V On-Site Accidents Involving Motorcycles	
	n	%	n	%	n	%
Monday	594	14.2	488	11.3	13	25.0
Tuesday	554	13.2	501	11.6	6	11.5
Wednesday	565	13.5	524	12.1	5	9.6
Thursday	571	13.7	617	14.3	9	17.3
Friday	738	17.6	653	15.1	4	7.7
Saturday	719	17.2	853	19.7	9	17.3
Sunday	441	10.5	690	16.0	6	11.5
Total	4182	100.0	4326	100.0	52	100.0

χ^2 = 85.40 with 6 d.f.*** (1973 Indiana Other Motor Vehicles vs. 1973 Indiana Motorcycles)

χ^2 = 11.919 with 6 d.f. NS (1973 Indiana Motorcycles vs. Phases I thru V)

Sources Indiana—1973 ISP statistics; IRPS—Phases I thru V on-site accidents
NS—Not Significant

* $p \leq .05$
** $p \leq .01$
*** $p \leq .001$

characteristic, motorcyclist age, is not represented properly. The IRPS sample is significantly different from the ISP age distribution; it is underrepresented with motorcyclists less than 20 and overrepresented with older age groups. No significant differences exist for any of the other comparisons (accident configuration, month of accident, day of week, time of day, urban and rural places, accident severity, road surface condition, light conditions, motorcyclist sex and alcohol presence).

4.2.3 Motorcycle Accident Causes

In order to analyze M/A causes, accident causative errors of motorcyclists (n = 54) and

Table 4-4

Comparison of Motorcycle Accidents and other Motor Vehicle Accidents by Time of Day

Time of Day	1973 Indiana Accidents Involving Other Motor Vehicles		1973 Indiana Accidents Involving Motorcycles		Phases I thru V On-Site Accidents Involving Motorcycles	
	n	%	n	%	n	%
12:00 A.M. - 12:59 A.M.	89	2.2	105	2.5	-	-
1:00 A.M. - 1:59 A.M.	55	1.4	71	1.7	-	-
2:00 A.M. - 2:59 A.M.	60	1.5	53	1.2	-	-
3:00 A.M. - 3:59 A.M.	45	1.1	33	.8	-	-
4:00 A.M. - 4:59 A.M.	24	.6	14	.3	-	-
5:00 A.M. - 5:59 A.M.	36	.9	18	.4	1	1.9
6:00 A.M. - 6:59 A.M.	87	2.1	55	1.3	2	3.8
7:00 A.M. - 7:59 A.M.	173	4.3	94	2.2	3	5.8
8:00 A.M. - 8:59 A.M.	187	4.6	61	1.4	2	3.8
9:00 A.M. - 9:59 A.M.	158	3.9	61	1.4	2	3.8
10:00 A.M. - 10:59 A.M.	159	3.9	100	2.3	3	5.8
11:00 A.M. - 11:59 A.M.	216	5.3	196	4.6	2	3.8

Table 4-4 continued

12:00 P.M. - 12:59 P.M.	255	6.3	238	5.6	2	3.8
1:00 P.M. - 1:59 P.M.	208	5.1	271	6.4	5	9.6
2:00 P.M. - 2:59 P.M.	247	6.1	289	6.8	4	7.7
3:00 P.M. - 3:59 P.M.	405	10.0	399	9.4	5	9.6
4:00 P.M. - 4:59 P.M.	409	10.0	440	10.3	5	9.6
5:00 P.M. - 5:59 P.M.	321	7.9	399	9.4	3	5.8
6:00 P.M. - 6:59 P.M.	218	5.4	329	7.7	3	5.8
7:00 P.M. - 7:59 P.M.	178	4.4	291	6.8	4	7.7
8:00 P.M. - 8:59 P.M.	168	4.1	266	6.2	2	3.8
9:00 P.M. - 9:59 P.M.	124	3.0	181	4.2	1	1.9
10:00 P.M. - 10:59 P.M.	131	3.2	176	4.1	1	1.9
11:00 P.M. - 11:59 P.M.	117	2.9	125	2.9	2	3.8
Total	4070	100.0	4265	100.0	52	100.0
	$\bar{X}^2$ = 273.01 with 23 d.f.***					
				$\bar{X}^2$ = 23.353 with 23 d.f. NS		

Sources: Indiana—1973 ISP statistics; IRPS—Phases I thru V on-site accidents
NS—Not Significant

* $p \leq .05$
** $p \leq .01$
*** $p \leq .001$

Table 4-5

Comparison of Motorcycle Accidents and other Motor Vehicle Accidents by Urban and Rural Places

Urban and Rural Places	1973 Indiana Accidents Involving Other Motor Vehicles		1973 Indiana Accidents Involving Motorcycles		Phases I thru V On-Site Accidents Involving Motorcycles	
	n	%	n	%	n	%
Rural	1476	35.3	1979	45.7	18	34.6
Urban	2706	64.7	2347	54.3	34	65.4
Total	4182	100.0	4326	100.0	52	100.0

$\bar{X}^2$ = 95.89 with 1 d.f.*** (1973 Indiana Other Motor Vehicles vs. 1973 Indiana Motorcycles)

$\bar{X}^2$ = 2.575 with 1 d.f. NS (1973 Indiana Motorcycles vs. Phases I thru V On-Site Motorcycles)

Sources: Indiana—1973 ISP statistics; IRPS—Phases I thru V on-site accidents
NS—Not Significant

* $p \leq .05$
** $p \leq .01$
*** $p \leq .001$

other vehicle drivers (n = 37) involved in IRPS-investigated motorcycle accidents are described and compared to expected causation rates as represented by the causal factor distributions of all drivers in the IRPS on-site sample.

Table 4-12 presents the distribution of accident-causing errors of motorcyclists. 44.4% of the 54 motorcyclists were in some way culpable (see row labeled "Human Factors"). 7.4% made recognition errors, 33.3%-decision errors, 9.3%-performance errors, 9.3%-affected by some psychological/physiological condition or state, 27.8% were affected by some environmental hazard and 1.9% had vehicle malfunctions. Of the four motorcyclists who made recognition errors, one was inattentive to traffic stopped or slowing ahead, one was inattentive to the position of his motorcycle on the road, one was inattentive to road features (such as oncoming curves, lane narrowings, etc.), and one was inattentive to road signs and signals providing driver information. Of the eighteen motorcyclists who made decision errors: 1) 66.7% were driving too fast; 2) 27.8% falsely assumed the other driver would stop or yield; 3) 27.8% improperly maneuvered their motorcycles by turning from the wrong lane, driving in the wrong direction of travel, passing at an improper location or driving too close to the center line or edge of road; 4) 22.2% were inadequately defensive by not adjusting their speed

Table 4-6

Comparison of Motorcycle Accidents and other Motor Vehicle Accidents by Accident Severity

Accident Severity	1973 Indiana Accidents Involving Other Motor Vehicles		1973 Indiana Accidents Involving Motorcycles		Phases I thru V On-Site Accidents Involving Motorcycles	
	n	%	n	%	n	%
Fatal	21	.5	101	2.3	2	3.8
Non Fatal Injury	937	22.4	3282	75.9	40	76.9
PD Only	3223	77.1	943	21.8	10	19.2
Total	4181	100.0	4326	100.0	52	100.0

$\bar{X}^2$ = 2601.95 with 2 d.f.*** (1973 Indiana other motor vehicles vs. 1973 Indiana motorcycles)

$\bar{X}^2$ = .705 with 2 d.f. NS (1973 Indiana motorcycles vs. Phases I thru V on-site)

Sources: Indiana—1973 ISP statistics; IRPS—Phases I thru V on-site accidents
NS—Not Significant

* $p \leq .05$
** $p \leq .01$
*** $p \leq .001$

appropriately; 5) 11.1% did not take proper evasive action; 6) 5.6% failed to signal for turn, and 7) 5.6% lost control by accelerating too fast. Performance errors made by motorcyclists were (n = 5): 1) made errors of overcompensation (40%); 2) allowed the motorcycle to go off the right edge of the road (40%), and 3) allowed the motorcycle to enter the opposing lane of travel (20%). Physiological/psychological conditions or states which adversely affected motorcyclists (n = 5) were: 1) vehicle unfamiliarity (40%); 2) driver inexperience (20%); 3) road area unfamiliarity (20%); 4) reduced vision (20%), and 5) "in-hurry" (20%). Accident causative environmental hazards confronted by motorcyclists (n = 15) were: 1) view obstructions (40%)—Note: three were hillcrest, sags, etc.; one roadside embankment, one roadside structure/growth and one parked vehicle; 2) slick roads (33.3%) Note: three because of gravel and/or sand on pavement and two because of wet roads; 3) special hazards (26.7%) Note: three non-contact vehicles, one object on road; 4) control hindrances (13.3%) Note: one drop-off at pavement edge and one control hindrance-other; 5) design problems (13.3%) Note: one road overly narrow and twisting and one design problem-other; and 6) one vision limitation caused

Table 4-7

Comparison of Motorcycle Accidents and other Motor Vehicle Accidents by Road Surface Condition

Road Surface Condition	1973 Indiana Accidents Involving Other Motor Vehicles		1973 Indiana Accidents Involving Motorcycles		Phases I thru V On-Site Accidents Involving Motorcycles	
	n	%	n	%	n	%
Dry	2718	68.5	3918	93.4	48	92.3
Wet	955	24.1	258	6.1	4	7.7
Snowy/Icy	284	7.2	6	.1	-	-
Other	10	.3	15	.4	-	-
Total	396	100.0	4197	100.0	52	100.0

$\bar{X}^2$ = 879.21 with 3 d.f.*** (1973 Indiana other motor vehicles vs. 1973 Indiana motorcycles)

$\bar{X}^2$ = .48 with 3 d.f. (NS) (1973 Indiana motorcycles vs. Phases I thru V on-site accidents)

Sources: Indiana—1973 ISP statistics; IRPS—Phases I thru V on-site accidents
NS—Not Significant

* $p \leq .05$
** $p \leq .01$
*** $p \leq .001$

by darkness (6.7%). Motorcycle degradations caused one accident; this was because of inadequate tread depth.

70.3% of the 37 other vehicle (O/V) drivers involved in M/As were culpable in some manner (see Table 4-12 for summary of other motor vehicle driver causative factors). 51.4% made recognition errors, 21.6%-decision errors, 5.4%-performance errors, 2.7%-affected by some physiological/psychological condition or state, 18.9%-affected by some environmental hazard and 2.7% had a vehicle malfunction. Recognition errors of O/V drivers (n = 19) were: 1) inattention to other traffic, improper lookout or other delays in perception when entering a travel lane from an intersecting street or alley (63.2%); 2) internal distractions (15.8%) Note: two were because of conversation and one was because of a loud noise in the car; 3) improper lookout prior to changing lanes and improper lookout-other (10.5%); 4) failure to observe and stop for stop sign (5.3%); 5) inattention to traffic stopped or slowing ahead (5.3%); 6) externally distracted by other traffic (5.3%); 7) other delays in perception (5.3%); and 8)

Table 4-8

Comparison of Motorcycle Accidents and other Motor Vehicle Accidents by Light Conditions

Light Conditions	1973 Indiana Accidents Involving Other Motor Vehicles		1973 Indiana Accidents Involving Motorcycles		Phases I thru V On-Site Accidents Involving Motorcycles	
	n	%	n	%	n	%
Daylight	2711	68.5	2952	70.6	41	78.9
Darkness	1053	26.6	1028	24.6	9	17.3
Dawn or Dusk	194	4.9	200	4.8	2	3.8
Total	3958	100.0	4180	100.0	52	100.0
	$\bar{X}^2$ = 4.60 with 2 d.f. (NS)					
			$\bar{X}^2$ = 1.72 with 2 d.f. (NS)			

Sources: Indiana—1973 ISP statistics; IRPS—Phases I thru V on-site accidents
NS—Not Significant

* $p \leq .05$
** $p \leq .01$
*** $p \leq .001$

delayed comprehension (5.3%). Decision errors of O/V drivers involved in M/As (n = 8) were: 1) improper maneuver — turned from the wrong lane (37.5%); 2) false assumption — assumed no traffic was coming (25%); 3) misjudgment of distance (12.5%); 4) improper driving technique — other (12.5%); and 5) driver could have accelerated out of danger but did not (12.5%). O/V driver performance errors (n = 2) were: 1) panic or freezing (50%), and 2) performance — other (50%). Other driver physiological/psychological conditions and states caused one M/A. In this instance, the driver was both emotionally upset and alcohol impaired. Environmental hazards which affected O/V drivers involved in M/As (n = 7) were: 1) view obstructions (85.7%) Note: three were due to parked traffic; one to hillcrests, sags, one to roadside embankments, and one to roadside structures or growth; and 2) a non-contact vehicle (14.3%). One O/V driver had a problem with his vehicle; his vision was obstructed due to water/condensation on windows.

When accident-causative errors of motorcyclists are compared with errors of all accident-involved drivers; motorcyclists are shown to be significantly less prone to recognition errors (p ≤ .001), are generally less culpable (human factors, p = .064) and have fewer accident causative

Table 4-9

Comparison of Accident-Involved Motorcyclists and other Motor Vehicle Drivers by Age of Driver

Age of Driver	1973 Indiana Accident-Involved Drivers		1973 Indiana Accident-Involved Motorcyclists		Phases I thru V On-Site Accident-Involved Motorcyclists	
	n	%	n	%	n	%
Less than 20	702	20.0	1526	37.3	9	17.0
20-24	660	18.8	1341	32.8	20	37.7
25-34	760	21.7	853	20.8	19	35.8
35-44	456	13.0	245	6.2	2	3.8
45-54	442	12.6	92	2.2	2	3.8
55-64	299	8.5	22	.5	1	1.9
Over 64	187	5.3	5	.1	-	-
Total	3506	100.0	4093	100.0	53	100.0

X^2 = 1202.13 with 6 d.f.***

X^2 = 15.222 with 6 d.f.*

Sources: Indiana—1973 ISP statistics; IRPS—Phases I thru V on-site accidents
NS—Not Significant

* $p \leq .05$
** $p \leq .01$
*** $p \leq .001$

vehicle malfunctions (p = .085). Test results of differences in causation frequencies for human factors, recognition errors, decision errors, performance errors, conditions and states, environmental factors and vehicle factors are presented in Table 4-12.

Other drivers involved in M/As, when compared to all accident-involved drivers are shown to be significantly more prone to recognition errors (p = .016); make significantly fewer decision errors (p = .044); are generally more culpable (p = .075) and are less affected by physiological/psychological conditions or states (p = .099). Test results of differences in causation frequencies for human factors, recognition errors, decision errors, performance errors, conditions and states, environmental factors and vehicle factors are presented in Table 4-12.

Table 4-10

Comparison of Accident-Involved Motorcyclists and other Motor Vehicle Drivers by Sex of Driver

Sex of Driver	1973 Indiana Accident-Involved Drivers		1973 Indiana Accident-Involved Motorcyclists		Phases I thru V On-Site Accident-Involved Motorcyclists	
	n	%	n	%	n	%
Male	2665	70.2	4055	96.4	54	100.0
Female	1129	29.8	153	3.6	-	-
Total	3794	100.0	4208	100.0	54	100.0

$\bar{X}^2$ = 1009.90 with 1 d.f.*** (1973 Indiana Accident-Involved Drivers vs. 1973 Indiana Accident-Involved Motorcyclists)

$\bar{X}^2$ = 2.017 with 1 d.f. NS (1973 Indiana Accident-Involved Motorcyclists vs. Phases I thru V On-Site Accident-Involved Motorcyclists)

Sources: Indiana—1973 ISP statistics; IRPS—Phases I thru V on-site accidents
NS—Not Significant

* p ≤ .05
** p ≤ .01
*** p ≤ .001

Table 4-11

Comparison of Accident-Involved Motorcyclists and other Motor Vehicle Drivers by Alcohol Involvement

Alcohol Involvement	1973 Indiana Accident-Involved Drivers		1973 Indiana Accident-Involved Motorcyclists		Phases I thru V On-Site Accident-Involved Motorcyclists	
	n	%	n	%	n	%
Not Drinking	2669	92.2	3223	91.3	45	95.7
Drinking	226	7.8	306	8.7	2	4.3
Total	2895	100.0	3529	100.0	47	100.0
	$\overline{X}^2$ = 1.45 with 1 d.f. NS					
			X^2 = 1.169 with 1 d.f. NS			

Sources: Indiana—1973 ISP statistics; IRPS—Phases I thru V on-site accidents
NS—Not Significant

* p ≤ .05
** p ≤ .01
*** p ≤ .001

Table 4-12

Comparison of Motorcyclists and Other Drivers Involved in Motorcycle Accidents With all Accident-Involved Drivers by Type of Culpability (Causal or S/I, Certain, or Probable Levels of Significance and Certainty)

Accident Cause	Motorcyclists n	Motorcyclists %	Motorcyclists Z-Test	Other Vehicle Drivers n	Other Vehicle Drivers %	Other Vehicle Drivers Z-Test	All IRPS On-Site Accident-Involved Drivers n	All IRPS On-Site Accident-Involved Drivers %
Human Factors	24	44.4	Z*=-1.85 p=.064	26	70.3	Z=1.784 p=.075	2126	56.9
Recognition Errors	4	7.4	Z=-6.76 p≤.001	19	51.4	Z=2.410 p=.016	1182	31.6
Decision Errors	18	33.3	Z=-.296 p=.764	8	21.6	Z=-2.010 p=.044	1314	35.2
Performance Errors	5	9.3	Z=1.062 p=.289	2	5.4	Z=.081 p=.936	191	5.1
Conditions or States	5	9.3	Z=.557 p=.575	1	2.7	Z=-1.651 p=.099	266	7.1
Environmental Factors	15	27.8	Z=.394 p=.697	7	18.9	Z=-1.010 p=.312	949	25.4
Vehicle Factors	1	1.9	Z=-1.723 p=.085	1	2.7	Z=-.901 p=.368	190	5.1
Total	54			37			3734	

*Example: $Z=(44.4-56.9)/\sqrt{(.44)(.556)/54}$; p is a two-tailed probability
Source: Phases II, III, IV & V on-site accidents

5.0 General Discussion

5.1 Introduction

The present section was written following completion of all of the substantive sections, to provided a **human factors-oriented synthesis** of information drawn from each of them. The perspective is necessarily that of the author.[1]

In the present study, efforts were expended in two principal directions: the development of a methodology to assess accident causes; and measurement of the relative frequencies of various accident causes — as defined within the framework of the methodology developed. Since (1) the process of attributing accident causes relied heavily on human judgements (of the accident investigators) and (2) the emerging frequencies of causes revealed the significant role that human (driver) behaviors play in accident causation, it was considered of value to attempt to synthesize the results of the various analyses directed at evaluating the research methodology and the role of the driver in accident causation.

Previous analytical and empirical studies of traffic accident causation have tended to define an accident cause as either an end event, behavior, or situation in a sequence of cause and effect relationships beyond which the accident became imminent (e.g., Perchonok, 1972) (1); or as any descriptor shown to be overinvolved in either an accident population, an accident site, or an accident-producing circumstance relative to a nonaccident population, site, or circumstance (A.D. Little, 1970) (2). The advantages and the shortcomings of the two approaches have been discussed elsewhere (Haight, Joksch, O'Day, and Waller, 1976) (3), but in general, the first one's major shortcoming is that it does not provide an accurate representation of the involvement of different accident causes relative to the frequencies of the behaviors themselves, whereas the major shortcoming of the latter approach is that it falls short of providing a theoretical explanation for any "accident causes," and may be susceptible to conclusions based on spurious relationships.

This study attempted to combine to some extent the two approaches. For the most part, a set of accident causes, or a hierarchy of accident causes, was developed independently of any empirical data, and then the relative occurrences of various accident causes **in an accident-involved population** were determined. Data obtained on this accident population were supplemented by normative data from the general driving population, and comparisons between the two populations were made along various dimensions in order to provide some indices of over-involvement. Unfortunately, these indices were limited to variables such as age, sex, etc., which cannot be described as causes in the cause-and-effect sense of the word.

The discussion below will attempt to synthesize the results pertaining to three major areas: an evaluation of the methodology for attribution of accident causes; the involvement of human

[1] The primary author of this discussion was David Shinar, Ph.D., a human factors psychologist.

Preceding page blank

factors in accident causation; and implications of the results for future research and safety programs.

5.2 Methodology Evaluation

5.2.1 Converging Operations

In the development of both an accident causation hierarchy and a causal assessment methodology, it is critical that the processes involved in the latter be robust and valid in order to be able to evaluate the former. Validity as used in this particular section refers only to the methodology, independently of the validity of the accident causes as true descriptors of reasons for accidents. Thus, this is an evaluation of the methodology per se.

One of the critical reflections of a valid model or methodology, is that it yields internally consistent results with different **converging operations** (converging operations are various experimental and statistical manipulations of the data). On the other hand, if the model — in this case, the accident causation hierarchy — is either methodology-bound or statistical manipulation-bound, then different patterns of data would emerge from different assessment methodologies and different statistical treatments, and thus, the results would be said to be interpretable only within a specific rigid methodology and/or statistical treatment. This would obviously weaken the generalizability of the results.

In the present study, much of the efforts were directed to providing converging operations that would test similar relationships so that any assessment of accident causation would hopefully be based on more than one statistical analysis. To some extent, converging operations were also applied to the evaluation of the hierarchy and the assessment methodology. The prime example is the comparison of frequencies of accident causes between on-site data and in-depth data. The two levels consist of different approaches to accident analysis (mostly because the in-depth investigation is delayed and consists of a much more formalized and detailed investigation of each of the driver-vehicle-environment components). Thus, differences between the on-site investigations and the in-depth investigations would indicate that the results obtained with either one alone are either not stable, or when the difference can be attributed to the increased accuracy of the in-depth team, the results would be said to be methodology-bound so that they can be obtained at only with that type and level of accident investigation. On the other hand, results obtained at both levels of investigation provide some construct validity for both the model and the data.

Converging operations designed to test the theoretical basis of some of the accident cause patterns were provided by special studies, such as those involved in assessing personality profiles that might be associated with increased involvement in accidents, and the involvement of specific driver characteristics such as vision and knowledge in accident causation. Finally, various parametric and nonparametric analyses, resting on different assumptions, were applied to the same data base. Thus, many of the results and conclusions are based on two or more of the following statistical procedures: regression analysis (analysis of variance, correlations, regressions); cluster analysis; Chi-square analysis; factor analysis; and an automatic interaction detector program.

5.2.2 The Causation Hierarchy

The human factors part of the accident causation hierarchy is patterned after a stage model of human information processing consisting of at least three additive stages involving recognition, decision, and response (e.g., Smith, 1968; Sternberg, 1969) (4,5). While various experimental techniques have been developed to probe the variables affecting each one of these stages, the consensus is that an overt response must of necessity reflect the involvement of all three. Thus, post hoc interviewing could not be viewed as a valid method for assessing an information processing failure specific to any of the component processes. Therefore, in localizing a driver error as a recognition error versus decision error, the reference is to a function rather than a stage.

The evaluation of the human factors accident causation hierarchy is in terms of two principal aspects: (1) its applicability to accident investigation, and (2) its internal consistency. The last implication is closely tied into the practicality of the definitions associated with each one of the accident causes, since either overly specific definitions, or insufficiently detailed definitions would yield low inter-investigator reliabilities.

The applicability of the causation hierarchy was evaluated by subjecting both the in-depth and on-site accident causation results to cluster analysis. It should first be noted that comparisons between the on-site cluster analysis and the in-depth cluster analysis yielded very similar patterns. Based on these analyses, the primary clusters of accident causes consisted of the following groups of drivers: drivers judged not to be at fault; drivers committing recognition errors; drivers committing decision errors; and drivers impaired by physical or mental conditions. In addition to the great similarity between the in-depth and on-site levels, these patterns of errors fit nicely within the conceptual human information processing model. Thus, these clusters manifest a tendency on the part of the investigators to pinpoint the critical error to a specific human information processing function. Had this not been the case, these groups would not have separated so nicely into the various component processes. While the separation of functions by the accident investigators is somewhat artificial (since there is overlapping among processes, and in a post hoc interview it is almost impossible to pinpoint the localization of the error in the sequence), it is useful to conceptualize driver errors in this fashion, and apparently, both on-site teams and in-depth teams were able to do so. Thus, at the very least, these patterns of results indicate both consistency across the two levels as well as appropriate applications of the accident causation model to attributing accident causes.

The consistency of the causation assessment methodology was assessed both by making within-case comparisons between the on-site and the in-depth teams, and by measuring the interjudge reliabilities between the different in-depth investigators. In general, the comparisons indicated both that the causal hierarchy, along with its set of definitions, is quite adequate as a set of descriptors of accident causes, and that the causal assessment methodology is sufficiently formalized to yield similar judgments across different people. To evaluate the hierarchy and its definitions, the frequency at which causes were misidentified by one of the two teams relative to the other was evaluated. Correlations between the on-site and in-depth conclusions were quite high (using any one of three measures of relationships: contingency coefficient; Cramer's V; uncertainty coefficient) and indicated that, at the most conservative level (for data corrected of coding errors on the fifty most frequent causes) misidentifications accounted for approximately 20% of the variance ($1-R^2$). The correlations between the in-depth and on-site, in specific categories, ranged from 1.0 for human conditions and states to .81 for human direct causes. These results indicate that in general, once a cause is identified, the hierarchy as defined is sufficiently detailed to allow different investigators to correctly identify the cause by using the proper label. This data is very supportive of the causal hierarchy as a workable set of accident cause definitions, though one should be aware that it does not address the issue of whether or not this group of "causes" is either exhaustive or true.

Comparisons between the on-site and in-depth results also allowed an evaluation of the two levels of accident investigation in terms of their ability to detect various accident causes. This was revealed by evaluating the rates of omission errors on the part of the on-site investigators (i.e., the number of times an accident cause was identified by the in-depth team but not identified by the on-site team). This type of evaluation does not reflect so much on the causal hierarchy and its definitions, as on the ability of on-site investigators to detect accident causes as they are defined by the causal hierarchy. In general, on-site investigators tended to omit (or miss) certain causes rather than to commit (or falsely identify) them. Of the fifty most frequent accident causes, 35% of the times a cause was identified by the in-depth team it was missed by the on-site team. A signal detection analysis indicated that of the fifty most frequent causes, those most likely to be missed are: the vehicular causes designated "inflation problems with tires" and "communication system failures;" the human direct causes labeled as "delayed recognition due to internal distraction," "improper maneuver," "improper driving technique," and "inadequately defensive driving"; decision errors involving inadequate signalling, improper evasive action and other errors; all causes labeled under performance errors (excluding inadequate directional control); environmental causes labeled "highway related design problems," and ambience-related problems (excluding those in which special/transient hazards were involved). These results can be used as a strong argument for the need for accident investigations at the in-depth level, at least as far as the detection of these factors. Furthermore, if an in-depth level of accident investigation were to be totally dropped from an accident investigation effort, a primary source of quality control of the on-site performance would be lost. In the present research, gross errors and inadequacies on the part of the on-site investigators were often detected in the process of evaluating cases in-depth, and whenever appropriate, or relevant for future investigations, information was fed back to the on-site team. Thus, it is likely that a continuous on-site investigation operating as the highest level of an accident investigation effort could deteriorate gradually, without anyone being able to detect this deterioration.

5.2.3 *The Clinical Assessment Method*

The most formalized aspect of the accident investigation process in this study was that of the in-depth level. The formalization was carried out from the initial form that was filled out for each accident through the process of presenting and evaluating the data, and to the accident cause description. While it was in no way possible to evaluate the validity of this process for detecting and correctly identifying accident causes, various analyses were conducted to examine the internal consistency of this methodology. The results, in general, indicated that the methodology was fairly free of large individual differences and area-of-expertise biases that could have been expected from the different investigators. The evaluation, however, did reveal some differences in the use of verbal labels of confidence (possible, probable, and certain levels of assuredness) among the various causal factor areas. The average subjective probability for certain judgments was 1.0 for human conditions and states and .92 for human direct causes. On the other hand, the average subjective probability for a probable cause was .61 for human conditions and states and .74 for human direct causes. This indicates that some biases existed for the group as a whole (since individual differences were small) in evaluating various categories of accident causes. One of the recommendations stemming from this analysis is to use only numerical subjective probability ratings, in the hope that these biases will then be minimized. The implication of the present results, however, is that a probable level of assuredness for human direct causes may not quite correspond to a probable level of assuredness for human conditions and states. Nonetheless, the differences were relatively small, and the overlap (across all causes) between the categories was not too large.

One bias that may have been shared by both the on-site and the in-depth investigators is the tendency to overestimate the human role in accident causation. The potential for such a bias exists since all accident causes were defined as conditions or performance below the currently existing norms. Whereas such norms are relatively easy to define for vehicle condition and almost as easy to define for the roadway environment, they are much more difficult to assess for the human operator. In this study, the definition of the "normal" driver was that of an alert driver exercising the "expected" defensive driving techniques. This obviously leaves much room for variation in expectations of the driver. Furthermore, while it is reasonable to expect that a driver should be alert and defensive in general, it is unreasonable to expect any driver to be able to remain alert and defensive continuously while driving. The normal driver is **not** capable of maintaining peak alertness continuously over long periods of time. Even under conditions of maximum motivation and relatively few distractions, alertness deteriorates rapidly within the course of one hour (c.f. vigilance studies). Thus, it is possible that probability estimates for human causes reflect a much higher expectation of the driver than is practically reasonable.

5.3 Human Factors in Accident Causation

The methodology developed in this study and the various statistical analyses used to assess the results yielded information in three different areas: the relative frequencies of various accident causes in the total highway traffic accident picture; some indications as to specific chains of events and interactions of variables that lead up to an accident; and information concerning the specific characteristics of drivers that are likely to be overinvolved in accidents or to commit specific accident-causing behaviors.

Prior to the discussion of these results, it is important to stress that this study (at least the causal tabulation aspect) was concerned with the identification of accident-causes — as defined by a sequence of cause-and-effect relationships that ultimately made the accident inevitable — rather than with a preconceived set of countermeasures that, had they been applied, would have prevented the accident. Thus, while the results may be said to adequately describe the various errors and deficiencies that cause accidents, they impart no immediate information concerning the effects of various potential countermeasures. Furthermore, the transition between "cause" as defined in this study and potential countermeasures is not a simple one. In the particular domain of human accident causes, very often the most effective countermeasure may be not in improving the driver, but rather in improving the vehicle or the environment, since it may be much easier to improve and standardize these two than to improve and standardize the driver according to some preconceived expectations. To illustrate, very often delayed recognition is assessed as an accident cause when, in fact, given the very small probability of the emergency situation, delayed recognition, some of the time, is the norm under which most drivers operate. Thus, an average braking reaction time of 0.24 seconds under optimal conditions may increase to 1.65 seconds under less than optimal conditions (Matson, Smith, and Hurd, 1955) (6). As drivers, we operate in biological time, which may fall far short of the physical time requirements for emergency situations. In such circumstances, only an environmental or vehicular modification can prevent an accident.

5.3.1 Driver Errors

Driver errors were classified as belonging to either recognition delays or failures, decision errors, performance errors, or critical nonperformance. In total, driver errors accounted for a greater percent of the accidents than did both environmental and vehicular causes combined. Both on-site and in-depth analyses indicated that human errors were involved at the probable level in more than 90% of the accidents, but were the sole cause of accidents in only 57% of the cases (based on probable cause data). Since the in-depth investigations were judged to be more accurate, and at this level of analysis were based on a sufficiently large sample of cases, only in-depth data will be used for the present discussion.

The most common of the human errors were recognition and decision errors, each involved in over 50% of the accidents at the probable level (or 41% and 29% of the accidents respectively at the certain level). The most common errors within those categories — each involved in more than 10% of the accidents at the probable level — were improper lookout, excessive speed, inattention, and improper evasive action. Improper lookout and inattention can both be taken to reflect a consequence of reduced alertness since, in the cases where improper lookouts were committed, as often as not the driver reported looking in the direction of the other vehicle but failing to "see" it. Also, in light of the finding that in over 60% of the cases where improper lookout was cited the driver's view was not obstructed, it is unlikely that improper lookout is caused or severely aggravated by view obstructions. There remains the question of what causes this reduced level of alertness and how it can be compensated for. The focused examination of the inattention errors failed to reveal any precipitating human condition or state in over 70% of the cases, thus providing no leads as to the causes of these reduced alertness manifestations. It is possible that these improper lookout and inattention errors are due to the simultaneous occurrence of reduced alertness and an increase in the inherent requirements of the driving task, both of which vary independently.

Improper lookout and inattention can perhaps be best understood within the framework of the "schema" theories of perception (e.g., Bartlett, 1932; Posner, 1969) (7, 8). According to these theories, recognition involves a process in which incoming visual information is compared against a memorial representation consisting of a basic prototype of which the incoming information is some transformation. Thus, the visual image of the same intersection from different points in the driver's path projects different images, all of which are transformations of the same prototype—i.e., the configuration of the basic elements making up that intersection. Since the schema—unlike a photograph—is not a complete representation, whenever attention is reduced the likelihood of overlooking (or of late detection of) a discrepancy increases. Improper lookout is typically in reference to missing an oncoming vehicle, an object that is not contained in the schema. In a highly automated driving task, such as visual scanning at an intersection, there is the possibility that a low degree of consciousness associated with the task may result in overlooking or delayed recognition of critical discrepancies between the schema and incoming information. If this in fact is the case, it may be important to know what is the driver's schema in such situations. This would then enable the manipulation of environmental cues so that they would be more conspicuous whenever they do not correspond to that schema. The benefit of conceptualizing the problem in terms of schema is that there are accepted experimental methods for the study of schemae and their relationships to various transformations.

The basic concept here is somewhat similar to expectancy. Whenever the events in the environment do not correspond to the driver's expectancy, they should be more conspicuous and be presented earlier in time, so that their incongruity with the schema will trigger an appropriate response. Knowledge of the driver's schema would in essence provide knowledge about his expectancies. One ongoing research program that is relevant to these factors is NHTSA's project on a driving simulator (Dr. Albert Burg, Principal Investigator).

One perhaps somewhat artificial distinction between improper lookout and inattention is the context in which each occurs. Improper lookout typically occurs at intersections, whereas inattention is typically cited on a straight road. While it is probable that drivers have different schemae for straight roads and intersections, the actual distinctions that govern their visual monitoring behaviors are not very well known.

The second and fourth ranking driver errors are excessive speed and improper evasive action, both classified as decision errors. There is a marked difference, however, between the two types of decision errors, in that excessive speed is a decision undertaken by the driver consciously or unconsciously before he enters the accident situation, whereas improper evasive action is a decision undertaken under temporal stress, when the threat of an accident already exists. Thus, excessive speed may be more reflective of a personality style that includes risk-taking or of social maladjustment factors, whereas improper evasive action probably reflects a lower level of skill and/or a poor information processing capability (in terms of responding quickly to emerging situations). Since the two errors reflect different underlying cognitive and personality processes, remediation programs would have to differ for these two. Improper evasive action may be situation-specific and may require better training for emergency situations or vehicle modification, such as anti-lock devices for the brakes, whereas excessive speed may be a pervasive behavior that, short of an attitude change or behavior modification of the driver, may be very difficult to change.

The fifth-ranking human error was internal distraction, classified as a recognition error. Internal distractions, perhaps more than any other error, exemplify the divided attention limitations of the human operator in general and the driver in particular. This limitation is not vision-dependent since the predominant type of distraction was conversation with a passenger, not necessarily requiring a shift in visual search behavior. While most drivers are able to divide their attention appropriately, reducing their attention toward extraneous sources (such as passengers) as they enter high-density and high-speed situations (such as in entering freeways), when the danger source is unexpected, the driver is likely to be caught off-guard talking to a passenger, with a reduced level of attention toward new events on the road.

Performance errors were the least common of the human errors, supporting the notion that the bulk of the driving requirements are information processing-related, rather than motoric.

5.3.2 Interactions of Human Direct Causes With Other Factors

A common characteristic of most accidents is that they result from multiple "causes" rather than a single one. Thus, a direct human error may be associated with a predisposing condition or state, or may be causal only as a result of its interaction with another environmental or vehicular cause. Knowledge of these interactions may be very useful in generating countermeasures.

One current view of the accident causation chain-of-events (e.g., Fell, 1976) (9) holds that the accident is only the end event in a series of events and behaviors leading up to it, in which each behavior or event that results from a previous one can be seen to be the cause of the succeeding one. Thus, one would expect that each one of the direct human causes cited would be preceded by a driver condition or state which would be judged to be causal in the context of the accident. Empirically, however, this was not the case, and for only 102 of the 720 drivers involved in the in-depth accident sample was one or more human state or condition cited by the in-depth accident investigation team (as a certain, probable, or possible cause). One probable reason for this is that it becomes increasingly difficult to identify causal factors the farther they are temporally removed from the accident.

Of the various conditions and states included in the hierarchy, roadway unfamiliarity was the most often associated with whether or not the driver committed an "error" (Volume II, Section 3.2). Specifically, improper lookout, improper maneuvers, and — in light traffic only — decision errors were associated with relatively low roadway familiarity. Since different roadways may be associated with different schemae, the more standardized the roadway environment the less will be the need for different schemae and the lower will be the information processing load on the driver. This may be one of the underlying reasons for the greater safety associated with the relatively uniform divided highway system.

An alternative approach used in this study was one in which the increased or decreased involvement of the direct cause was studied as a function of the human condition or state which was judged to be causal for that accident. The results (Volume I, Section 6.1) did in fact show some significant relationships between selected conditions and states and selected direct human causes. While some of these relationships were in accordance with expectations (such as an increase in errors coded as critical nonperformance when fatigue was causally-implicated), some were rather unexpected. Thus, it was found that alcohol tends to increase not only the critical nonperformance but also the probability of driving at an excessive speed. Alcohol was also associated with the reduced probability of having an accident as a result of improper lookout behavior. This last finding may be an artifact of the post hoc interviewing methodology, since drivers aware of being intoxicated may be less likely to admit improper lookout. Maintaining directional control was found to be related not only to driving experience in general but also to specific experience with the accident vehicle. Thus, vehicle unfamiliarity significantly increased the probability of committing an inadequate directional control error.

The interaction between alcohol and speed was also implied in the results of the cluster analysis (Volume II, Section 3.1), in which one of the clusters (Cluster F) was found to contain cases with both alcohol involvement and decision errors.

Since the driver does not operate in a vacuum, but rather in the context of the highway and vehicular environment, it was only natural to expect that many accidents would have a combination of human factors and environmental and/or vehicular factors. The data revealed that at the probable level, in 29% of the accidents both human and environmental factors were involved. The nature of these interactions was revealed by some of the specific statistical analyses. Perhaps the strongest relationship obtained was that between decision errors (specifically, false assumptions), and environmental factors (specifically, highway-related factors), which fell into the same cluster in the cluster analysis (Volume II, Section 3.1). It is possible that in all of these cases (14 accidents), the highway environment was sufficiently misleading to elicit inappropriate schemae in the driver's mind against which incoming information was compared. The possible role of the environment in creating an information overload was indicated by the overinvolvement of decision errors in the context of moderate or high traffic volumes (Volume II, Section 3.2).

The importance of proper highway design was also suggested by some of the interactions between driver conditions and environmental factors, which revealed that both vehicle unfamiliarity and area unfamiliarity significantly increased the likelihood of an accident due to an environmental factor. Specifically, area unfamiliarity increased the likelihood of an accident due to control hindrances by a factor of almost 6, and increased the likelihood of an accident due to inadequate signs or signals by a factor of 5. Obviously, the unexpected hindrances and inadequate signs or signals provide problems for the schemae-matching process, and in an accident-producing environment where time is precious may eventually cause an accident. The obvious recommendation in such cases is to standardize the design and placement of control signals and signs (as in fact has been recommended by the U.S. Dept. of Transportation), and to remove control hindrances to the maximum extent possible (though it is realized that some of these are transitory and cannot be totally eliminated).

The association between human factors and vehicular factors is much less clear. Human and vehicular factors occurred jointly in only 9% of the accidents, and any specific relationships could not be supported by any statistical analysis.

5.3.3 Individual Differences in Accident Causation

In attempting to understand why accidents happen, one direction of research has been to look for distinguishing features that would isolate the accident-involved driver from the nonaccident-involved driver. Various studies of an actuarial nature have indicated that in general males have higher accident rates than females, very young and very old drivers have higher accident rates than middle-age drivers, etc. The purpose of the research here was to investigate individual differences in accident causation one step further, by attempting to identify driver characteristics associated with more specific measures of accident involvement. Specifically, analyses were conducted to define the driver who is overinvolved in accidents **in which he/she is considered culpable or at-fault,** in the sense of committing a "human error." At yet a greater level of detail, several analyses were aimed at isolating driver characteristics that correlate with specific accident causes. This section will review the major findings in this area.

Comparisons between the at-fault and not at-fault drivers revealed that males were slightly more at-fault than females, and for both groups younger drivers (less than 25 years old) and older drivers (over 64 years old for males and over 45 years old for females) were more culpable than drivers between these extremes. Analyses conducted separately for males and females, with the effects of age partialled out, showed that culpable men had little road area familiarity and were less familiar with their vehicles than would be expected for their age. The effect of driver experience was significant prior to adjustment for age, but not significant after this adjustment, indicating that the two variables are confounded with each other. In contrast, culpable women were found to have little road area familiarity but less driving experience than would be expected for their age. While these results may be of some value, they only go a short way toward explaining the mechanisms involved in accident causation. Within the framework of the present study it is much more fruitful to examine the more driver-related characteristics that were found to be associated with culpability.

Comparisons among clusters revealed no significant differences between the at-fault drivers and not at-fault drivers in their knowledge of the driving task as measured by the driver knowledge test, but did indicate some significant differences in vision and personality. Of all the visual performance tests, differences in the expected direction were revealed only on dynamic visual acuity, which was poorer for the at-fault drivers than for the not at-fault drivers. This finding implicates the role of dynamic visual acuity in safe driving even more than the previous results, obtained by Burg (1964) (10) and Henderson and Burg (1974) (11), which indicated a slight positive correlation between dynamic visual acuity and accident involvement (frequency and rate of accidents). In terms of personality characteristics, based on the driver profile analysis, the not-at-fault drivers were better adjusted socially but — surprisingly — had poorer impulse control than the at-fault drivers.

Further attempts to identify particular accident causes with particular personality and driver vision characteristics revealed that drivers for whom conditions and states were cited had a significantly slower reaction time than other drivers. In addition, these drivers were shown to have poorer personal adjustment based on the profile analysis. These two results indicated that conditions and states may impair the information processing functions in a very important way by slowing the driver's reaction time (which is critical in case of an accident) and may furthermore be symptomatic of more permanent characteristics. Thus, it is possible that many of the conditions and states are merely symptoms of deep-seated problems that, if they were to be removed, would be replaced by other behaviors that may be just as dangerous to driving (e.g., speeding). This suggestion is supported by the finding (Volume II, Section 2.3) that at-fault drivers were significantly less adjusted as measured by both the social adjustment scale and the personal adjustment scale, than the not-at-fault drivers. While as a group the at-fault drivers were not significantly different from the not at-fault drivers in their alcohol/drug use and in their prior record, those drivers cited for alcohol as a human condition and state had significantly poorer impulse control and a higher probability of alcohol/drug use history than the not-at-fault drivers.

Analyses of the recognition errors did not indicate an overwhelming support for the notion that deficiencies in the basic visual skills underlie the majority of recognition problems. Poor performance on the vision test was essentially unrelated to recognition errors though it did appear to be related to whether or not the driver was at-fault. These results suggest that recognition errors can be interpreted more as attention failures than as as sensory deficiencies.[2] Vision may play a role in very critical circumstances, especially when peripheral vision is involved, as was indicated by the overinvolvement of people with deficient peripheral detection capability in right-angle accidents. The driver personality profile analysis failed to reveal any personality characteristics that may be related to recognition errors. On the other hand, recognition errors were associated with slow reaction times — both simple and choice — again supporting the argument that critical delays in the information processing functions are more likely to lead to accidents whenever a presentation of the information is compressed in time.

[2] This conclusion must be considered tentative since the analyses of the vision tests indicated low reliability for many of the measures.

Drivers identified as making decision errors had a significantly worse prior record than not-at-fault drivers.

5.4 Implications for the Future Research and Safety Program

In the course of this research program, the analytical methodology was continuously refined. Statistical analyses of the final "system" led to several conclusions. The first conclusion is that, given the sufficiently detailed causal hierarchy, subjective judgments of accident causes can be used with a relatively high degree of interjudge reliability, at least for the causes defined in this study. Secondly, as defined in this study, it became apparent that human factors are the most frequently observed category of accident causes; i.e., the overwhelming majority of accidents are preceded by an inappropriate driver behavior (or the lack of an appropriate driver behavior) but for which the accident would have been prevented. This recurring data pattern, substantiated by the trend analysis, should not be interpreted to imply that the improvement of the highway system depends on a driver improvement program, but rather to imply that to err — as defined in this study — is human. Therefore, in many instances, a human error should be regarded as a parameter around which other components of the highway system should be reevaluated.

The discussion below, concerning potential benefits of other various countermeasures, is highly speculative. This is because whenever a countermeasure is suggested based on the present data, there is an implicit assumption that, given the existence of that countermeasure, everything else would remain the same. To illustrate, skidding on icy roads is a problem in which both slick roads and excessive speed could be causal factors; a potential countermeasure is the use of studded tires. There remains the question, then, of whether driver velocity would change if the driver had studded tires — the assumption being that behavior (i.e., driving speed) would remain the same. A case in point is a recent study that examined the interaction between driver speed and the use of studded tires. It demonstrated that drivers with studded tires drove on icy roads at a higher velocity than drivers without studded tires but still maintained a greater safety margin than the drivers with nonstudded tires (12). Thus, perhaps the most appropriate perspective from which to evaluate the potential countermeasures is to regard them as research hypotheses; i.e., ideas which, based on the present data, might be useful for further testing.

5.4.1 Vehicle Countermeasures

The high frequency of delayed recognition errors — due to either inattention or improper lookout — can be interpreted as warranting the installation of vehicular systems that would reduce the lag in communicating the driver's response to the vehicle's action. In many ways, vehicle design considerations have attempted to reduce system lags by reducing steering wheel freeplay and braking time. Further improvements have been tested by using braking systems incorporating anti-lock and radar-actuation devices. One potential improvement that should not be neglected is that of providing better communication systems among vehicles. Thus, the potential benefits of a deceleration-sensitive rear light was dramatically demonstrated by Voevodsky (1974) (13) with a reduction of rearend accidents by close to 50%. To the extent that delayed recognition is due to initial poor distance judgment, a heads-up display that would provide problem drivers with better information on intervehicular distance may also reduce the frequency of this type of accident (Gantzer and Rockwell, 1968) (14).

This study has also indicated the overinvolvement of speeding when alcohol was a causal factor. Since various alcohol ignition interlock devices have already been considered and rejected for practical uses, a modified use of such devices would be to mechanically restrict intoxicated drivers from exceeding certain speeds. This device would then compensate for the slowed reaction time of an intoxicated driver by forcing him/her to drive at slower than normal speeds.

5.4.2 Environmental Countermeasures

The ultimate purpose of the highway environment is to provide not only comfortable driving, but also information that would be interpreted correctly by the driver. It is at those instances when information in the environment is either totally missed or misinterpreted that driver misjudgments are most likely to occur and accidents are most likely to result.

Environmental causes — typically control hindrances and inadequate signs and signals — occurred most often in combination with decision errors. It has been shown (c.f. Forbes, 1972) (15) that the placement and nature of signs and signals are important factors in influencing the time needed to detect and respond to them appropriately. Both delayed recognition and misjudgment due to misinterpretation of information could be greatly reduced if all the highway-related information were to be standardized in terms of its placement and its design. The Department of Transportation "Manual on Uniform Traffic Control Devices" goes a long way toward that goal. The existence, however, of control hindrances and inadequate signing and signals indicates that problems remain. While it may be prohibitive in cost to correct these problems on all the roads of America, the accident analysis procedures used in this study would be very appropriate for identifying the accident causes and potential countermeasures at high accident sites.

5.4.3 Driver Improvement

Perhaps the most immediate applications of this study's results on the role of human factors in accidents are in the areas of driver screening and improvement programs. This is because the identification of driver errors leads most directly to hypotheses concerning ways to eliminate these errors. It should be borne in mind that driver change, however, is perhaps the most difficult of all changes of the highway environment. This can be exemplified by the repeated, and not too successful, efforts to eliminate drunken driving. In this particular area, neither educational efforts nor severe punishment (Lawrence, 1976) (16) have proven very effective. Nonetheless, the results obtained in this study do point the way to some potential driver improvement programs.

A direct application of this study's findings is to use the results to raise driver awareness of the particular driver errors that lead to accidents. It is highly probable that most drivers are not quite aware of the high incidence with which reduced attention — leading to delayed recognition and an improper lookout — actually causes accidents. In this context, since we know that it is impossible to maintain a continued high level of attention, driver programs should identify the specific environments in which delayed recognition and improper lookouts occur. This type of information would help drivers allocate their attentional capacities differentially as the driving environment changes. To illustrate, accident-causing improper lookouts are most frequent in intersections where the relevant visual field is much wider than it is on the continuous road. Similarly, educational programs that would include knowledge on the effects of various impairments (i.e., conditions and states) on specific accident-causing behaviors (direct human causes) would also be beneficial. The data here on the relationship between indirect human factors and direct human errors is rather small. To the extent that the same pattern of results is supported by further studies, however, it would be beneficial for drivers to know that vehicle unfamiliarity increases the likelihood of having an accident due to inadequate directional control, whereas area unfamiliarity increases the likelihood of having an accident due to excessive speed.

Some of the findings concerning the relationships between accident involvement and driver characteristics (age, sex, personality) have potential implications for licensing. Here, however, ethical issues arise as to whether licenses should be refused or revoked from the driver on the basis of some criterion that is not based on actual driving behavior. Present practices base licensing considerations solely on driving performance and driving-related performance (driving knowledge tests, visual acuity). The findings here indicate that accident involvement may be related to some basic personality characteristics (such as personal and social maladjustment). These, in turn, probably influence the driving style that may be exhibited in normal driving situations but **not** in the driving test. While it is unlikely that personality measures would be used as criteria for licensing, it is possible to view such measures as additional sources of information that should be considered for repeated violators and high accident drivers. These types of measures may then be used to separate drivers who may have had a high frequency of accidents by "chance" from those whose accidents reflected a personality style.

6.0 Summary, Conclusions and Recommendations

In this section, results are summarized and conclusions and recommendations presented for both Volumes I and II of this Final Report. Causal result tabulations and analyses are based on combined data from Phases II through V, and in order to simplify the presentation, results from the in-depth team (Level C) are emphasized. These tabulations are based on 420 accidents investigated by the in-depth team, and 2,258 accidents investigated by the on-site teams, during Phases II through V.

6.1 Volume I: Causal Factor Tabulations and Assessments

6.1.1 Section 3.0: Causal Result Tabulations

1. Overall, and in each of the data collection phases, of the human, vehicular, and environmental factors which were assessed, those categorized as "human factors" were the most frequently cited as accident causes, followed by environmental and vehicular factors, respectively. Human factors were identified by the in-depth team as causes of between 70.7 and 92.6% of the combined Phase II, III, IV and V accidents (definite and probable result figures, respectively). Environmental factors were cited as causes of between 12.4 and 33.8% of these accidents, while vehicular factors were identified as causes in 4.5% to 12.6% of the accidents investigated. The on-site/technician teams (Level B) reported similar results: human factors, 64.3—90.3%; environmental factors, 18.9—34.9%; and vehicular factors, 4.1—9.1%.

2. Of the five major categories of human direct causes which were defined, recognition and decision errors predominated. These categories were ranked as follows: (1) recognition errors (in-depth team definite and probable results of 41.4 and 56.0%, respectively); (2) decision errors (28.6—52.1%); (3) performance errors (6.9—11.2%); (4) critical non-performances (1.7—2.1%); and, (5) non-accident/intentional involvements (none identified).

3. Below the major categories of human direct causes mentioned in the preceding paragraph, a number of more specific human direct cause categories were defined. Among these, those most frequently cited as accident causes were: (1) improper lookout (17.6—23.1%); (2) excessive speed (7.9—16.9%); (3) inattention (9.8—15.0%); (4) improper evasive action (4.8—13.3%); and (5) internal distraction (5.7—9.0%).

4. The leading environmental factors were: (1) view obstructions (3.8—12.1%); (2) slick roads (3.8—9.8%); (3) transient hazards (1.9—5.2%); (4) design problems (1.9—4.8%); and (5) control hindrances (1.2—3.8%).

5. Vehicular factors were categorized first in terms of the major vehicular systems. According to this breakdown, the most frequently implicated categories were: (1) braking systems

(2.9—5.2%); (2) tires and wheels (0.5—4.0%); (3) communications systems (0.2—1.7%); (4) steering systems (0.2—1.0%); and (5) body and doors (0.5—0.7%).

6. Assessments were also made for more specific kinds of problems within each major system. At this level, the most frequently-implicated vehicular causal factors were: (1) gross brake failure (1.9—3.1%); (2) inadequate tread depth (0.2—2.6%); (3) side-to-side brake imbalance (1.0—1.9%); (4) underinflation (0.0—1.4%); and (5) vehicle-related vision obstructions (0.2—1.0%).

7. Based on both on-site and in-depth probable cause data from Phases II through V, it was found that at about the seventh or eighth year of vehicle age, an overinvolvement in accidents resulting from mechanical problems begins. The probability of an accident-involved vehicle 8 years of age or older being cited for a causative vehicular problem was more then 2 times greater than for accident-involved vehicles in general.

8. The most frequently-implicated human condition or state was alcohol-impairment, which the in-depth team assessed as a cause in 0.5—3.1% (definite — probable involvement) of the combined Phase II-V accidents. Comparable results from the on-site team, examining a greater number of accidents and with less potential for bias through non-cooperation of impaired drivers, were 2.9—6.1%. Note that accidents investigated represented all severities of police-reported accidents, and are consequently comprised in large measure of either property damage or minor personal injury accidents (approximately 70% were property damage only). Results here should therefore not be confused with those cited for only serious or fatal accidents; alcohol is often cited as being involved in 40 to 50% of these serious accidents. Results for alcohol-impairment varied considerably from phase to phase and as a function of whether accidents were selected from all hours of the day or only from limited periods, and the reader is therefore cautioned to consult the text for further clarification.

Recommendations

General

1. The causal factor tabulations serve a "problem identification" function, for use in planning future countermeasure activity. Inevitably, such "problems" must be viewed in the context of the process through which they were identified, and the types of factors considered must be taken into account. It certainly does not follow that because a factor has been classified as, for example, a human factor, the most cost-effective solution will be one aimed at changing driver behavior. Possibly, highway or vehicle design changes may provide a better remedial measure. For example, although "inattention to traffic stopped or slowing ahead" has been tabulated as a frequently-involved human causal factor, it may well be that the most cost-effective solution is either redesign of highways or signals to minimize "stop and go" traffic situations (environmental measure), or the installation of radar-warning braking systems or improved brake lights (vehicle measures).

2. In the same sense, indications of the relative involvement of, for example, human factors as compared to vehicular factors, are informative and accurate only when the kinds of assessments which were included and the process which produced them are understood. Note, for example, that the "vehicular causal factors" assessed generally assumed the current state-of-the-art; current original-equipment performance provided a baseline for assessment. Consequently, vehicle results have few direct implications for such issues as the desirability of vehicle handling standards. In much the same way, environmental design factors were considered relative to existing standards; thus, the absence of a divided highway and median strip would not be considered a potential causal factor, even though it might have prevented an accident from occurring. Consequently, although human factors were identified much more frequently than either vehicular or environmental factors, it is entirely possible that improvements in either the vehicular or environmental areas could prove more cost effective than correction or elimination of many of the human errors identified. It is likely that a mix of countermeasure efforts encompassing all three targets (driver, vehicle, and environment) will often be needed.

3. In many applications, these limitations (as described above) pose little problem. For example, for a driver examiner conducting a driving test, the listing of causal factors provides a suitable guide as to the kinds of behaviors the examiner should emphasize, as well as the vehicular and environmental hazards he or she should stress. The examiner is not so much interested in the range of safety countermeasures available, as in knowing the relative importance of different kinds of driving behavior, and the causal factor tabulations should serve this purpose well. Similarly, vehicle factor tabulations are of use to inspection programs, mechanics, vehicle owners, and others concerned with vehicle maintenance; results serve to indicate the extent to which different defects, degradations, maladjustments, and failures are causally-implicated in accidents.

Human Factors

1. Major emphasis should be placed on developing countermeasures to reduce the incidence and consequences of improper lookout, excessive speed, inattention, and improper evasive action (the four leading human direct causes). It is likely that alcohol-impairment also warrants special concern due to the greater severity of accidents where it is involved (see Volume I, Section 5.0).

2. Knowledge of the importance of these driving errors and the context in which they are most likely to result in accidents must be communicated to drivers. Information from this and other studies of accident causes should be incorporated in state driver license manuals, written and on-road driving license tests, and driver education curricula. The Department of Transportation/NHTSA public information papers, announcements, and televised messages should also incorporate this information.

3. "Improper lookout" was the leading accident cause identified. It is important to recognize that nearly one-fourth of all the accidents which IRPS investigated resulted from drivers who changed lanes, passed, or pulled out from an intersecting alley, street, or driveway without looking carefully enough for oncoming traffic. More focused examinations indicated that about half of the individuals cited for "improper lookout" had totally failed to make any surveillance effort, while the remainder had looked but failed to see oncoming traffic which should have been visible. Further research is needed to identify the behavioral components and level of attention which comprise a "proper lookout," so that adequate training, licensing, and enforcement measures can be devised. More focused analyses of the interactions with environmental design features are also necessary, so that roadways, signs, signals, and other environmental features can be set to minimize the incidence of "improper lookout." It is significant that for the drivers who "looked but failed to see," approximately 40% faced a view obstruction which added to the difficulty of their surveillance task, even though it was assessed that this difficulty could and should have been easily overcome. Also of significance is the over-involvement of drivers 65 years of age and over in committing "improper lookout"; of drivers over 65 who caused accidents, approximately half had made errors of this kind. Future research should try to identify the relevant mechanisms (e.g., mechanical difficulties in turning the head, reduction in visual field or other visual skills, or changes in field dependence) in order to suggest appropriate countermeasures, such as specialized training programs.

4. Particularly relevant in considering countermeasures for the "excessive speed" category is the overrepresentation of males and females less than 20 years of age among those cited for this factor (18.1% of males under 20 years of age committed this error, compared to only 10.2% of accident males generally; 8.6% of females under 20 committed this error compared to 5.2% for accident females, generally). The interaction with roadway familiarity also merits attention. Most of the excessive speed errors occurred with reference to "road design," primarily in the sense of exceeding the critical speed for a curve and thereby losing control. The motivations underlying risk-taking behavior among young drivers (particularly males), as well as their skills in vehicle handling and judgment of roadway requirements, may require closer examination, and possibly a reevaluation of present driver training programs.

5. "Inattention" most frequently involved a delay in detecting that traffic ahead was either stopped or decelerating, and less frequently a failure to observe critical road signs and signals. Aside from informing drivers (through public information and driver education programs, etc.) of the importance of attentiveness to the driving task, possible areas of improvement include changes in the size, prominence, or placement of road signs and signals; other environmental changes to reduce the incidence of sudden stops; installation of in-vehicle communication systems, such as radar warning or actuation systems to avoid

contact in the rear-end configuration mode; and installation of improved brake lights (e.g., with possible changes in intensity, color, or pulsation characteristics).

6. Many drivers were cited for "improper evasive action." The two major subcategories of this error involved either failure to attempt an appropriate (and often easily accomplishable) evasive steer, or negation of what would have been a successful evasive steer through over-braking, with a resultant lock-up of the front wheels (rendering the steering input ineffective). Again, a first action should be to inform drivers of the nature and attendant risks of these particular errors. However, further advances would require careful research to determine the most effective means of upgrading the evasive skills of drivers. Perhaps a classroom experience can be beneficial, but it is likely that simulator and actual in-vehicle practice would be required. Four wheel anti-lock braking systems are an effective vehicle-oriented countermeasure for front wheel lock-up through over-braking. Possibly, the relationship between braking pedal displacement and/or force and braking power on existing braking systems might also be improved.

Environmental Factors

1. Undoubtedly, environmental improvements, including implementation of divided highways and elimination of many at-grade intersections, have contributed heavily to the continuing reduction in fatality rates over the past 50 years or so. Yet the IRPS hierarchy was aimed at assessing the relative importance of various kinds of problems and deficiencies within the current highway system, rather than the benefits of further improvements and upgrading beyond a currently acceptable status. In this sense, study results may be more directly informative to highway maintenance personnel than, for example, to a state or federal highway safety planner concerned with determining whether money could be best spent in dividing a highway or putting in an overpass, rather than on other countermeasures.

2. Within this context, the major problems identified were view obstructions (such as trees, shrubbery, or parked cars restricting sight-distances at intersections), and slick roads (a factor which was tallied whenever it was judged that a particular accident would not have happened on dry pavement). Much less frequently involved were maintenance problems (such as missing signs or inoperable signals); control hindrances (such as pavement edge drop-offs); and inadequate signs and signals (e.g., curve warning sign needed but not provided).

3. Accidents in which *view obstructions* were involved most frequently occurred at regular road/road intersections, generally having stop signs on only two of the legs, and with the erring driver almost always on a controlled leg. The erring driver was often intent on going straight and sometimes on turning left, but was almost never attempting to turn to the right. While some of these view obstructions would be difficult to remove — such as buildings,

legally-parked cars, and large embankments — the biggest share (more than half) consisted of trees and bushes, which might more easily be removed — particularly if removal efforts were focused only on intersections which accident records indicate to have high accident rates and/or frequencies. Countermeasures here include local surveys to identify view obstruction problems, and direct appeals to property owners to have such problems corrected. State and civic leaders can also work with business and civic groups, and through the news media, to encourage business and property owners to assess their own property to ensure that they are not contributing to this important safety problem. Another large share of these view obstructions resulted from parked vehicles, nearly half of which were illegally parked. Hence, installation and enforcement of parking prohibitions serves an important safety function; it is important that law enforcement and the public alike perceive this importance.

4. Under the "slick roads" category, rain-slickened roads predominated (possible causal factors in up to 10% of these accidents), while snow or ice covered roads were implicated as causally relevant in up to 4% of these accidents. Interactions with vehicular factors — especially tire tread depth — are evident; vehicle and tire problems were more frequently implicated when the road surface was damp or when precipitation was heavy, with control losses often occurring on curves. In addition to informing and better educating drivers in the safe negotiation of rain, snow and ice-slickened roadways, potential countermeasures lie in the areas of improved road design to eliminate such curves where possible; pavement grooving or other procedures to improve wet road traction, particularly at locations indicated to have a disproportionate number of accidents under wet road conditions; and improved tire design and inspection programs to improve traction on wet, snow, or ice-covered roads. Some research suggests that a major problem with slick roads is that they are not perceived as such by drivers; hence, variable signing systems that provide information on road slipperiness might also be of benefit.

Vehicular Factors

1. Vehicular results were assessed with reference to the current "original equipment" state-of-the-art, and therefore do not directly indicate the safety benefits of possible future improvements, such as four wheel anti-lock braking systems or significantly improved handling characteristics. Results are, however, directly useful in targeting systems for vehicle inspection programs, and for focusing the attention of vehicle owners and others who play a role in vehicle maintenance.

2. Results indicate that brake failures, inadequate tread depth, and brake imbalances are the three leading vehicular accident causes. Consequently, these should be priority items in efforts to upgrade vehicle inspection and maintenance programs, and should be emphasized in consumer information/education programs aimed at making vehicle owners more active and knowledgeable participants in maintaining safe vehicle condition. Owners need to

know what items are critical to inspect, how they can be checked, and which items require the attention of a qualified mechanic. Following the three priority items, the vehicular factors meriting greatest attention are underinflation, vehicle-related vision obstructions, excessive steering freeplay, inoperable lights and signals, and inoperable door latching mechanisms.

3. Among accident-causing brake system problems, gross failures and side-to-side imbalances predominated. More than half of the components responsible for the causal brake problems observed were contained within the wheels. The failures encountered resulted from such factors as wear and adjustment permitting over-travel of wheel cylinder pistons, and dislodging of the star wheel assembly through improper assembly of self-adjustor mechanisms. Most of these failures occurred in older vehicles having only single chamber master cylinders. Side-to-side imbalances most frequently resulted from metal-to-metal contact, permitted by excessively worn linings, and less frequently from friction material contamination. In order to achieve their accident-reduction potential, inspection programs must be able to detect and objectively evaluate these problems. It is likely that a good visual inspection, such as could be accomplished through wheel pulling, would detect the vast majority of these problems. Alternatively, testing on a dynamic brake tester, or on-road testing from relatively high speeds, are probably superior means of detecting side-to-side imbalances, although they most likely would not detect and permit correction of those in-wheel problems which led to brake failure. Factors external to the wheel which accounted for brake failures included brake hose failures and problems in the master cylinder (e.g., sand in the compensator port, out-of-round primary piston seal).

4. Regarding inadequate tread depth, it was found that 19% of the vehicles IRPS inspected on Level C had at least one tire with less than 2/32" of tread, while 10% had at least two tires below this level, 3.5% had three, and 0.7% (five vehicles) had all four tires below this standard. This was true despite Indiana's annual vehicle inspection program, which incorporates a 2/32" tread depth standard. While problems with the inspection program may be partially responsible (it was estimated that 29% of a set of degraded components[1] which IRPS found on accident-involved vehicles were present and should not have passed at the time of the vehicle's last state inspection), normal wear of tires between yearly inspection intervals is a major factor (i.e., a tire which passes today could be below the standard a month or two from now). An alternative would be to increase the inspection standard to some higher figure (perhaps 4/32"), although consumer opposition and increased enforcement difficulties might be anticipated. Alternatively, owners can be at least given a warning if they are below some higher standard (such as 4/32"), possibly with an estimate as to when the 2/32" level will be reached.

[1] The components in this set consisted of wipers, exhaust, freeplay/steering system, and tread depth. These items constitute a subset of components evaluated by the in-depth team.

5. Underinflation was primarily implicated as a possible or probable factor contributing to poor vehicle handling in control loss situations. Based on the high incidence of improperly-inflated tires on vehicles IRPS inspected, it appears unlikely that the typical owner engages in routine checks on inflation, or is adequately concerned about the potential influence of improper inflation on vehicle control. In addition to better informing and educating drivers on this subject, vehicle inspection stations can be required to advise owners regarding tire pressure problems, major oil companies and service station operators can be encouraged to actively participate in checking pressures and advising motorists; and visible pressure warning indicators can be installed to inform drivers when inflation problems exist. In addition to safety, energy conservation and tire life benefits can also be stressed. While underinflation can also lead to tire failure, study results do not support sudden failures as a frequent cause of accidents.

6. Particular attention should be directed to providing adequate consumer information and education concerning vehicle maintenance. Contemporary concerns regarding consumer fraud may have created an atmosphere of skepticism which may sometimes result in desirable repairs and other maintenance practices not occurring. For example, it is possible that consumers may resist installation of new wheel cylinders and seals when having brakes relined, and mechanics may be reluctant to recommend it. In addition, mechanics may feel compelled to eliminate these items in a relining estimate, in order to assure that their bid is competitive. An informed consumer should be able to better distinguish unnecessary from valid preventative maintenance actions.

7. In the continued upgrading of vehicle inspection programs, it is necessary not only to key on those systems and components which are responsible for accidents, but to ensure that inspection procedures, and inspector skills and equipment are up to the task through adequate training, licensing, and program monitoring. For example, brake hose or line failure was responsible for several of the brake failures which caused accidents, yet a visual brake hose and line examination is not required in many programs. In some, at least, a high pedal force application is required, which might detect some incipient failures. However, it is believed that a visual examination could detect additional problem cases; those brake hose failures in the IRPS file which resulted from rubbing against an improperly-installed muffler, and from rubbing against a wheel rim during turns, are cited as examples. However, such a requirement implies a need for training as to likely failure points or sources of interference, and to assess degrees of deterioration in lines and hoses. It continues to be true that in many states inspection personnel receive no training whatever, and licensing requirements are often minimal. The inspection activity must also be adequately monitored to ensure that there is accountability on the part of inspectors and inspection stations for their performance. Too often, consumer complaints comprise the major source of information on station performance.

8. While most of the vehicular problems which caused accidents could have been prevented by

"proper maintenance," the possibility of reducing the need for such maintenance through design innovations and improvements must not be overlooked. While failure to perform needed maintenance poses one set of problems (e.g., as when worn linings permit metal-to-metal contact, leading to a brake imbalance), maintenance carries with it the possibility of improper repair or assembly (e.g., as where an improperly-assembled self-adjuster leads to brake loss through overextension of a wheel-cylinder piston, or where a new and slightly different muffler puts the tailpipe in contact with a brake hose). Desirable improvements might include seals which prevent friction materials contamination over extended periods; longer-lasting brake linings and pads; driver warning/information systems to warn drivers and possibly encourage correction of degraded conditions; and component parts (such as brake adjuster mechanisms) which are designed to decrease the likelihood of improper assembly (especially by the growing number of amateur and owner-mechanics).

9. Vehicle causation problems should continue to be monitored in the future, since the continuous introduction of mechanical innovations will alter the relative involvement of the various problems and systems, requiring a periodic readjustment of inspection items and programs. The dual-chamber master cylinder, in particular, should cause a gradual reduction in the causal involvement of brake failures, which were the predominant vehicle problem in the IRPS data. The advent of disc brakes may also gradually alter these results, particularly as disc brake-equipped vehicles begin to make up a significant proportion of the high mileage/order vehicle population—which was responsible for a disproportionately large share of vehicle problems in the IRPS data.

6.1.2 Section 4.0: Trend Analysis Across Phases

1. For the overall categories of human, environmental and vehicular factors, phase-to-phase changes were large enough to be reflected in several statistically-significant trends. Involvement of human and environmental factors tended to decrease from phase-to-phase, while vehicular factor results varied erratically. Reasons for these changes were not clearly identified, and could reflect variances arising from the clinical assessment procedure..
2. For the ten most frequently identified causal factors, significant trends were identified either in the on-site or in-depth data for five factors. These were: (1) inattention (downward trend, on-site); (2) improper evasive action (downward trend, on-site and in-depth); (3) false assumption (downward trend on-site, mixed trend in-depth); (4) improper driving technique (mixed trend on-site and in-depth); and (5) inadequately defensive driving technique (mixed trend on-site).
3. However, for the two highest ranking human factors (improper lookout and excessive speed), the two most frequent environmental factors (view obstructions and slick roads), and the most frequent vehicular accident cause (brake system problems), significant trends did not occur in either on-site or in-depth data. Thus, for the most frequently cited human,

environmental, and vehicular factors, results changed very little across the four phases (II-V), either on-site or in-depth.

6.1.3 Section 5.0: Analysis of Accident Severity as a Function of Accident Causation

1. In this analysis, accidents involving individual causal factors were compared with all accidents investigated, in terms of the proportion involving either property damage (PD only), or personal injury/fatality (PI/F). Only two causal factors were found to be significantly more serious (in overrepresenting the PI/F class) in both the on-site and in-depth data; these were alcohol-impairment and excessive speed.

2. In addition, in the on-site data only, accidents involving control hindrances (an environmental factor including such problems as pavement edge drop-offs) and tire/wheel problems, were significantly more serious. These factors therefore merit increased concern beyond that indicated merely by their frequency of involvement.

3. Factors associated with less than expected severity (in the sense of significantly underrepresenting the PI/F class of accidents) were false assumption, external distraction, and improper lookout.[2] Note that the last of these — improper lookout — was the study's most frequently implicated causal factor, according to both on-site and in-depth data. Its importance by virtue of frequency of involvement is offset somewhat by its lesser severity. In contrast, the increased severity associated with the second-ranking factor — excessive speed — greatly increases its importance.

6.1.4 Section 6.0: Driver Conditions and States in Combination with Other Factors

1. This analysis investigated interactions of causally-implicated "human conditions and states" (which may be considered human indirect causes as opposed to direct behavioral causes), with both human direct causes and environmental causal factors. One or more condition or state was cited at the "possible cause" level or above for 102 of the 720 drivers tested and interviewed by the in-depth team; these were compared with the direct causes attributed to the same drivers at the "probable cause" level or above, and to the environmental factors cited as causally-relevant to their accidents, at these same levels.

2. Numerous statistically significant interactions were identified, including the following: when alcohol impairment was causally implicated, the likelihood of excessive speed and "other direct causes" being cited was significantly increased. The causal implication of fatigue was associated with a greater incidence of critical non-performance (falling asleep), inattention, and "other direct causes;" reduced vision was associated with increases for improper lookout and view obstructions; emotional upset with inattention; "in-hurry" with excessive speed; driver inexperience with inadequate directional control and highway

[2] On-site data. In the in-depth data, none of the factors significantly underrepresented the PI/F class.

design factors; vehicle unfamiliarity with inadequate directional control, highway design, and slick roads; and roadway unfamiliarity with excessive speed, control hindrances, and inadequate signs and signals.

Recommendations

1. Should future studies yield the same pattern of relationships observed here, there would be numerous possible applications to a variety of countermeasure programs. For example, driver education/information programs might:

   - Stress that if driving while under the influence of alcohol, key concerns are to avoid falling asleep and speeding (while the point on speeding may be well-known, recognition of falling asleep as a problem — like the possible increased risk of internal distraction — may be much less wide-spread).
   - Stress that when emotionally upset, drivers make special efforts to keep their minds on their driving and to remain attentive.
   - Place added emphasis on informing new (inexperienced) drivers of the need to avoid being internally distracted (e.g., by passengers or adjustment of tape players). An emphasis on proper evasive action and retaining control may also be indicated.
   - Stress to drivers operating unfamiliar vehicles the increased risk of control loss.
   - Stress the importance when driving on unfamiliar roads of consciously reducing speed to account for unexpected, deceivingly tight or unusually slippery curves.

2. This analysis might have been improved by comparing the *presence* of these human conditions and states with the human direct causes, as well as vehicular and environmental factors. The causal judgment associated with the conditions and states in this analysis complicates interpretation and may assume too much in terms of the independence of the assessments of the direct and indirect causes (e.g., between the assessment for fatigue and cricitical non-performance/falling asleep).

3. In any future effort of this kind, interactions between the various human, vehicular, and environmental direct causes should be examined. This would promote a better understanding of the causal mechanisms.

6.1.5 Section 7.0: Analysis of Assessment Practices

1. As a part of this assessment, comparisons were made between the in-depth team's subjective (numerical) probability estimates of the causal involvement of a factor, and its application of the three assuredness labels — certain, probable, and possible — to the same factor. A general conclusion is that the in-depth team was either conservative in the use of the numerical ratings, or extravagant in the assignment of the verbal labels of at least certain

and probable causes. For example, whereas "certain" was described as having an "analogous confidence level" of 95% or better, the numerical judgments associated with that assessment had a median value of .90, with an interquartile range of between .88 and 1.00.

2. Based on the limited set of 54 drivers/vehicles considered in this assessment, there were no statistically significant differences between individual in-depth team members in their mean subjective probability assessment values, either within individual types of factors (i.e., human, environmental, or vehicle), or across all factors.

3. In addition, mean scores varied only slightly as a function of the area of expertise represented by the team member, and none of these differences were significant. In other words, team members with human factors expertise assigned neither more nor less credence on the average to the involvement of human factors (or for that matter, to the involvement of environmental or vehicular factors). Only in the case of vehicular factors was there found to be a slight (but non-significant) tendency by the engineers to assign greater weight to the involvement of vehicular factors.

4. While these analyses fall far short of a check on the external validity of the causal assessments, they are nonetheless reassuring in indicating that a consistently applied and systematic assessment procedure was used to obtain these results.

Recommendations

1. In any future effort of this kind, whenever subjective estimates of "causal involvement" are required, it is recommended that numerical probability scales be used instead of such verbal labels as "certain, probable, or possible." The use of numerical values frees the judge from narrow restrictions and provides him/her with a wider potential range of evaluations. The system has further advantages in that verbal labels may then be provided post hoc to describe any range of subjective probabilities, thus eliminating the phenomena of overlapping between subjective categories. The numerical ratings would also eliminate the observed problem of the varying correspondence obtained between verbal categories and numerical ratings for each of the different causal factor areas (e.g., human vs. vehicular).

2. The making of subjective probability judgments is a skill that must be learned, and both experience in this project and related research indicate that a person's original subjective numerical estimates may vary significantly from either the true value or the values later estimated, after additional practice. Adequate practice and perhaps training should therefore be provided.

3. Evaluations are more accurate when people are assigned the role of estimators of component probabilities rather than estimators of product probabilities. Hence, it is probably better to have team members evaluate existence and involvement separately and then combine the product mathematically, rather than have them evaluate the derived

involvement immediately. However, training should make the judges aware of the problems of regression toward the mean, in which as the number of ratings that go into making a final evaluation increase, so do the evaluations tend to regress more and more toward the mean, making extreme values less and less likely.

4. In training accident investigators to make subjective probability judgments, one potential criterion to evaluate progress could be the independence between their evaluations of involvement and existence. Independence between the two statistics should be obtained whenever all the potential factors within a given system are considered.

5. Since speciality areas were not found to affect judgments, perhaps a psychophysical scale can be derived, using a simulator, in which forms of real or staged accidents can be used to relate the actual contribution of various potential factors to the final collision. This could be used as part of a training program and would provide investigators with benchmark probability estimates for various causal factors. To illustrate, various levels of braking deficiencies could be shown to cause an accident (given a certain time-distance relationship between cars) with varying levels of probability.

6. The evaluations here were based in part on having different people evaluate the same accident, and in part on having different people evaluate different accidents. In no case, however, were there two people representing the same area of expertise evaluating the same accident. A more scientifically sound procedure to assess future clinical evaluation processes in terms of their consistency, biases, or efficiency should involve different MDAI teams evaluating the same accidents. This can be done on an experimental basis by providing different accident investigation teams with either real or simulated accident descriptions, slides, graphs, etc. In this particular case, the use of simulated accidents or staged accidents would be an even better tool since it could also help in testing the validity of the clinical assessment procedures.

7. The "clinical assessment approach" should be carefully integrated with statistical (correlative) approaches to "causal factor"/problem identification and definition. For example, accident-causing behaviors identified through the clinical approach should then be further evaluated to better estimate the the relative risk of these behaviors through accident and control/exposure data comparisons, when possible. Similarly, statistical comparisons may identify potential problems which can then be observed and better understood through clinical observations.

8. Evaluations of any subjective assessment procedure should be conducted on an on-going basis, for use as a management tool. In this way, any unusual biases or other problems associated with a particular individual or a particular discipline can be pinpointed and remedial action taken.

6.1.6 Section 8.0: Level B vs. C Comparisons

1. In comparing results for accidents investigated separately by first an on-site and then an in-depth team, correlations (Cramer's V) between teams was less than desired — ranging from .44 across all factors to .59 for environmental factors. Disagreements resulted from both *omissions* (where in-depth cited a factor but on-site did not), and *commissions* (where the reverse was true).

2. The level of coding errors was found to be small; correction of coding errors increased correlations by an average of only .07.

3. For corrected data, correlations based on correct identifications and misidentifications only (with the commission/omission errors excluded) ranged from V = .82 for human direct causes to V = 1.00 for human conditions and states.

4. Based on definitions in this analysis, the level of *disagreements* was higher than desirable for most of the detailed causal categories. However, **it should be noted that the definitions for agreement and disagreement were exceedingly stringent;** citation of a factor at the "possible cause level" by one team, in the absence of any mention by the other team, was considered a disagreement, and a decision by both teams to *omit* (not cite) a factor was not counted as an agreement.

5. The proportion of agreements was much higher for human direct and environmental factors, than for human conditions/states and vehicular factors.

6. Of the disagreements, the most prominent were on-site omissions — particularly for human conditions and states (i.e., frequently the in-depth team cited a human condition or state at the "possible cause" level or higher, when the on-site team failed to cite the same factor at all). Note that some conditions and states may depend more than others on identification by the on-site team at the accident scene (perhaps alcohol-impairment), while others may be more readily detected off-scene by the in-depth team (possibly reduced vision as measured by the driver vision tester).

7. Further analyses were conducted employing statistics derived from signal detection theory. The pattern of results obtained indicated that, in general, on-site was relatively conservative in their citings, leading to a relatively high rate of "misses" (i.e., failures to cite factors which were judged causal by in-depth), and a very low rate of "false alarms" (citing a factor not judged causal by in-depth).

8. For vehicular factors, this analysis revealed the on-site teams to have particular problems in assessing the involvement of imbalanced brakes, suspension problems, and (possibly) the involvement of communications systems. On the other hand, on-site dealt much better with gross brake failures and degradations, as well as steering problems. Even for these factors, however, approximately 50% of the cases detected (i.e., cited at the possible level or above) by the in-depth team remained undetected by the on-site team.

9. This same analysis showed that among human direct factors, on-site did particularly well in assessing external distractions, improper lookout, and inadequate directional control, and was also reasonably accurate in tallying instances of "failing to observe and stop for a stop sign" (although this is actually not considered a "causal factor" within the IRPS scheme). On-site investigators also did an adequate job in assessing inattention, excessive speed, overcompensation, and recognition delays other than internal distraction. On the other hand, on-site was found to have difficulty in detecting the role of misjudgment of distance, improper driving techniques, inadequately defensive driving techniques, inadequate signaling, and improper evasive action. Somewhat less difficulty was experienced with respect to internal distraction, false assumption, and improper maneuver.

10. For human conditions and states, on-site performed satisfactorily (as judged by in-depth team performance) in assessing the involvement of alcohol impairment, driver inexperience, and road/area unfamiliarity. Performance was less satisfactory for other factors, and inadequate for the overall physical/physiological impairment[3] and mental/emotional stress categories.

11. For environmental factors, the on-site teams did well in assessing the involvement of control hindrances, view obstructions, and special/transient hazards. Problems were experienced in adequately detecting the involvement of slick roads, inadequate signs or signals, and highway design problems.

12. A previous comparison (discussed in *Interim Report II*) showed that based on Phase II-IV data, the reported involvement percentages for the various causal factors are generally quite similar in both on-site and in-depth data. Based on Phase II, III, and IV data, results from the in-depth and on-site levels were: human factors, 95.3 and 91.7%; environmental factors/including slick roads, 34.9 and 38.5%; and vehicular factors, 12.6 and 11.3% respectively.

13. *Interim Report II* also indicated that of the ten most frequently cited causal factors, large differences in results in the Phase II-IV data were observed for only two factors: improper driving technique (10.1% in-depth vs. 4.8% on-site), and inadequately defensive driving technique (10.1% in-depth vs. 5.0% on-site). Percentages were quite similar for the remaining eight categories.

14. However, based on an earlier agreement/disagreement analysis employing slightly different procedures and definitions, *Interim Report II* also indicated that the teams often differed as to the specific causal factors cited. It was found that the factor most consistently applied was ambient vision limitations (teams agreed in naming this factor 11.7 times as

[3] Under physical/physiological impairment, the comparatively good performance for the alcohol impairment assessment was offset by poor performance on "other drug impairment" and other physical/physiological problems.

often as they disagreed), while among the least consistently applied was improper driving technique (the teams *dis*agreed 2.7 times as often as they agreed). Again, note that an agreement by both teams that a factor was not involved was not counted as an "agreement" for purposes of these statistics (although this would have greatly improved the agreement/disagreement ratios presented).

15. As in the present analysis, *Interim Report II* indicated that the most important problems in assessing the top-ranking causal factors were that the on-site teams often failed to detect the involvement of improper evasive action, improper driving technique, and inadequately defensive driving technique, in situations where the in-depth results indicated they should.

Recommendations

1. It would have been beneficial to have continually and systematically monitored causal agreements and disagreements between teams on accidents which they both investigated, and to have used this information on an on-going basis to pinpoint problems of interpretation or use of the assessment procedure by individual teams or investigators, and to otherwise refine and improve the assessment process.

2. Were this study to be continued, immediate attention would be required in upgrading the performance of the on-site teams in evaluating the involvement of misjudgement of distance, improper driving techniques, inadequately defensive driving techniques, inadequate signaling, improper evasive action, slick roads, inadequate signs, or signals, highway design problems, imbalanced braking, suspension problems, and vehicle communication systems.

3. Further research and experimentation is in order to determine optimum team make-up and configuration, as a function of data items sought. Such work would be aimed at determining optimum numbers and assignments of team personnel; related skill, training, education, and experience requirements; as well as equipment and procedural requirements, including off-scene vs. on-scene collection and timeliness/response specifications. Trade-offs will certainly exist between numbers of cases acquired, data per case, and data accuracy. It is believed that to date, no controlled experiments or other substantial research on this subject have been conducted, which would provide an adequate scientific basis for tailoring a field collection effort to specific accident data needs.

4. Future training programs for on-site type ("level two") teams should consider including information that would explain decision theory and its implications for the different types of errors (false alarms and misses) and correct decisions (hit and misses). These should be explained within the objectives of the program so that investigators will be able to exercise influence over their criterion in evaluating the contribution of potential accident causes, whenever subjective assessments are required.

5. To the extent that the results obtained in the present analysis are valid, accident investigations at an on-site level of effort should be considered appropriate for assessing the "culpability" of drivers; but in assessing specific causes, it is recommended that either the investigator's training or evaluation criteria be changed with respect to those factors for which on-site performance was poorest (based on $d' < 1.96$ and/or hit rate = 0). These factors, labeled in the text, are 9, 14, 18, 19, 20, 21, 22, 24, 25, 34, 40, 41, 43, 45, 48, and 49.

6. Since in the process of comparing the two levels of accident investigation coding errors were found at a significant — though relatively infrequent — rate, further quality control might improve the validity of the data.

7. Further research is needed to better determine if the signal detection theory model is in fact appropriate for this type of data and application. The utilization of the SDT statistics does not necessarily imply that the accident investigator is operating as a signal detector when searching for accident causes. Some of the tests that should be conducted would involve testing of the individual "receiver operating characteristic" (ROC) curves that would indicate whether in fact the assumptions of normality and equal variance of the signal and signal plus noise distribution are warranted on an individual basis.

6.1.7 Section 9.0: Representativeness of Study Samples and Study Area

1. In this section, descriptors of Monroe County drivers, vehicles and roads were compared with available national statistics. In addition, Monroe County accident descriptors were compared with available national accident descriptors. Finally, the on-site and in-depth samples were compared with all police-reported accidents occurring in the county, and post hoc adjustments for non-uniform sampling were made to the on-site causation results.

2. The Monroe County study area — in terms of drivers, vehicles, and roadways — agreed particularly well with national data for vehicle model year, vehicle make and driver sex. It was found to differ from the nation principally with respect to driver age (younger drivers overrepresented), and road and street system mileage (proportion of municipal mileage correct, but state and U.S. highways underrepresented and county roads overrepresented). In addition, the proportion of surfaced roadways was also greater than for the nation as a whole (which is in conflict with any pre-conceived notion that the Monroe County study area is more rural or primitive than the U.S. driving environment, generally). Note, however, that causation involvement rates were found to be relatively insensitive to the non-representativeness of these variables (Volume I, Table 9-6).

3. In the comparison of reported Monroe County *accidents* to available national accident descriptors, Monroe County was found to compare particularly well as to hour of accident and type of involved vehicle, but to differ somewhat with respect to accident driver sex (women overrepresented), place of accident occurrence (rural accidents overrepresented), accident light condition (daylight overrepresented), accident type (multi-vehicle collisions

overrepresented; pedestrian, non-motor vehicle, and fixed object accidents underrepresented), road surface condition (wet roads overrepresented), accident driver age (young drivers overrepresented), and accident severity (property damage accidents overrepresented). Again, it should be noted that for each of these variables, causation involvement rates were found to be relatively insensitive to the degree of non-representativeness experienced (Volume I, Table 9-6).

4. The Phase II-V on-site sample is representative of 1972-1974 reported Monroe County accidents (i.e., does not vary to a statistically significant extent) in terms of place of occurrence (urban or rural), driver sex, and driver age. The most non-representative characteristics are light conditions (on-site sample overrepresented daylight accidents); road surface condition (overrepresented accidents which occurred on dry road surfaces); weather conditions (overrepresented clear conditions); hour of accident (overrepresented accidents occurring between noon and 3:59 p.m.); character of location (underrepresented open road, non-intersection accidents); investigation source (underrepresented non-police reported accidents — expected since only police-investigated accidents met the criteria for investigation); and arrest status (overrepresented drivers who were not arrested). Note that with the exception of investigation source, the effects of non-representativeness of each of these variables has been examined and found to be extremely insignificant in terms of overall involvement of human, vehicular, and environmental factors.

5. The Phase II-V in-depth sample was found to be representative of the 1972-1974 reported Monroe County accidents (again, in the sense of not varying to a statistically significant extent) with respect to weather conditions, character of location, road surface condition, driver license status, and driver sex. The most non-representative characteristics of the Phase II-V in-depth accidents are light conditions (in-depth sample overrepresented daylight accidents); hour of accident (overrepresented accidents occurring from noon to 3:59 p.m.); accident type (overrepresented non-collision/running off road accidents); investigation source (underrepresented accidents not investigated by police agencies — again, an artifact of the selection criteria that only police-investigated accidents were considered); and arrest status (overrepresented drivers who were not arrested). Again, these differences have been found to have only a minor or insignificant effect on the aggregate causal result percentages (Volume I, Table 9-6).

6. While the effects of nonrepresentativeness on the specific, detail level causal factors were not examined, from the data presented in Volume I, Section 3.2.3, it is evident that results regarding the involvement of alcohol-impairment as an accident cause varied as a function of the extent of coverage provided (i.e., according to whether accidents were selected from all hours of the day or only from limited periods). The overall effects of hours of coverage on alcohol-impairment are not clear (Volume I, Figure 3-5). However, for on-site team results (which are probably less influenced by selection biases arising from non-cooperation of drinking drivers), more frequent involvement was consistently recorded during 24-hour per

day coverage than during periods of limited coverage (from 11:30 a.m. to 10:30 p.m.). This would indicate a greater involvement of alcohol-impairment in late night and early morning accidents. Overall, since 24-hour per day coverage was not provided continually throughout Phases II-V, this would indicate that the aggregate results for alcohol-impairment in Phases II-V are understated.

7. Overall, considering the degree of representativeness of Monroe County and the IRPS accident samples, as well as the effects of non-uniform sampling on estimates of causal involvement, it is concluded that the study area and samples are adequate to provide reasonable and useful estimates of the relative involvement of the kinds of human, vehicular, and environmental factors assessed.

Recommendations

1. Although the relationships were not strong and the effects of non-uniform sampling on IRPS' aggregate results were quite small, the accident causation judgments were shown to be related to various accident, driver, vehicular, and environmental descriptors. This means that estimates regarding the role of the various human, vehicular, and environmental factors can be inaccurate if the samples are chosen incorrectly, or if adequate post hoc adjustments are not made.

2. With this in mind, it is recommended that when clinical assessment procedures are used in the future, samples to be chosen to minimize potential biases on these causal assessments, and that adjustments be made to the aggregate measures of involvement, in order to minimize the influence of non-representative samples. Most likely some post hoc numerical adjustments will be required, since inevitably some drivers either cannot or will not cooperate, creating the likelihood that certain situations will be improperly represented. These kinds of situations can occur when drivers are worried about future litigation, reside far from the study area, or are fatally injured. Where possible, extra effort should be exerted to assure that some of the "non-cooperatives" in fact are sampled (i.e., that there is penetration of the nonresponse groups). In addition, police reports on accidents involving uncooperative drivers should be compared to similar data collected for the volunteer drivers, in order to detect and account for any systematic bias. At a minimum, variables which have been shown to influence causation estimates should be considered when sampling procedures are developed. These are as follows:

   - Estimates of human involvement in accidents will be understated if the following are undersampled: arrested drivers; non-licensed or out-of-state drivers; urban accidents; dry or wet road surface accidents; dawn or dusk accidents; and accidents occurring between 8:00 a.m. and 7:59 p.m. Human involvement will also be understated if the following are oversampled: drivers aged 25-64; multiple vehicle accidents; and motorcycle accidents.
   - Environmental involvement will be understated if the following are undersampled: single

vehicle accidents; accidents during rainy, snowy, or foggy weather conditions; rural accidents; accidents on wet, or snow/ice covered roads; and non-intersection accidents.

- Estimates of vehicular involvement in accidents will be understated if the following are undersampled: drivers under 20 years of age; single vehicle accidents; or accidents occurring on wet road surfaces.

6.2 Volume II: Special Analyses

6.2.1 Section 2.0: Driver Attributes and Relationship to Accident Causation

6.2.1.1 Section 2.1: Driver Vision Testing

1. A Driver Vision Test (DVT) which is an integrated battery of 12 different driving-related tests, covering such visual skills as acuity for static and dynamic targets, visual field, and dynamic movement detection thresholds, was administered both to drivers who had been involved in accidents and a non-accident control group.

2. It was found that test/re-test correlations were statistically significant for most of these 12 separate tests, but were adequately high on only three tests: (1) static acuity in normal illumination; (2) static acuity in the presence of spot glare; and (3) dynamic visual acuity.

3. Given the 30 to 40 minute administration time, the DVT was found unduly time consuming for use in routine driver licensing, in its present configuration. However, investigations were made which suggest that for licensing purposes the DVT could be significantly shortened. For example, results show that all four tests of static foveal acuity correlated with each other more than with any of the other tests, and dynamic visual acuity correlated highly with most of the measures reflecting movement threshold acuity. Some of these tests may therefore be deleted.

4. Dynamic Visual Acuity (DVA) was found to be the test which best discriminated between accident at-fault drivers and a control group of non-accident drivers, once the effects of age were controlled for.

5. In another analysis, drivers who were judged to have committed accident-causing recognition errors were compared with those who had committed other errors; and with those who were involved in accidents but had committed no errors. The drivers who had committed recognition errors scored significantly poorer on the test of static acuity under low levels of illumination, than drivers who had committed no errors (20/88 vs. 20/75). Drivers who had committed "other errors" also scored more poorly than no-error drivers.

6. A separate analysis was performed examining measures hypothesized to have particular relevance to involvement in either right angle or rear-end collisions. As hypothesized, it was found that increased involvement in right angle collisions was associated with lower

sensitivity to peripheral movement in-depth. Less clearly, it appeared that involvement in rear-end collisions increased as the ability to detect angular movement in the central visual field decreased. For those with poor dynamic visual acuity — which by far was the visual ability found to be most consistently related to accidents — there was increased involvement in both right angle and rear-end collisions, with the increase in the rear-end configuration being somewhat greater.

7. Of the more reliable measures provided by the DVT in its present form, **dynamic visual acuity** appears to be the only variable which is consistently and significantly related to accident involvement. Static acuity under normal illumination — presently the only visual screening criterion in most licensing tests — was not shown to be causally-related to accidents (with the particular device and procedures used in this study). The importance of most other measures of visual performance (e.g., static acuity under low levels of illumination and peripheral movement in-depth for large targets) cannot be adequately determined before the reliability of these measures is improved.

Recommendations

1. Results suggest that the DVT is adequate for testing foveal static acuity under normal and glare conditions, but is less than satisfactory in measuring static acuity under low levels of illumination — unless a sufficient dark adaptation period is provided. The DVT does, however, yield a stable measure of dynamic visual acuity and effective visual field.
2. The present administration and scoring procedures render measures of both central and peripheral movement detection too unreliable to be useful; accordingly, improvements are required in these areas.
3. For licensing purposes, the DVT requires too much time in its present configuration, and the equipment is excessively bulky as compared to devices presently in use. It is recommended that improvements can be made in both respects by retaining only tests found to be definitely related to driving ability, and which are independent of each other. The factor analysis and various validity analyses suggest that two candidate tests for a reduced battery are: (1) foveal static acuity (under low level illumination), and (2) dynamic visual acuity.
4. Before such recommendations are implemented, the unreliable tests must be improved. This is necessary before any definite conclusions about relevance to driving ability and accident avoidance can be reached. The pattern of results suggests that such improvements can be achieved by increasing the mechanical reliability of the DVT on one hand, and the objectivity of the scoring procedures on the other. Such methodological improvements in a modified and improved version of the DVT are currently being pursued under another NHTSA-sponsored contract.

6.2.1.2 Section 2.2: Driver Knowledge Testing

1. An analysis was undertaken to determine the usefulness of a particular driver knowledge test as an indicant of accident involvement or type of driving error. A 20-question driving knowledge test was constructed from a large pool of multiple choice items provided by NHTSA, along with nine supplementary questions provided by IRPS. The questionnaire was administered to 178 drivers from an accident group and 133 drivers from a control group.

2. Driver knowledge test scores varied significantly as a function of age. Drivers under 20 years of age scored relatively low. Drivers 20 to 34 scored the highest, but with a deterioration of scores beginning at age 35 and continuing, such that drivers 65 years of age and over scored the lowest.

3. Of the 20 questions, males performed significantly better on four questions, and marginally better on an additional two. Females performed marginally better on one of the questions. In terms of total test score, males scored significantly higher. The questions best answered by males appeared to concentrate on handling in emergencies and mechanical considerations, rather than on general driving style or laws.

4. As might have been expected, those who had received formal driver training scored significantly better than those who had not. The questions best answered by those who had had driver training emphasized general driving style and laws rather than emergency handling or mechanics.

5. In a separate analysis, a comparison was made among the test scores of those judged at fault in accidents, those involved but not-at-fault, and a control group of non-accident drivers; no statistically significant differences were identified for any of the individual questions, or for total driver knowledge test score. Consequently, this analysis provides no support for the idea that driver knowledge (as measured by this test) is related to accident involvement. One problem with this evaluation, however, was that in the time which elapsed between the accident and the knowledge test, drivers committing certain errors may have learned through discussions of the accident with friends, parents, their insurance company, etc.

6. In yet another analysis, relationships were examined between particular questions and the incidence of accident-causing behaviors or problems which were hypothesized as being possibly related to them. Again, no statistically significant relationships were identified.

Recommendations

1. Despite the discouraging results obtained here, it is highly unlikely that all aspects of driving performance are unrelated to the content areas and driving skill requirements which have been previously identified. Apparently, when driving performance is measured by accident involvement, other skills and knowledge than that measured by this knowledge test is

relevant. In the future, more specific and relevant definitions of driver knowledge should be tested.

2. Accordingly, one recommendation is that driver knowledge should be tested in the behavioral areas that have been determined to be the major causes of accidents, and that this testing should take place immediately following the accident — before any additional learning takes place. Questions that assess proper visual surveillance techniques, awareness of the risk of inattention, proper evasive maneuvers, etc., are possibly more directly relevant to accident avoidance than questions dealing with maintenance, driving style, or knowledge of traffic regulations.

3. In addition, driver knowledge of accident avoidance maneuvers should be tested under temporal stress. The drivers frequently reported that they "knew" that they had performed an inappropriate avoidance maneuver, but in the limited time available had responded "instinctively." When taking the knowledge test, these drivers often answered related questions appropriately. Hence the need to measure both whether drivers know the right answer, and how much time is needed to reach the correct decision. Perhaps testing could be conducted in an active simulation environment, in which the driver is required to actually perform the appropriate motor response.

6.2.1.3 Section 2.3: Methodology Development—New Driver Measures

1. This section built on previous research aimed at ascertaining distinguishable characteristics of the overinvolved or "problem driver." Driver characteristics and traits (independent variables) such as prior record, alcohol/drug usage, social adjustment, personal adjustment, and impulse control were examined in terms of their relationship to various on-road behaviors (dependent variables) characteristic of risk-taking, poor decision making, and poor perceptual-motor skill.

2. In a preliminary study, a group of young accident repeaters was compared with a matched group of non-accident drivers, in terms of alcohol/drug use, personal adjustment, social adjustment, impulsivity and clerical ability. The high-accident group scored reliably higher on measures of alcohol/drug use, and on one or more measures of personal maladjustment, social maladjustment, impulsivity, and clerical speed/accuracy. The discriminant function was able to correctly assign 42 of the 46 matched subjects (i.e., over 90%).

3. In a second validation study comparing new groups of high and non-accident young drivers, the discriminant function from the original study correctly assigned 12 of 14 matched subjects (i.e., over 85%). This study substantiated the validity of these measures of social and personal adjustment, at least for the type of young licensed drivers studied.

4. Results of the original and validation studies were combined and further analyzed,

providing a total N of 60 licensed college freshmen, ages 18 and 19. Results from these analyses are consistent with the idea that personal maladjustment (i.e., problems with one's self) and social maladjustment (i.e., problems with society) are related to accident involvement. To a lesser extent cognitive abilities (e.g., clerical abilities) and impulsivity are also related to accidents.

5. In a separate analysis, a comparison was made between drivers judged to have committed an error and those who were error-free. It was found that drivers who had committed errors tended to score higher in both personal and social maladjustment (i.e., were more maladjusted). In a subsequent analysis, scores were compared among drivers who had committed a recognition error, a non-recognition error, or were error-free. Marginally reliable differences were obtained, with the no-error group scoring best on personal and social adjustment, while the "other-error" group scored worse than the recognition error group. Thus, the scales tested were not able to predict type of error, but did appear related to accident causation.

6. A subsequent analysis was performed to better determine the relationship of these "driver profile scores" to specific types of driving errors. This analysis showed that:

   - Drivers who were cited for any causative human factor, especially a human condition/state, alcohol-impairment, or inattention, were more personally maladjusted than the no-error controls. One hypothesis is that personal problems may preoccupy or distract the driver.

   - Drivers committing almost any error, especially recognition and decision errors (and possibly those cited for alcohol-impairment), were more anti-social than controls. Possibly socially maladjusted drivers may make a conscious decision to drive more recklessly.

   - Drivers cited for causally-relevant alcohol-impairment tended to lack impulse control. These three sets of findings suggest that personal maladjustment, social maladjustment and lack of impulse control may all be factors underlying accident involvement by reason of alcohol impairment. Further research is needed to clarify this point.

Recommendations

1. Results are highly encouraging for the idea that high accident drivers differ from no accident drivers, as a group, and are promising in their support of several theoretical notions concerning the differences. This is true despite the last three of these related studies being based on information which had been previously collected in the course of in-depth (Level C) investigations. (Existing questions on the in-depth human factors form were used to form ad-hoc scales for measures such as personal and social maladjustment). This leads to the recommendation that the five-step sequence as proposed in the text be pursued.

2. A recommended next step would be initiation of a prospective study in which an entire battery of questions specifically designed around these scales are given to a stratified, representative sample of the general driving population, for comparison with data on their previous crashes and violations. The fifth and concluding step would involve a major study in which the entire revised battery is administered to a representative sample of accident-involved drivers, in order to examine in detail the extent to which different types of accident causing behaviors are related to different basic human traits. A follow-up study would then monitor driver records for a future period to determine the predictive validity of the measures used.

6.2.1.4 Section 2.4: Driver Characteristics and Culpability

1. In this section, accident-involved drivers which IRPS investigators assessed as having committed errors (i.e., "culpable drivers"), were compared with non-culpable accident drivers in terms of their age, sex, driving experience, vehicle familiarity, annual mileage, and road/area familiarity.

2. Based on this analysis, it was found that for both men and women, culpable drivers had significantly less road/area familiarity than did non-culpable drivers.

3. Non-culpable men, in addition to having significantly more road/area familiarity, were characterized as having more familiarity with their vehicles than would be expected for their age, and as being between the ages of 35-54. Culpable men were characterized as having little road/area familiarity, having less familiarity with their vehicles than would be expected for their age, and as being either young (15 to 19) or old (over 64).

4. In addition to having significantly more road/area familiarity, non-culpable female drivers were characterized as having more driving experience than would be expected for their age, and as being either over 54 or between 35 and 44 years of age. Culpable female drivers were characterized as having little road/area familiarity, an intermediate (moderate) level of driving experience for their age, and as being either under 25 or between the ages of 45 and 54.

Recommendations

This analysis has been conducted in such a manner that differences between drivers arising out of relatively uncontrollable risks (such as annual miles traveled by the different groups) have been controlled for, so that the differences which remain can be assumed to be accounted for primarily by "unsafe driving practices." It is therefore recommended that drivers be provided with information sufficient to let them know if and when they are falling into one of these unsafe, "high culpability" groups or situations, and that further research be conducted to determine exactly what kinds of driving behaviors or practices are involved, leading to the increased risk.[4]

6.2.2 *Section 3.0: Special Analyses: Human, Vehicular, and Environmental Characteristics in Accident Causation*

6.2.2.1 *Section 3.1: Cluster Analysis*

1. In this section, information regarding a sample of 353 of the drivers/vehicle units involved in accidents investigated in-depth (Phases II-V), were used as inputs to a cluster analysis. In this manner, the *drivers which were most similar on the basis of causation variables were* grouped together, and differences between groups in terms of other variables (such as driver knowledge, vision, and personal adjustment), were measured.

2. Results of the cluster analysis of the causal hierarchy indicate that the investigators used the hierarchy consistently, in that there were clear groupings or clusters of drivers/vehicles. These "natural" groupings tended to set apart drivers in terms of whether they had made decision errors, recognition errors, or were "not-at-fault," and in terms of whether environmental factors or human conditions and states had been assigned as causally-relevant to them. This pattern is consistent with the causal factor hierarchy. While the initial groupings were produced using 353 drivers from the in-depth file, in 14 separate random samplings of 200 driver/vehicle units from the on-site file, a similar cluster structure consistently emerged (up to and including the five-cluster level).

3. Comparisons were made between a number of the clusters, in order to measure differences on additional descriptors which had not been used in the formation of the clusters. For example, the members of the largest cluster (n = 133), none of whom had committed any assignable error, were compared with combined members of the seven remaining at-fault clusters. Significant differences were identified for nine of the 29 variables compared; for example, members of the not-at-fault cluster scored significantly better in terms of both dynamic visual acuity and social adjustment. Differences were not significant with respect to driver knowledge test score, reaction time, socio-economic status, personal adjustment, alcohol usage, prior driving record, or age. On the other hand (as might be expected from the discussion on the confounding of age and vision in Section 2.1 of Volume II), the not-at-fault drivers scored more poorly on static acuity and, unexpectedly, on impulse control.

4. This and other inter-cluster comparisons demonstrated that the grouping of drivers into such clusters was informative in terms of additional driver attributes not used in the process of deriving the clusters.

---

[4] Further analyses have been conducted regarding types of unsafe driving practices associated with these driver groups, as a part of the "Tri-Level Study of the Causes of Traffic Accidents," Modification for Special Data Analyses, Task 4."

6.2.2.2 *Section 3.2: AID Analysis*

1. In the automatic interaction detector (AID) analysis, the absence or presence of a variety of causal factors was the dependent variable, and the independent variables were 10 selected driver demographic and environmental characteristics.

2. Based on the AID analysis, road/area familiarity emerged as an extremely important variable; the human factors summary, a variable that indicates whether or not a particular driver was identified as having committed *any* attributable error, split first on the road familiarity descriptor, indicating that this was the most important descriptor in differentiating drivers who made errors from those who did not. One or more human causal factors was assigned for 69% of those who were unfamiliar with the road (i.e., drove it less than once per week), but for only 53% of those who drove the road once per week or more frequently.

3. The most frequently implicated human causal factors in the IRPS hierarchy were divided between either of two broad categories — recognition errors or decision errors. With *recognition errors* as the dependent variable, the sole split occurred (as for the human factors summary) on the road familiarity variable, with drivers who were more familiar with the road being less likely to have committed a recognition error. With *decision errors* as the dependent variable, however, an entirely different split occurred based on traffic volume at the time of the accident; decision errors were cited for 36% of the drivers who had accidents in "light traffic," but for only 27% in moderate or heavy traffic. However, as one might expect, decision errors were cited more frequently among drivers who were unfamiliar with the road. In addition, drivers between the ages of 25 and 64 were much less likely to be cited for decision errors than either young drivers or drivers 64 and over. Since the "excessive speed" category comprises a large proportion of all factors occurring under the decision errors heading, the rationale for the excessive speed split in large measure explains the decision error split (see below).

4. For the most frequently-implicated causal factor — improper lookout — road familiarity and driver age were close competitors to split the overall sample, with road familiarity actually producing the split. Drivers who were unfamiliar with the road, or who were 65 years of age or older, were substantially more likely than other drivers to have committed an improper lookout error.

5. For the second-ranking causal factor — excessive speed — the initial split occurred for traffic volume (as it did for the decision errors category of which it is the largest component), with excessive speed being cited for slightly under 5% of drivers in moderate or heavy traffic, but for nearly 14% of drivers in light traffic. This result could have been anticipated, since it is consistent with conditions which provide an opportunity to speed. In addition, young drivers were found nearly three times as likely as drivers 20 or older to be cited for excessive speed; males were twice as likely as females; less experienced drivers

(those with two years or less driving experience) were roughly two and one-half times as likely as more experienced drivers; and those who were relatively unfamiliar with their vehicle were roughly twice as likely as those who were more familiar.

6. For vehicular causal factors overall, the possible initial splits were pavement condition (dry, wet, snow, slush, or ice covered), precipitation intensity, driver age, and driving experience, with the split actually occurring for pavement condition; vehicular factors were cited as causes in 8.0% of accidents occurring on "wet" pavement, compared to 3.5% in accidents occuring on "dry, icy, or snowy" pavement. The high identification rates for wet pavement and precipitation are consistent with the fact that a majority of the vehicular factors were related to either tires or brakes — problems which would be greatly intensified by environmental factors that might increase stopping distances or reduce traction laterally.

Recommendations

1. Low road familiarity appeared related to the commission of a broad range of human causal errors, and further research is warranted to better identify reasons for this problem, as well as ways to alleviate it. For example, it might be possible to identify discrete components of familiarity in perceptual and behavioral terms, leading to design of training programs which would teach drivers to learn more rapidly the relevant information from a new road. Equally, new signing and/or roadway design requirements might be desirable, to better "cue" drivers as to roadway alignment changes and related needs for speed adjustment. Other aspects of the problem may lie in either program management or funding. For example, it may be that an adequate system to identify locations needing warning signs, and to periodically check these locations and perform needed replacement or maintenance, has not been provided. In other cases, the need may be known, but funds may not be adequate to provide such signing.

2. Even with 2,433 accident driver/vehicle combinations (with no missing data) available from the IRPS on-site investigation level for this analysis, the decomposition of the sample into subparts quickly produced relatively small groups of interest that could not be adequately studied or further decomposed due to their small size. It is therefore important that future national data collection efforts incorporate an easily and consistently applied "causal assessment" scheme to aggregate additional cases and thereby increase the ability of researchers to analyze relatively large subgroups of these categories.

6.2.3 Section 4.0: Motorcycle Accidents and Causes

1. In this section, three separate analyses were conducted: (1) an assessment of differences between accidents involving motorcycles and those involving other types of vehicles; (2) a

comparison of the 52 motorcycle accidents investigated by IRPS as a part of the "Tri-Level Study" with those reported state-wide by the Indiana State Police in 1973; and (3) an analysis of the 52 accidents investigated by IRPS in terms of causes assessed for both the motorcycles and the other involved vehicles.

2. As compared to reported accidents involving other types of vehicles, motorcycle accidents were more frequently single vehicle, rural, and non-intersection; occurred more frequently during the warmer months and on weekends; were more likely to occur during the afternoon or evening (rather than in the morning or early morning hours); more frequently occurred on dry road surfaces; and were more frequently injury-producing. The accident-involved motorcyclists were younger than drivers of other accident-involved vehicles, and were more frequently male. However, there was no recorded difference between motorcyclists and other accident-involved drivers with respect to the (police-recorded) presence of alcohol.

3. The 52 motorcycle accidents investigated by IRPS during the five yearly study phases were representative of all 1973 Indiana State Police-reported motorcycle accidents with respect to accident configuration, severity, place of occurrence, month, day of week, time of day, road surface condition, and light conditions. IRPS accident-involved motorcyclists were representative with respect to sex and presence of alcohol, but overrepresented the 20-34 year age group, and underrepresented motorcyclists less than 20.

4. Primary causes assessed for the 52 motorcyclists were human decision errors and environmental factors. The most frequent decision error was excessive speed, followed by false assumption and improper driving technique. The most frequent environmental factors for motorcyclists were view obstructions (e.g., hillcrests and sags), followed by slick roads and special hazards (primarily non-contact vehicles).

5. Other motorists in motorcycle accidents (i.e., drivers of other vehicles which collided with motorcycles), were most frequently assigned recognition errors (i.e., failure to recognize an oncoming motorcycle), decision errors, and environmental factors. Many recognition errors occurred when entering a travel lane from an intersecting street or alley. These involved inattention to other traffic, improper lookout, and "other delays in perception." Another frequent recognition error was internal distraction (e.g., conversation with a passenger). The most prevalent decision error was improper maneuver (e.g., turn from wrong lane), while view obstructions (e.g., other parked vehicles), were the most frequent environmental causes.

6. As compared to all other accident-involved drivers, motorcyclists in the IRPS sample were less frequently cited for human errors, made significantly fewer recognition errors, and had fewer accident-causing vehicle malfunctions.

7. On the other hand, as compared to accident-involved drivers generally, the drivers of

vehicles striking motorcycles in the IRPS sample were more frequently culpable, made significantly more recognition errors, made significantly fewer decision errors, and were less likely to be affected by adverse physiological/psychological states (e.g., alcohol impairment was less frequently involved than for accident-involved drivers generally).

8. In summary, a major problem is that other motorists often fail to see oncoming motorcyclists, particularly at intersections. The striking "other vehicle" driver is less likely to be involved by reason of alcohol-impairment than are accident drivers generally, while for motorcyclists it appears that alcohol involvement is neither more nor less frequent than for accident drivers generally.

Recommendations

Obviously a much larger data base than the 52 motorcycle accidents examined by IRPS would be required to confidently list the related problems and to provide adequate guidance to such countermeasures as driver education, vehicle inspection, or vehicle design. However, these results can be used to help inform motorcyclists of the danger that other drivers will fail to see them, and to underscore the importance of keeping the headlight on, wearing highly visible clothing, and decreasing speed at intersections.

VOLUME II: REFERENCES

Section 1.0

1. Joscelyn, K.B., and J.R. Treat, "Results of a Study to Determine the Relationship Between Vehicle Defects and Crashes." Vols. I and II, Final Report, Institute for Research in Public Safety, Indiana University School of Public and Environmental Affairs, prepared under Contract No. DOT-HS-034-2-263, NHTSA (DOT Report Nos. DOT-HS-800-850 and 851; NTIS PB-221 976/4 and PB-221 977/2), November 1, 1972.
2. Institute for Research in Public Safety, "Tri-Level Study of the Causes of Traffic Accidents: Interim Report I, Vols. I (Research Findings) and II (Appendices)," Institute for Research in Public Safety, Indiana University School of Public and Environmental Affairs, prepared under Contract No. DOT-HS-034-3-535, NHTSA (DOT Report Nos. DOT-HS-801-334 and 335; NTIS PB-239 828/7G1 and PB-240 547/0G1), August 31, 1973.
3. Institute for Research in Public Safety, "Tri-Level Study of the Causes of Traffic Accidents: Interim Report II, Vols. I (Causal Factor Tabulations and Trends) and II (Final Report on the Potential Benefits of Radar Warning, Radar Actuated and Anti-Lock Braking Systems in Preventing Accidents and Reducing Their Severity), prepared by the Institute for Research in Public Safety, Indiana University School of Public and Environmental Affairs, under Contract No. DOT-HS-034-3-535, for the NHTSA (DOT Report Nos. DOT-HS-801-968 and 631; NTIS PB-257 473/9WT and PB-247 091/2WT), December 31, 1974.
4. Joscelyn, K.B., and J.R. Treat, "Interim Report of a Study to Determine the Relationship Between Vehicle Defects and Crashes: Methodology." Interim Report, prepared by the Indiana University Institute for Research in Public Safety under Contract No. DOT-HS-034-2-263, for the NHTSA (DOT Report No. DOT-HS-800-661), November 1, 1971.

Section 2.0

Section 2.1

1. Allen, M. J. *Vision and Highway Safety.* Philadelphia: Chilton Book Co., 1970.
2. Babrik, P. "Automobile Accidents and Driver Reaction Pattern." *Journal of Applied Psychology* 52 (1968):49-54.
3. Burg, A. "An Investigation of Some Relationships Between Dynamic Vision Acuity, Static Visual Acuity, and Driving Record." UCLA Department of Engineering, Report No. 64-18, April, 1964.
4. Burg, A. "The Relationship Between Vision Test Scores and Driving Record: General Findings." UCLA Department of Engineering, Report No. 67-24, June, 1967.
5. Burg, A. "Vision Test Scores and Driving Record: Additional Findings." UCLA Department of Engineering, Report No. 68-27, December, 1968.
6. Cornsweet, T.N. *Visual Perception.* New York: Wiley, 1970.

7. Fergenson, P.E. "The Relationship Between Information Processing, Driving Accidents, and Violation Record." *Human Factors* 13(1971):173-76.

8. Goldstein, L. A. *Research on Human Variables in Safe Motor Vehicle Operation: A Correlational Study of Predictor Variables and Criterion Measures.* Washington, D.C.: George Washington University, 1961.

9. Hartmann, E. *Driver Vision Requirements: 1970 International Automobile Safety Conference Compendium.* New York: SAE, Inc., 1970.

10. Henderson, R. L. and Burg, A. "The Role of Vision and Audition in Truck and Bus Driving." Final Report No. DOT-FH-11-7923, Systems Development Corporation, Santa Monica, California, December, 1973.

11. Henderson, R. L. and Burg, A. "Vision and Audition in Driving." Final Report No. DOT-HS-009-1-009, Systems Development Corporation, Santa Monica, California, April, 1974.

12. Herano, R. M. "Relationship of Field Dependence and Motor Vehicle Accident Involvement." *Perceptual and Motor Skills* 31(1970):272.

13. McKnight, A. J. and Adams, B. B. *Driver Education Task Analysis.* Vol. I. *Task Descriptions.* Alexandria, Virginia: Human Resources Research Organization, 1970.

14. Mourant, R. R. and Rockwell, T. H. "Strategies of Visual Search by Novice and Experienced Drivers." *Human Factors* 14(1972):325-35.

15. Rockwell, T. H. "Skills, Judgment and Information Acquisition. In T. W. Forbes (Ed.) *Human Factors in Highway Traffic Safety Research.* New York: Wiley, 1972.

Section 2.2

1. Highway Safety Research Institute, "Development of a National Item Bank for Tests of Driving Knowledge." Prepared under Contract No. FH-11-7616, NHTSA, February, 1972.

2. McKnight, A. J., and Adams, B. B., *Driver Education Task Analysis.* Vol. I. *Task Descriptions.* Alexandria, Virginia: Human Resources Research Organization, 1970.

Section 2.3

1. Adams, J. R. "Psychosocial Factors and Accidents in the Highway Transportation System." In T. W. Forbes (Ed.), *Human Factors in Highway Traffic Safety Research.* New York: Wiley, 1972. Pp. 331-47.

2. Asher, W. and Dodson, B. The Prediction of Automobile Accidents Following the Senior Year in High School. *Behavioral Research in Highway Safety* 1(1970):180-95.

3. Baker, S. P. "Characteristics of Fatally Injured Drivers." NHTSA Technical Report, prepared under Contract FH-11-7092 by Johns Hopkins University, for NHTSA, 1970.

4. Barmack, J. E. and Payne, D. E. "Injury Producing Private Motor Vehicle Accidents among Airmen." *Highway Research Board Bulletin,* No. 285, 1961.

5. Beamish, J. J. and Malfetti, J. L. "A Psychological Comparison of Violator and Non-violator Automobile Drivers in the 16-19 Year Age Group." *Traffic Safety Research Review* 6(1962):12-15.

6. Brezina, E. H. "Traffic Accidents and Offenses: An Observational Study of the Ontario Driving Population." *Accident Analysis and Prevention* 1(1969):373-95.

7. Burg, A. "Characteristics of Drivers." In T. W. Forbes (Ed.) *Human Factors in Highway Traffic Safety Research*. New York: Wiley, 1972.

8. Brody, L. *Personal Characteristics of Chronic Violators and Accident Repeaters*. New York: New York University Center for Safety Education, 1957.

9. Brown, P. L. and Berdie, R. F. "Driver Behavior and Scores on the MMPI." *Journal of Applied Psychology* 51(1967):96-100.

10. Brown, S. L. and Bohert, P. J. *Alcohol Safety Study: Drivers Who Die*. Houston, TX: Baylor University College of Medicine, 1968.

11. Carlson, W. L. and Klein, D. "Familial vs. Institutional Socialization of the Young Traffic Offender." *Journal of Safety Research* 2(1970):13-25.

12. Cobb, P. W. *Automobile Driver Tests Administered to 3663 Persons in Connecticut, 1936-37, and the Relation of the Test Scores to Accidents Sustained*. Washington, DC: Highway Research Board Report, 1939.

13. Conger, J. J., Gaskill, H. S., Glad, D. D., Rainey, R. V., Sawrey, W. L., and Turrell, E. S. "Personal and Interpersonal Factors in Motor Vehicle Accidents." *American Journal of Psychiatry* 113(1957):1069-74.

14. Conger, J. J., Gaskill, H. S., Glad, D. D., Hassill, L., Rainey, R. V., and Sawrey, W. L. "Psychological and Psychophysical Factors in Motor Vehicle Accidents." *Journal of the American Medical Association* 169(1959):1581-87.

15. Coppin, R. S. *The 1964 California Driver Record Study, Part 5 — Driver Record by Age, Sex and Marital Status*. Sacramento, California: California Department of Motor Vehicles, 1965.

16. Choppin, R. S. and VanOldenbeek, G. *The Fatal Accident Re-Examination Program in California*. Sacramento, CA: California Department of Motor Vehicles, 1966.

17. Coppin, R. S., McBride, R. S., and Peck, R. C. *The 1964 California Driver Record Study, Part 9 — Prediction of Accident Involvement from Driver Record and Biographical Data*. Sacramento, CA: California Department of Motor Vehicles, 1967.

18. Crancer, A. *Involvement of the Problem Driver in Fatal Motor Vehicle Accidents, Report 2*. Olympia, WA: Washington Department of Motor Vehicles, 1967.

19. Crancer, A. and McMurray, L. *Accident and Violation Rates of Washington Drivers with Medical Licensing and Driving Restrictions. Report 7*. Olympia, WA: Washington Department of Motor Vehicles, 1967.

20. ______________. *Credit Ratings as a Predicter of Driving Behavior and Improvement, Report 10*. Olympia, WA: Washington Department of Motor Vehicles, 1968.

21. Crancer, A. and Quiring, D. L. *Driving Records of Persons Hospitalized for Suicide Gestures, Report 12*. Olympia, WA: Department of Motor Vehicles, 1968a.

22. ____________. *Driving Records of Persons with Selected Chronic Diseases, Report 15.* Olympia, WA: Washington Department of Motor Vehicles, 1968b.

23. Crancer, A. and O'Neal, P. A. *Record Analysis of Drivers with License Restrictions for Heart Disease, Report 25.* Olympia, WA: Washington Department of Motor Vehicles, 1969.

24. Cresswell, W. L. and Froggatt, P. *The Causation of Bus Driver Accidents: An Epidemological Study.* London: Oxford University Press, 1963.

25. Dennis, W. "Differential Social Characteristics of Convicted Automobile Drivers." In A. P. Weiss and A. R. Lauer (Eds.) *Psychological Principles in Automobile Driving.* Columbus, OH: Ohio State University, Contributions in Psychology No. 11, 1939.

26. ENO Foundation for Highway Traffic Control, *Personal Characteristics of Traffic Accident Repeaters.* Saugatuck, CT: ENO Foundation, 1948.

27. Farmer, E. and Chambers, E. G. *A Study of Accident Proneness Among Motor Drivers.* London: Industrial Health Research Board, No. 84, 1939.

28. Ferdon, G. C., Peck, R. C. and Coppin, R. S. "The Teen-Aged Driver: An Evaluation of Age, Experience and Driver Training as They Relate to Driving Record." In *Highway Research Record* No. 163. Washington, DC: National Academy of Sciences, Highway Research Board, 1967.

29. Finch, J. R. and Smith, J. P. *Psychiatric and Legal Aspects of Automobile Fatalities.* Springfield, IL: Thomas, 1970.

30. Fischer, R. S. "Multidisciplinary Accident Investigation." Washington, DC: Department of Transportation, NHTSA, Report DOT-HS-800-692, 1972.

31. Froggatt, P. and Smiley, J. A. "The Concept of Accident Proneness: A Review." *British Journal of Industrial Medicine* 12(1964):1-12.

32. Goldstein, L. G. *Research on Human Variables in Safe Motor Vehicle Operation: A Correlational Summary of Predictor Variables and Criteria Measures.* Washington, DC: George Washington University, 1961.

33. Goldstein, L. G. "Human Variables in Traffic Accidents: A Digest of Research and Selected Bibliography." *Highway Research Board, Bibliography No. 31.* Washington, DC: National Academy of Sciences, National Research Council, 1962.

34. Goldstein, L. G. "Youthful Drivers as a Special Safety Problem." *Accident Analysis and Prevention* 4(1972):153-89.

35. Goldstein, L. G. and Mosel, J. A. "A Factor Study of Drivers Attitudes with Further Study of Aggression." *Highway Research Board Bulletin No. 1972,* 1956.

36. Haner, C. F. "Use of Psychological Inventories for Youthful Male Drivers." *Traffic Safety Research Review* 7(1963):5-9.

37. Harrington, D. M. and McBride, R. S. "Traffic Violation by Type, Age, Sex and Marital Status." *Accident Analysis and Prevention* 2(1970):67-79.

38. Harrington, D. M. "The Young Driver Follow-Up Study: An Evaluation of the Role of Human Factors in the First Four Years of Driving." *Accident Analysis and Prevention* 4(1972):191-240.

39. Heath, E. D. "Relation Between Driving Record, Selected Personality Characteristics and Biographical Data on Traffic Offenders and Non-Offenders." *Highway Research Board Bulletin No. 212,* 1959.

40. Henderson, R. L., Burg, A. and Brazelton, F. A. "Development of an Integrated Vision Testing Device: Phase I, Final Report." Santa Monica, CA: System Development Corporation, Report No. TM(L) — 4848/0000/00, 1971.

41. Henderson, R. L. and Burg, A. "The Role of Vision and Audition in Truck and Bus Driving." Santa Monica, CA: System Development Corporation, Report No. TM(L) — 5260/0000/00, 1973.

42. Hertz, D. "Personality Factors in Automobile Accidents." *Harefuah* 79(1970):165-67.

43. Institute for Research in Public Safety, "Tri-Level Study of the Causes of Traffic Accidents: Interim Report I, Volume I, Research Findings." Institute for Research in Public Safety, Indiana University School of Public and Environmental Affairs, prepared under Contract No. DOT-HS-034-3-535, NHTSA (DOT Report No. DOT-HS-801-334; NTIS PB-239 828/7GI), August 31, 1973.

44. Kaester, N. F. "The Similarity of Traffic Involvement Records of Young Drivers and Drivers in Fatal Traffic Accidents." *Traffic Safety Research Review* 8(1964):34-39.

45. Kenel, F. "The Effectiveness of the Mann Inventory in Classifying Young Drivers into Behavioral Categories and its Relationship to Subsequent Driver Performance." Unpublished Ph.D. dissertation, Michigan State University, 1967.

46. Klein, D. "Some Social Characteristics of Accident Victims." *Traffic Safety* 74(April 1974):9-10, 34-36.

47. Kraus, A. S., Steele, R., Ghent, W. R. and Thompson, M. G. "Pre-Driving Identification of Young Drivers with a High Risk of Accidents." *Journal of Safety Research* 2(1970):55-56.

48. Leveonian, E. "Personality Characteristics of Juvenile Driving Violators." *Accident Analysis and Prevention* 1(1969):9-16.

49. MacDonald, J. M. "Suicide and Homicide by Automobile." *American Journal of Psychiatry* 121(1964):336-70.

50. McFarland, R. A., Moore, R. C. and Warren, A. B. *Human Variables in Motor Vehicle Accidents — A Review of the Literature.* Cambridge, MA: Harvard School of Public Health, 1955.

51. McFarland, R. A. and Moseley, A. L. *Human Factors in Highway Transport Safety.* Cambridge, MA: Harvard School of Public Health, 1954.

52. McFarland, R. A. and Moore, R. C. "Youth and the Automobile." In E. Ginzberg (Ed.) *Values and Ideals of American Youth.* New York: Columbia University Press, 1960.

53. McFarland, R. A. "Psychological and Behavioral Aspects of Automobile Accidents." *Traffic Safety Research Review,* 12(1968):71-80.

54. McFarland, R. A., Domey, R. G., Dugger, B. C., Crowley, T. J. and Stoudt, H. W. *An Evaluation of the Ability of Amputees to Operate Highway Transport Equipment.* Boston, MA: Harvard School of Public Health, 1968.

55. McGuire, F. L. "The Safe Driver Inventory: A Test for Use in the Selection of the Safe Automobile Driver." *United States Armed Forces Medical Journal* 6(1956a):1249-64.

56. ______________. "Psychological Comparison of Automobile Drivers: Accident and Violation-Free Versus Accident-Violation Incurring Drivers." *United States Armed Forces Medical Journal* 7(1956b):1741-48.

57. McMurray, L. *Emotional Stress and Driving Performance: The Effect of Divorce, Report 16.* Olympia, WA: Washington Department of Motor Vehicles, 1968.

58. Miller, L. and Dimling, J. A. *Driver Licensing and Performance: Volume I. Report 224.* Lexington, KY: Spindletop Research, 1969.

59. Munsch, G. "The Predisposition for Accidents Among Motor Vehicle Drivers in Younger Age Groups." Paper presented to Second Congress of International Association for Accident and Traffic Medicine. Stockholm, 1966.

60. O'Leary, P. "An Assessment of the Effectiveness of the Mann Attitude Inventory as a Predictor of Future Driving Behavior." Unpublished Ph.D. dissertation. Michigan State University, 1967.

61. Paykel, E. S. "Life Changes and Depression." *Archives of General Psychiatry* 21(1969):753-60.

62. Pelz, D. C. and Schuman, S. H. *Dangerous Young Drivers, Report 2.* Ann Arbor, MI: Highway Safety Research Institute, University of Michigan, 1968.

63. ______________. "Motivational Factors in Crashes and Violations of Young Drivers." Paper presented at meeting of American Public Health Association, Minneapolis, 1971.

64. Quenault, S. W. *Driver Behavior — Safe and Unsafe Drivers, Report LR70.* Crowthorne, England: Ministry of Transport, 1967.

65. Rainey, R. F., Conger, J. J., Gaskill, H. S., Glad, O. D., Sawrey, W. L., Turrill, E. S., Walsmith, C. R. and Keller, L. "An Investigation of the Role of Psychological Factors in Motor Vehicle Accidents." *Highway Research Board Bulletin No. 212,* 1959.

66. Rommel, R. C. S. "Personality Characteristics and Attitudes of Youthful Accident-Repeating Drivers." *Traffic Safety Research Review* 3(1959):13-14.

67. Schmidt, C. W., Perlin, S., Townes, W., Fisher, R. S., and Shaffer, J. W. "Characteristics of Drivers Involved in Single-Car Accidents." *Archives of General Psychiatry* 27(1972):800-03.

68. Schuster, D. H. and Guilford, J. P. "The Psychometric Prediction of Problem Driving." *Human Factors* 6(1964):393-421.

69. Schuster, D. H. "Prediction of Follow-Up Driving Accidents and Violations." *Traffic Safety Research Review.* 12(1968):17-21.

70. Selzer, M. L. and Payne, C. E. "Automobile Accidents, Suicide, and Unconscious Motivation." *American Journal of Psychiatry* 119(1962):237-40.

71. Selzer, M. L. Rogers, J. E. and Kern, S. "Fatal Accidents: The Role of Psychopathology, Social Stress, and Acute Disturbance." *American Journal of Psychiatry* 124(1968):46-54.

72. Selzer, M. L. and Vinokur, A. "Detecting the High Risk Driver: The Development of a High Risk Questionnaire." US-DOT-NHTSA Report No. DOT-HS-801-099, 1974.

73. Shaffer, J. W. Perlin, S., Schmidt, C. W., Himelfarb, M. "Assessment in Absentia: New Directions in the Psychological Autopsy." *The Johns Hopkins Medical Journal* 130(1972):308-16.

74. Shaffer, J. W., Towns, W., Schmidt, C. W., Fisher, R. S., and Zlotowitz, H. I. "Social Adjustment Profiles of Fatally Injured Drivers." *Archives of General Psychiatry* 30(1974):508-11.

75. Schuman, S. H., Pelz, D. C., Ehrlich, N. J. and Selzer, M. L. "Young Male Drivers, Impulse Expression, Accidents and Violations." *Journal of the American Medical Association* 200(1967):1026-30.

76. Shaw, L. and Sichel, H. S. *Accident Proneness*. Oxford, England: Pergamon Press, 1971.

77. Sterling-Smith, R. S. and Fell, J. C. "A Human Factors Analysis of Most Responsible Drivers in Fatal Accidents." Paper presented at the 17th Annual Conference of the American Association for Automotive Medicine, Oklahoma City, OK, 1973.

78. Solomon, D. *Accidents on Main Rural Highways Related to Speed, Driver and Vehicle*. Washington, DC: US Government Printing Office, 1964.

79. Tillman, W. A. and Hobbes, G. E. "The Accident-Prone Automobile Driver." *American Journal of Psychiatry* 106(1949):321-31.

80. Waller, J. A. and Goo, J. T. "Highway Crashes and Citation Patterns and Chronic Medical Conditions." *Journal of Safety Research* 1(1969):13-27.

81. Whittenburg, J. A., Pain, R. F., McBride, R. and Amidei, J. *Driver Improvement Training and Evaluation: Volume I*. Washington, DC: American University Development Education and Training Research Institute, 1972.

82. Willett, T. C. *Criminal on the Road*. London: Tavistock, 1964.

Section 3.0

1. Institute for Research in Public Safety, "Tri-Level Study of the Causes of Traffic Accidents: Interim Report I, Vol. I, Research Findings." Prepared by the Institute for Research in Public Safety, Indiana University School of Public and Environmental Affairs, under Contract No. DOT-HS-034-3-535, for the NHTSA, August 31, 1973.

2. Sonquist, J. A., and J. N. Morgan, *The Detection of Interaction Effects*, Monograph No. 35, Survey Research Center, Institute for Social Research, The University of Michigan, Ann Arbor, 1964.

3. Sonquist, J. A., E. L. Baker, and J. N. Morgan, *Searching for Structure*. Ann Arbor, MI: Institute for Social Research, University of Michigan, 1974.

4. Sonquist, J. A., *Multivariate Model Building*. Survey Research Center, Ann Arbor, MI: Institute for Social Research, The University of Michigan, 1970.

5. Blalock, H. M., *Social Statistics*. New York: McGraw-Hill, 1960. Pp. 266-269.

6. Inter-University Consortium for Political Research, *OSIRIS II OS User's Manual*. Ann Arbor, MI: The Institute for Social Research, The University of Michigan, January, 1971.

Section 4.0

1. Berger, W. G., Reiss, M. L., and Valette, G. R., *Analysis of Motorcycle Accident Reports and Statistics*. Motorcycle Safety Foundation, February, 1974.

Section 5.0

1. Perchonok, K. "Accident Cause Analysis." Cornell Aeronautical Laboratory, report prepared for the U. S. Department of Transportation, DOT-HS-800-716, 1972.
2. Arthur D. Little, Inc. *The State of the Art of Traffic Safety: A Comprehensive Review of Existing Information*. New York: Praeger, 1970.
3. Haight, F. A., Joksch, H. C., O'Day, J., and Waller, P. FF. "Review of Methods for Studying Pre-Crash Factors." Final report for Department of Transportation, Report No. DOT-HS-4-00897-4, May, 1976.
4. Smith, E. E. "Choice Reaction Time: An Analysis of the Major Theoretical Positions." *Psychological Bulletin* 69(1968):77-110.
5. Sternberg, S. "The Discovery of Processing Stages: Extensions of Donders' Method." *Acta Psychologica* 30(1969):276-315.
6. Matson, P. M., Smith, W. S., and Hurd, F. W. *Traffic Engineering*. New York: McGraw-Hill, 1955.
7. Bartlett, F. C. *Remembering*. Cambridge, England: Cambridge University Press, 1932.
8. Posner, M. I. "Abstraction in the Process of Recognition." In G. H. Bower and J. P. Spence (Eds.), *The Psychology of Learning and Motivation: Volume III*. New York: Academic Press, 1969.
9. Fell, J. C. "A Motor Vehicle Accident Causal System: The Human Element." *Human Factors* 18(1976):85-94.
10. Burg, A. "An Investigation of Some Relationships Between Dynamic Visual Acuity, Static Visual Acuity and Driving Record." Report No. 64-18, Los Angeles: University of California, Department of Engineering, April, 1964.
11. Henderson, R. L. and Burg, A. "Vision and Odition in Driving." Final report for U.S. Department of Transportation, Report No. DOT-HS-801-265, November, 1974.
12. Rumark, K., Berggrund, U., Jernberg, P., and Ytterborn, U., "Studded and Unstudded Vehicle Speeds on Icy and Dry Roads." Department of Psychology, University of Uppsala, Sweden, Report No. 165, 1974.
13. Voevodsky, J. "Evaluation of a Deceleration Warning Light for Reducing Rear-End Automobile Collisions." *Journal of Applied Psychology* 59(1974):270-73.
14. Gantzer, D. and Rockwell, T. H. "The Effect of Discrete Headway and Relative Velocity Information on Car-Following Performance." *Ergonomics* 2(1968):1.
15. Forbes, T. W. "Visibility and Legibility of Highway Signs." In T. W. Forbes (Ed.), *Human Factors in Highway Traffic Safety Research*. New York: Wiley, 1972.
16. Lawrence, R. H. "The Scandinavian Myth: The Effectiveness of Drinking-And-Driving Legislation in Sweden and Norway." *The Journal of Legal Studies, 1976*.

APPENDIX A
SCATTER PLOT DIAGRAMS

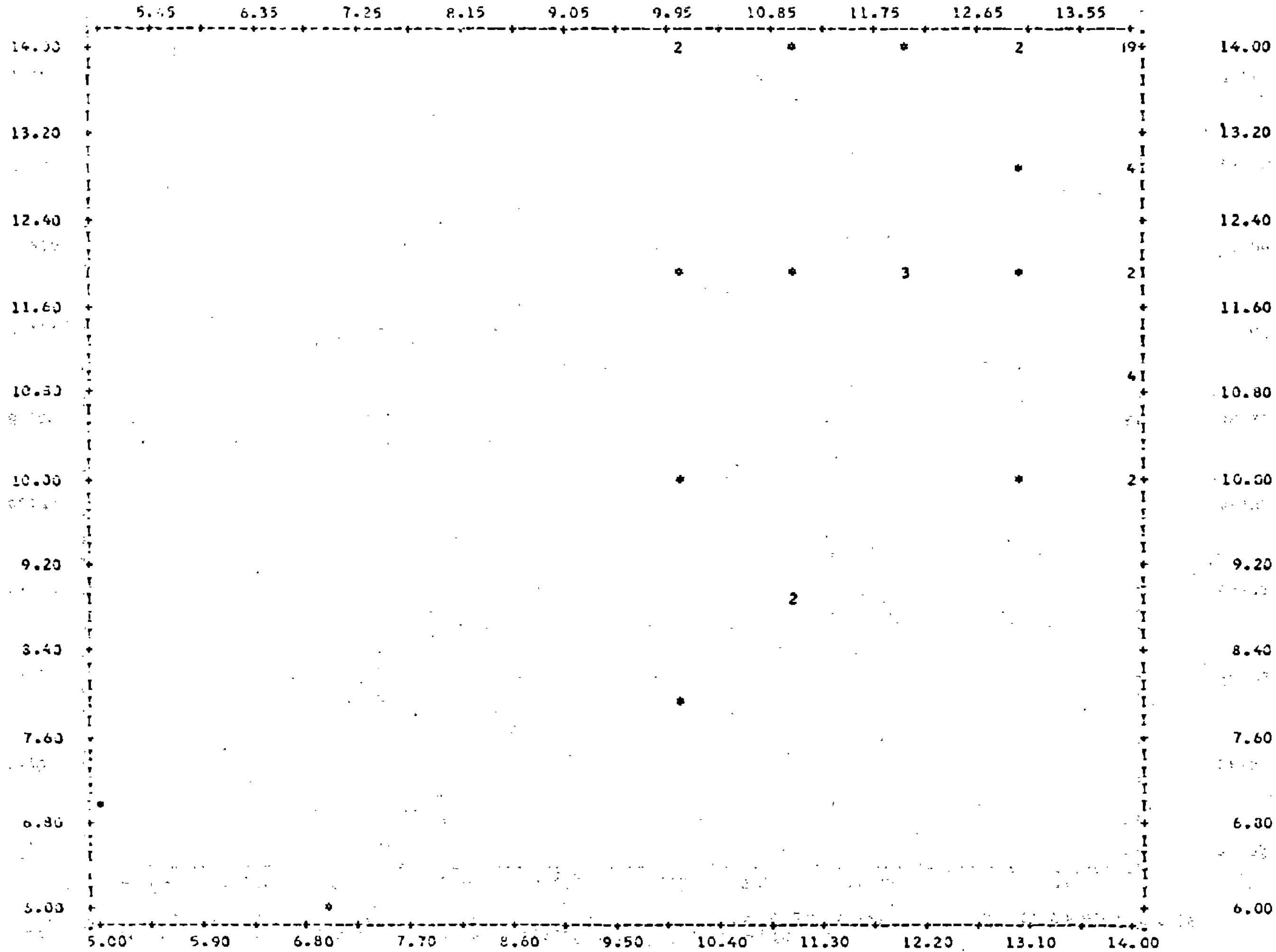
Test-retest scatter plots for each of the DVT measures used in the reliability analysis.

Notes:

1. In all cases the ordinate value represents the initial test score and the abscissa represents the retest scores.

2. The numbers within the plots represent the number of cases with a given test retest score combination, and an asterick represents a single case.

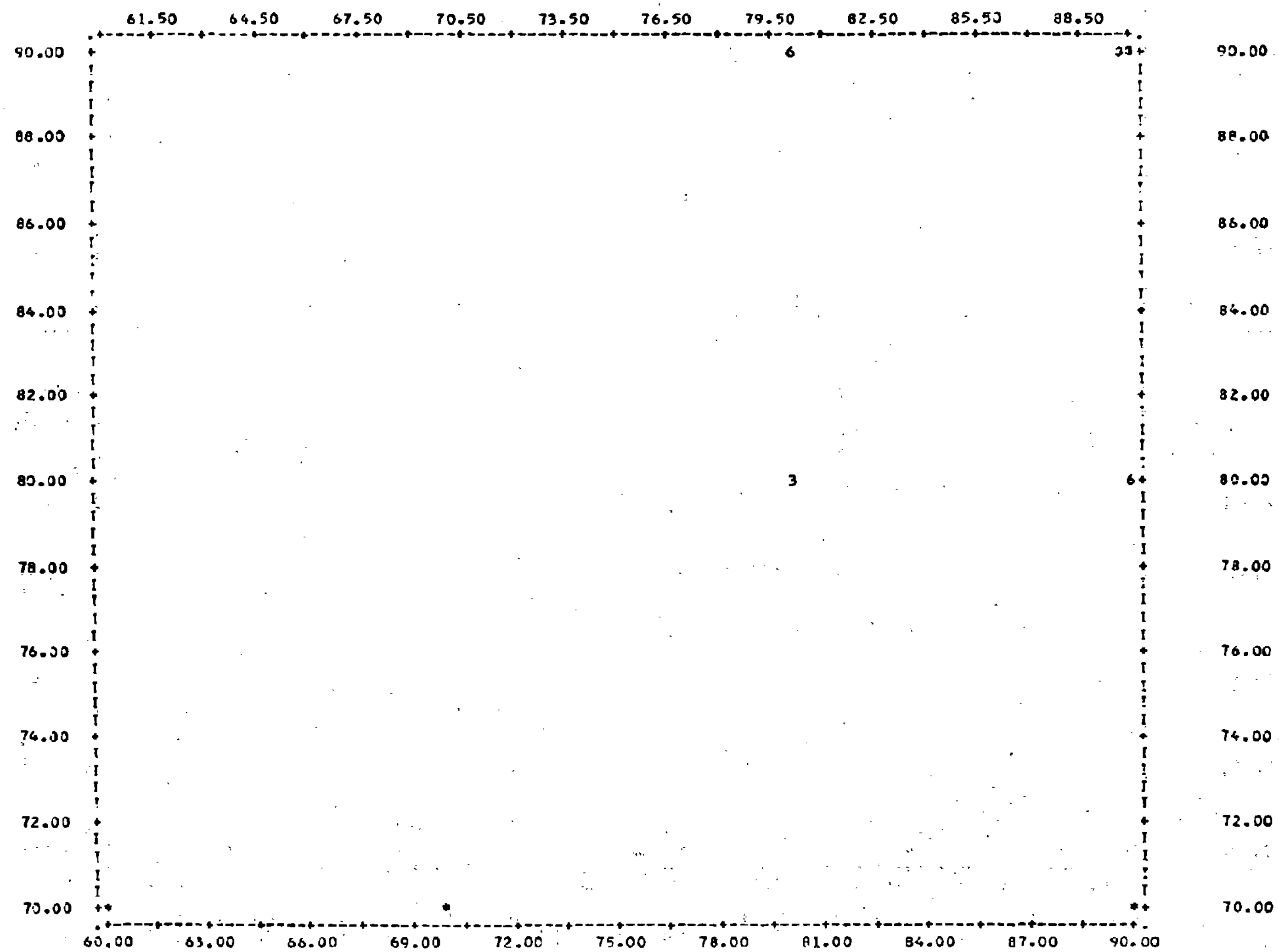
FILE DVTO (CREATION DATE = 75/01/29.) DYNAMIC VISION TEST-RETEST RESULTS
SCATTERGRAM OF (DOWN) VAR089 FIELD OF VISION-TOTAL (ACROSS) VAR091 FIELD OF VISION-TOTAL RETEST



PLOTTED VALUES - 51 EXCLUDED VALUES- 0 MISSING VALUES - 0

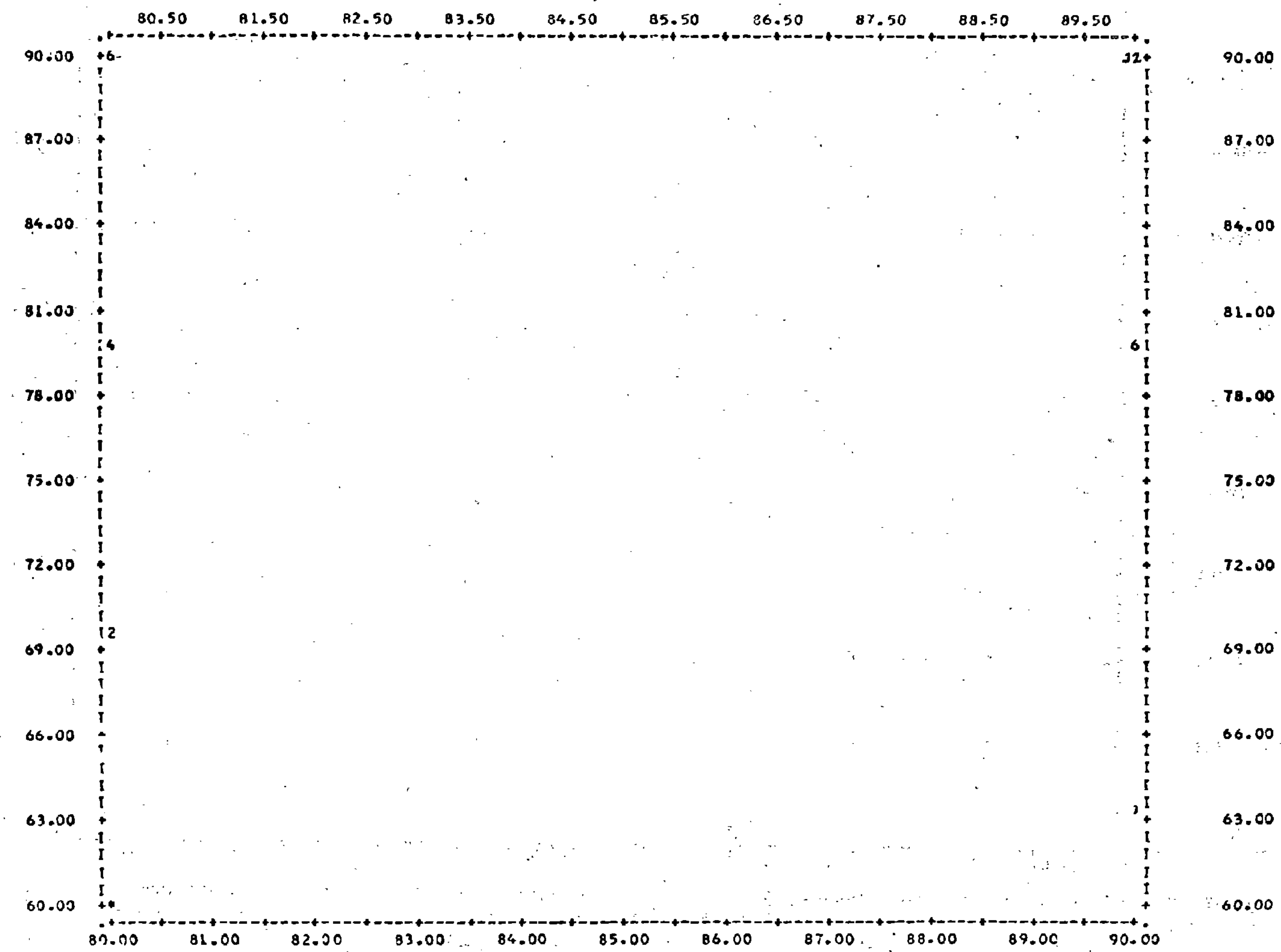
INDIANA UNIVERSITY--INSTITUTE FOR RESEARCH IN PUBLIC SAFETY--   75/01/29.   PAGE   10

FILE   DVTD   (CREATION DATE = 75/01/29.)   DYNAMIC VISION TEST-RETEST RESULTS
SCATTERGRAM OF   (DOWN) VAR040   FIELD OF VISION-LEFT   (ACROSS) VAR092   FIELD OF VISION-LEFT RETEST



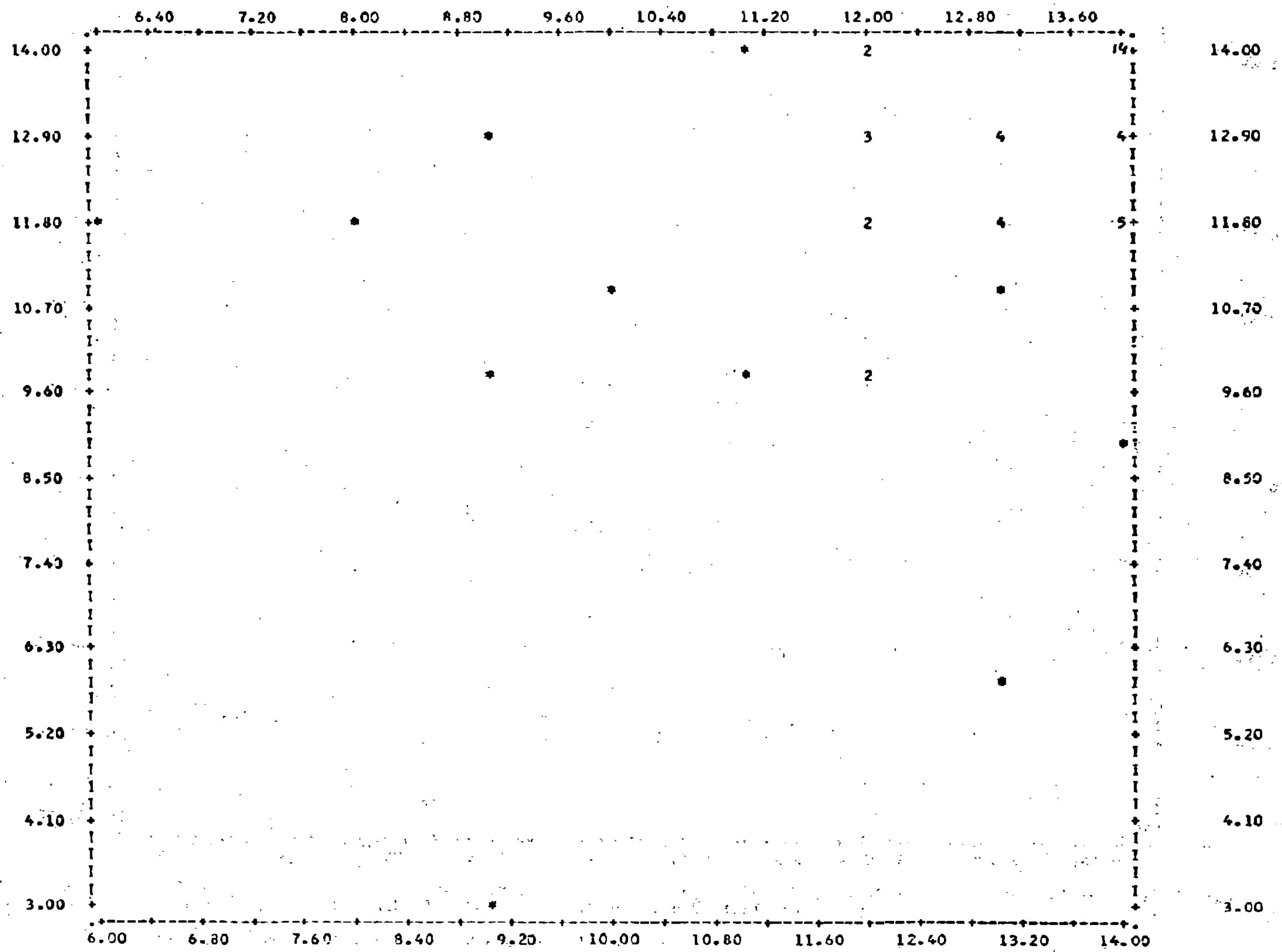
PLOTTED VALUES -   51   EXCLUDED VALUES-   0   MISSING VALUES -   0

FILE DVT) (CREATION DATE = 75/01/29.) DYNAMIC VISION TEST-RETEST RESULTS
SCATTERGRAM OF (DOWN) VAR041 FIELD OF VISION-RIGHT (ACROSS) VAR093 FIELD OF VISION-RIGHT RETEST



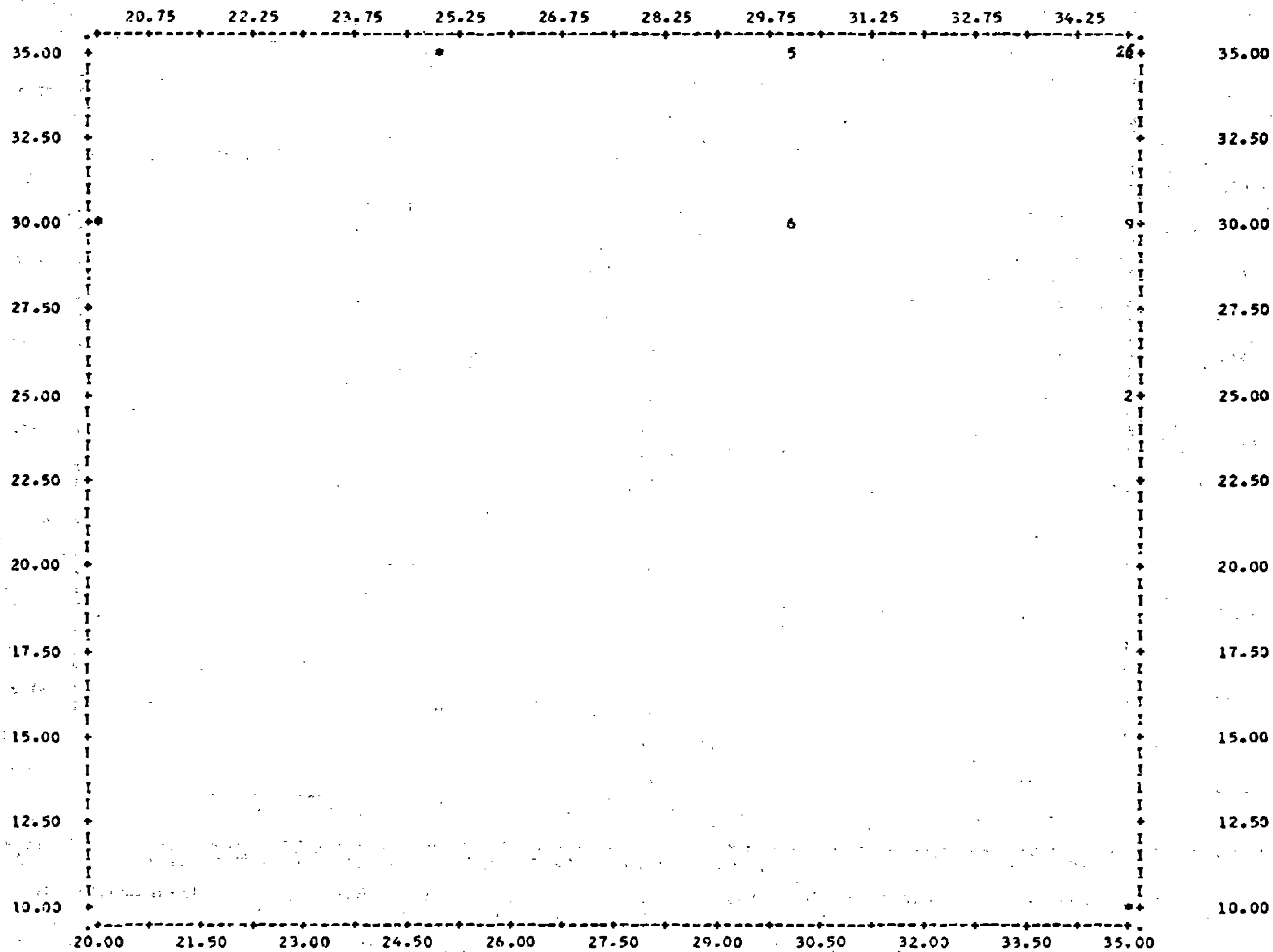
PLOTTED VALUES - 51   EXCLUDED VALUES- 0   MISSING VALUES - 0

FILE DVTD (CREATION DATE = 75/01/29.) DYNAMIC VISION TEST-RETEST RESULTS
SCATTERGRAM OF (DOWN) VAR045 D A AND I 35 DEG ANGLE-TOTAL (ACROSS) VAR094 D A AND I 35 DEG ANGLE-TOTAL RETEST



PLOTTED VALUES - 51   EXCLUDED VALUES- 0   MISSING VALUES - 0

FILE DVTD (CREATION DATE = 75/01/29.) DYNAMIC VISION TEST-RETEST RESULTS
SCATTERGRAM OF (DOWN) VAR047 D A AND I 35 DEG ANGLE-RIGHT (ACROSS) VAR096 D A AND I 35 DEG ANGLE-RIGHT RETEST

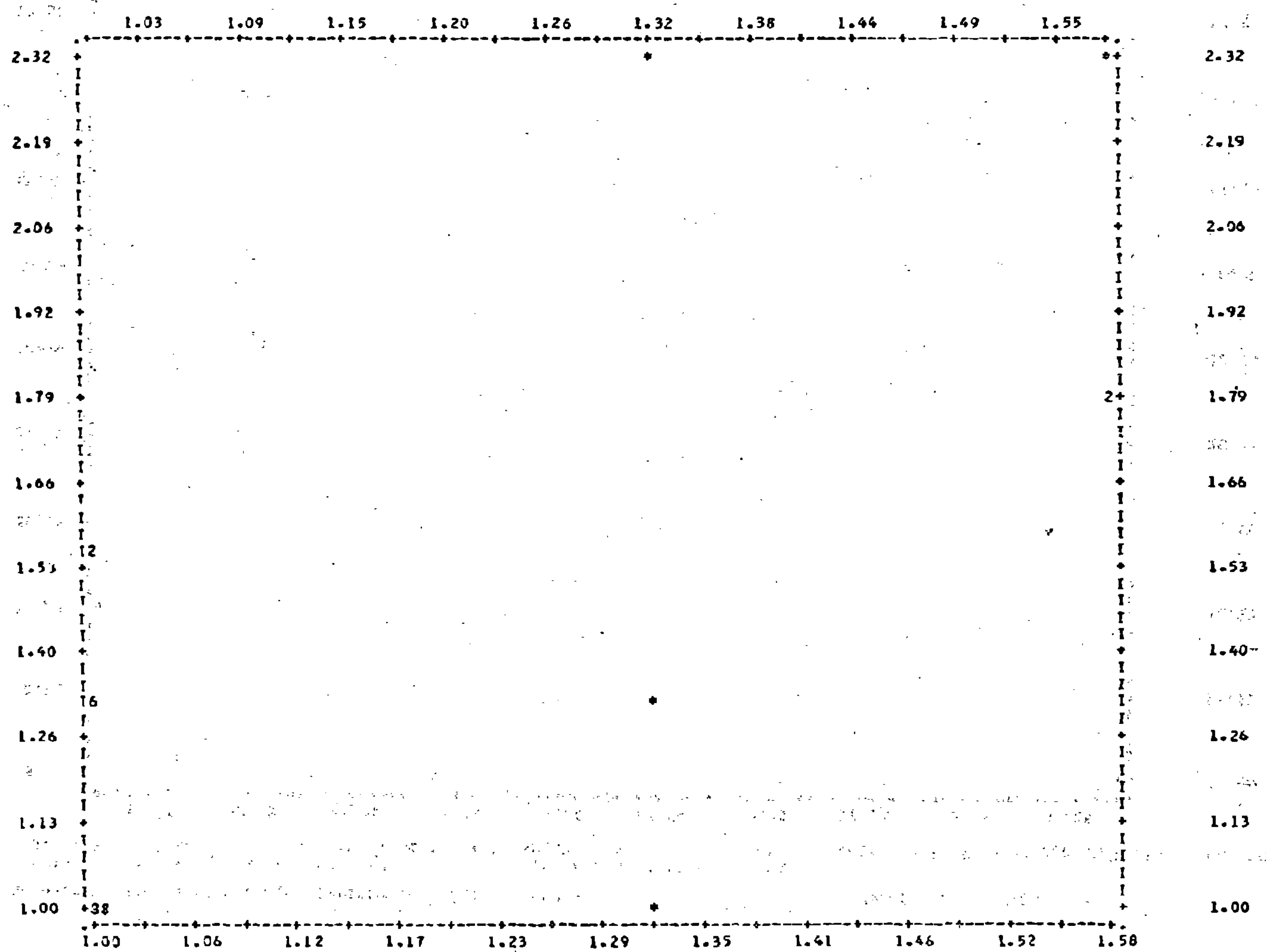


PLOTTED VALUES - 51 EXCLUDED VALUES- 0 MISSING VALUES - 0

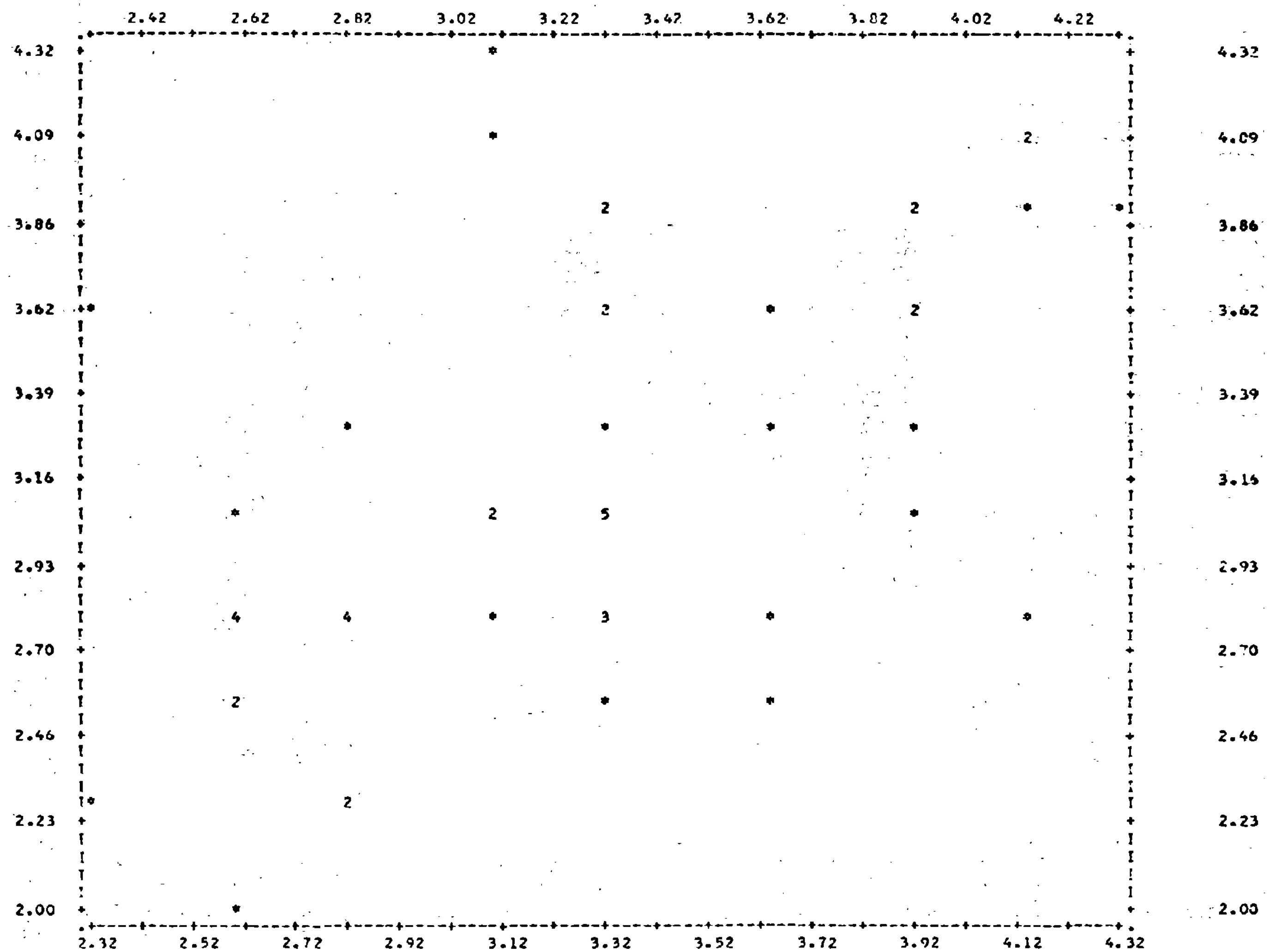
PLOTTED VALUES - 51 EXCLUDED VALUES- 0 MISSING VALUES - 0

INDIANA UNIVERSITY--INSTITUTE FOR RESEARCH IN PUBLIC SAFETY-- 75/01/29. PAGE 15

FILE DVTO (CREATION DATE = 75/01/29.) DYNAMIC VISION TEST-RETEST RESULTS
SCATTERGRAM OF (DOWN) VAR048 STATIC ACUITY NO GLARE-NORMAL (ACROSS) VAR097 STATIC ACUITY NO GLARE-NORMAL RETEST



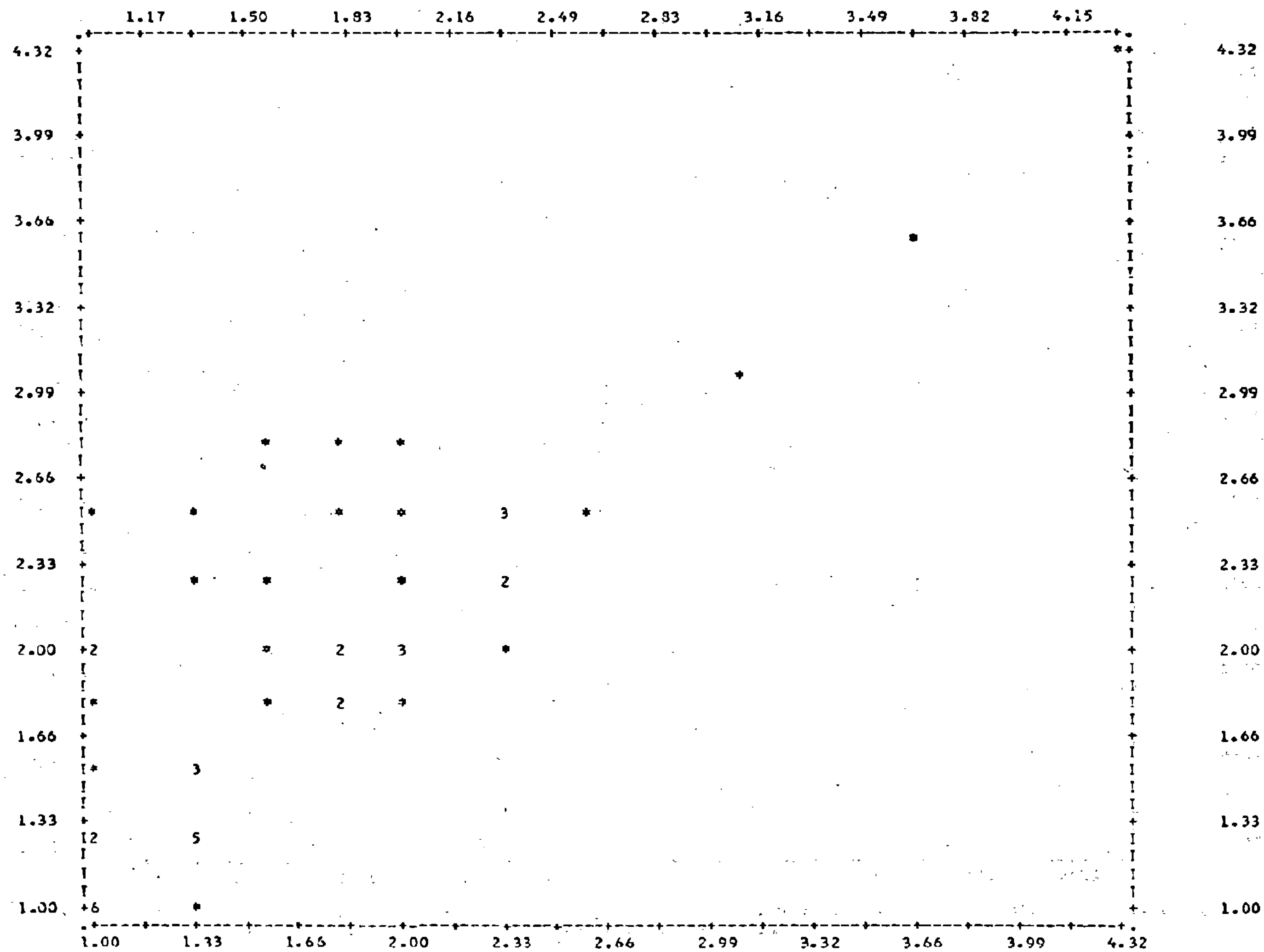
FILE   DVTD   (CREATION DATE = 75/01/29.)   DYNAMIC VISION TEST-RETEST RESULTS
SCATTERGRAM OF   (DOWN) VAR049   STATIC ACUITY NO GLARE-LOW LEVEL   (ACROSS) VAR098   STATIC ACUITY NO GLARE-LOW LEVEL RETES



PLOTTED VALUES -   51   EXCLUDED VALUES-   0   MISSING VALUES -   0

INDIANA UNIVERSITY--INSTITUTE FOR RESEARCH IN PUBLIC SAFETY-- 75/01/29. PAGE 17

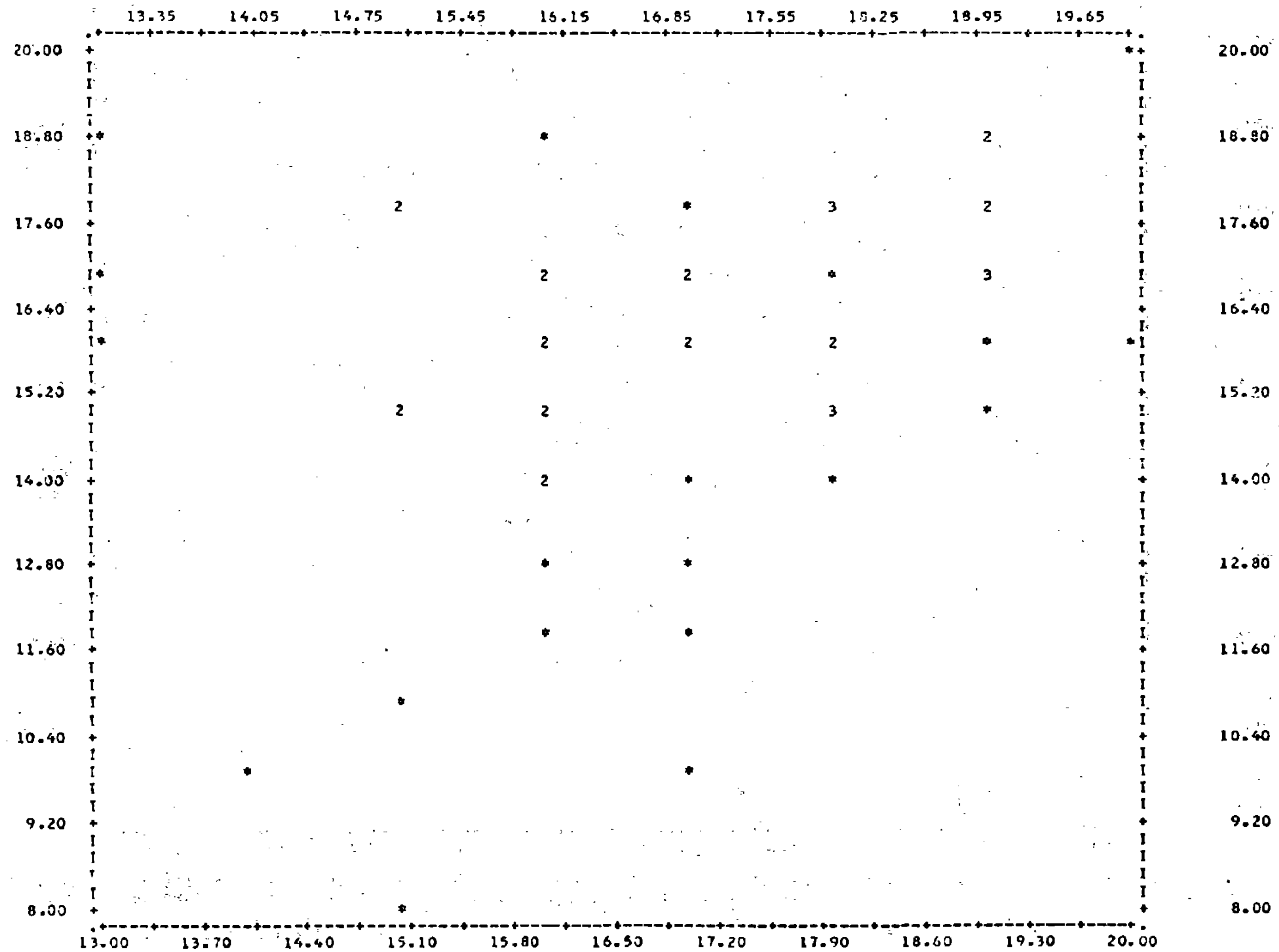
FILE DVTD (CREATION DATE = 75/01/29.) DYNAMIC VISION TEST-RETEST RESULTS
SCATTERGRAM OF (DOWN) VAR051 STATIC ACUITY-SPOT GLARE (ACROSS) VAR099 STATIC ACUITY-SPOT GLARE RETEST



PLOTTED VALUES - 51 EXCLUDED VALUES- 0 MISSING VALUES - 0

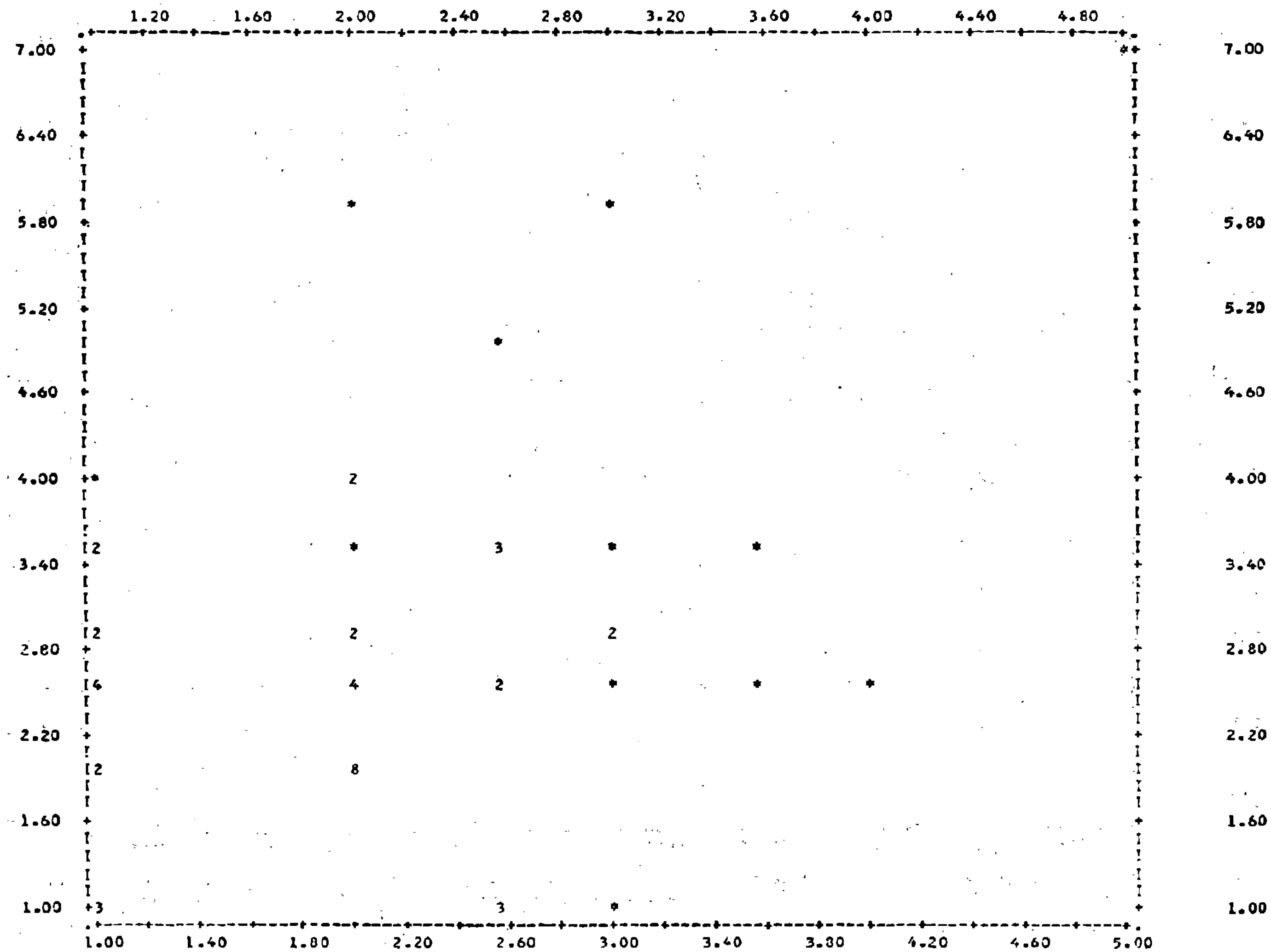
INDIANA UNIVERSITY--INSTITUTE FOR RESEARCH IN PUBLIC SAFETY-- 75/01/29. PAGE 18

FILE DVTD (CREATION DATE = 75/01/29.) DYNAMIC VISION TEST-RETEST RESULTS
SCATTERGRAM OF (DOWN) VAR052 CENTRAL ANGULAR MOVEMENT-TOTAL (ACROSS) VAR100 CENTRAL ANGULAR MOVEMENT-TOTAL RETEST



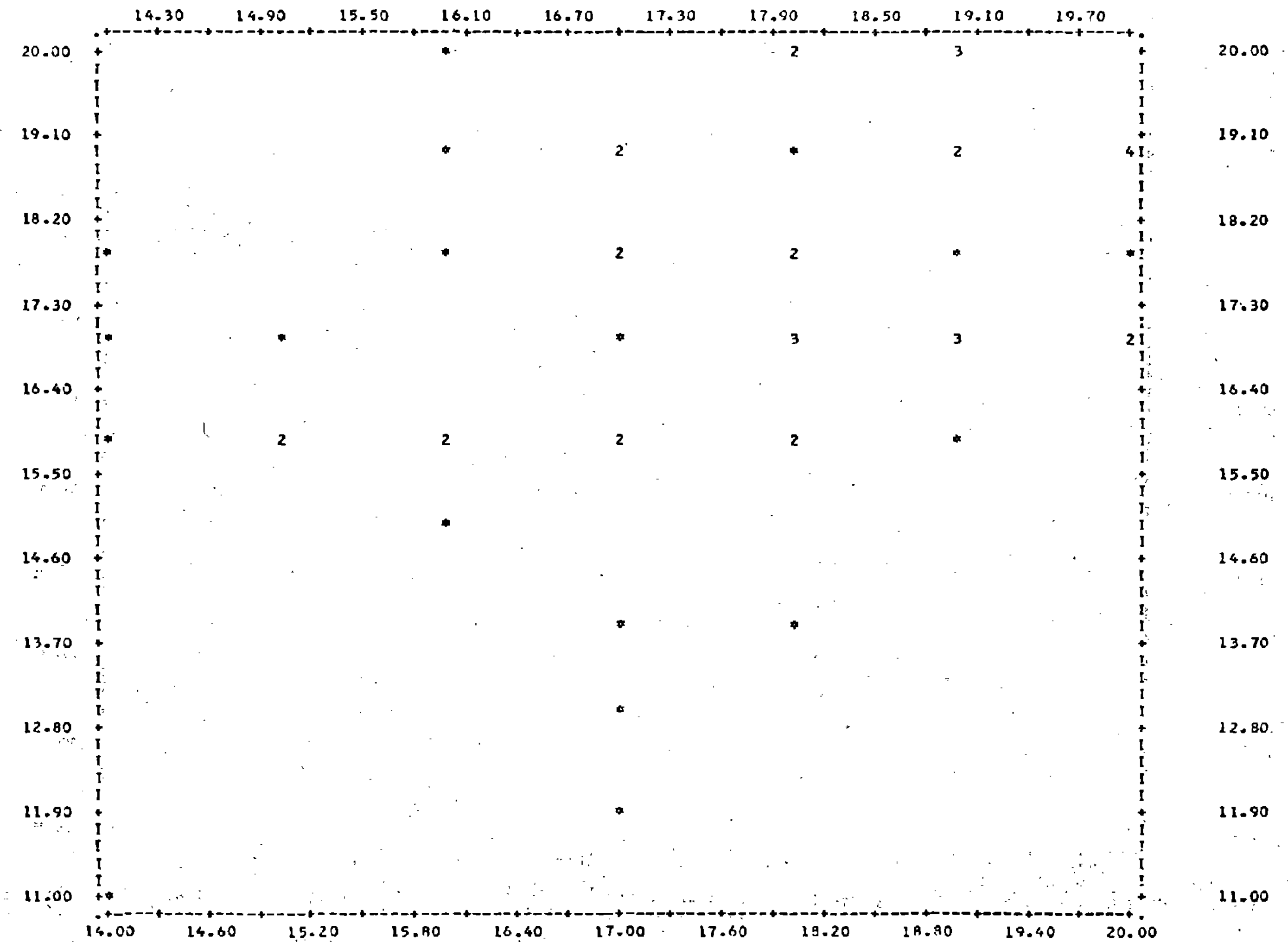
PLOTTED VALUES - 51 EXCLUDED VALUES- 0 MISSING VALUES - 0

FILE DVTD (CREATION DATE = 75/01/29.) DYNAMIC VISION TEST-RETEST RESULTS
SCATTERGRAM OF (DOWN) VAR053 CENTRAL ANGULAR MOVEMENT-THRESHOLD (ACROSS) VAR101 CENTRAL ANGULAR MOVEMENT-THRESHLD RETE



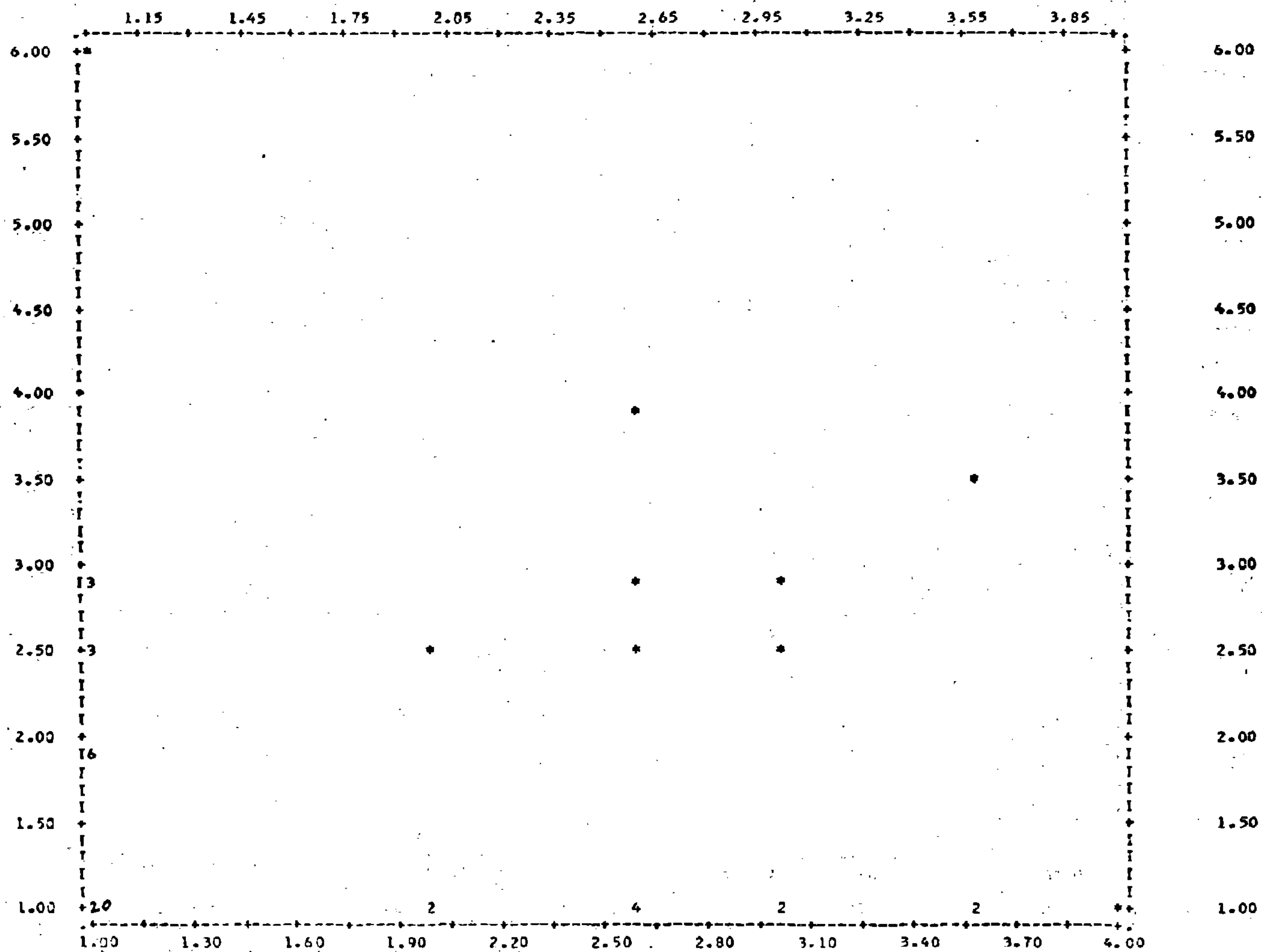
PLOTTED VALUES - 51 EXCLUDED VALUES- 0 MISSING VALUES - 0

FILE DVTO (CREATION DATE = 75/01/29.) DYNAMIC VISION TEST-RETEST RESULTS
SCATTERGRAM OF (DOWN) VAR054 CENTRAL MOVEMENT INDEPTH-TOTAL (ACROSS) VAR102 CENTRAL MOVEMENT INDEPTH-TOTAL RETEST



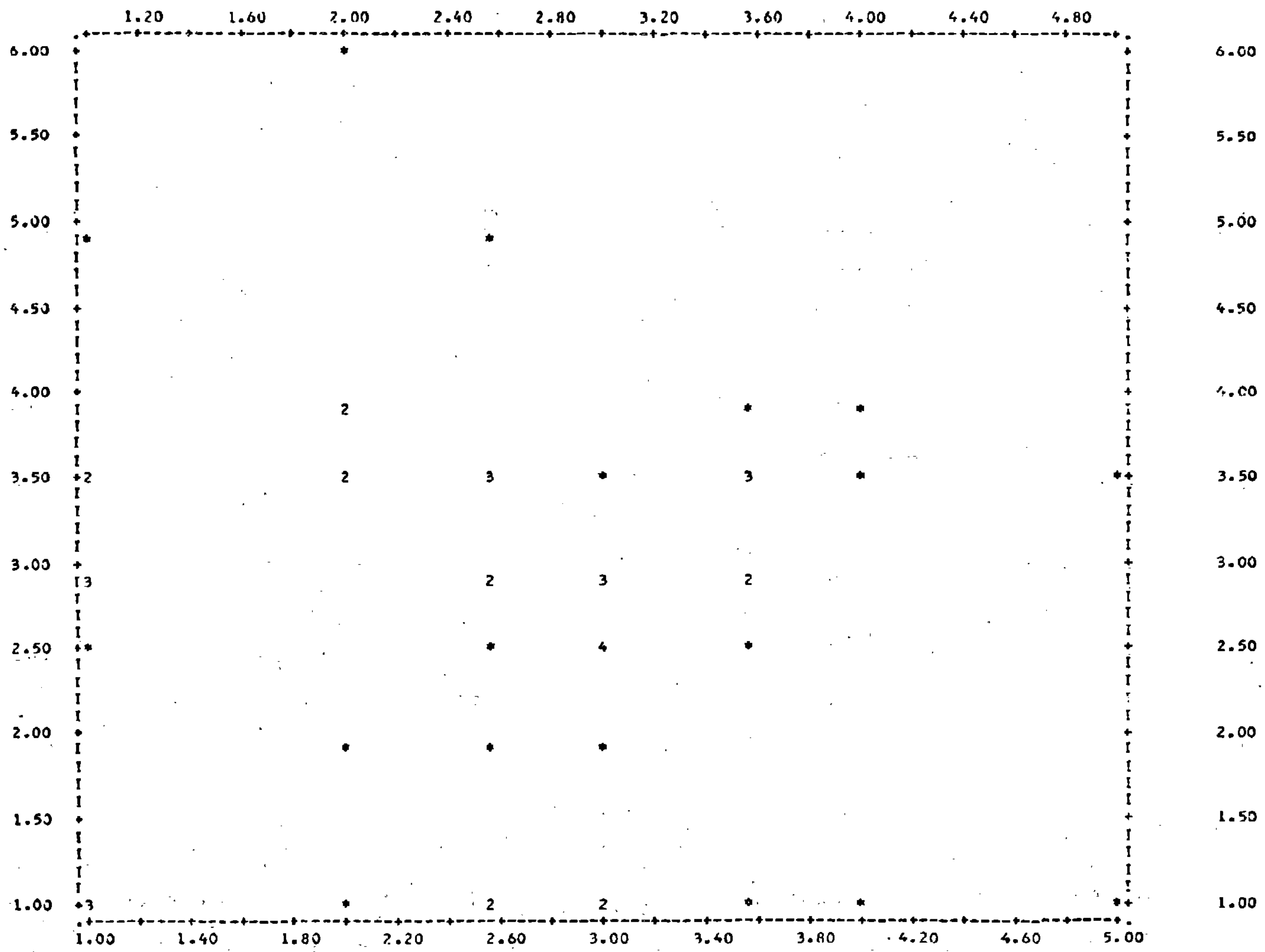
PLOTTED VALUES - 51 EXCLUDED VALUES- 0 MISSING VALUES - 0

FILE DVTD (CREATION DATE = 75/01/29.) DYNAMIC VISION TEST-RETEST RESULTS
SCATTERGRAM OF (DOWN) VAR055 CENTRAL MOVEMENT INDEPTH-THRESHOLD SMALL (ACROSS) VAR103 CENTRAL MOVEMENT INDEPTH-TH SMALL RETE



PLOTTED VALUES - 51 EXCLUDED VALUES- 0 MISSING VALUES - 0

FILE DVTO (CREATION DATE = 75/01/29.) DYNAMIC VISION TEST-RETEST RESULTS
SCATTERGRAM OF (DOWN) VAR056 CENTRAL MOVEMENT INDEPTH-THRESHOLD LARGE (ACROSS) VAR104 CENTRAL MOVEMENT INDEPTH-TH LARGE RETE



PLOTTED VALUES - 51   EXCLUDED VALUES- 0   MISSING VALUES - 0

```
INDIANA UNIVERSITY--INSTITUTE FOR RESEARCH IN PUBLIC SAFETY--                    75/01/29.     PAGE   23

FILE   DVTD     (CREATION DATE =  75/01/29.)   DYNAMIC VISION TEST-RETEST RESULTS
SCATTERGRAM OF   (DOWN) VAR063   DYNAMIC VISION ACUITY                    (ACROSS) VAR105   DYNAMIC VISION ACUITY RETEST

              1.72      1.99      2.27      2.54      2.81      3.09      3.36      3.64      3.91      4.18
        .+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+.
  4.49  +                                                                                                   *+  4.49
        I                                                                                                    I
  4.20  +                                                                                                    +  4.20
        I                                                                                                    I
  3.91  +                                                                                                    +  3.91
        I                                                                                                    I
  3.62  +                                                                                                    +  3.62
        I                                                                                                    I
  3.33  +                                                                                                    +  3.33
        I                                                                                                    I
  3.03  +                                                                                                    +  3.03
        I                                                                                                    I
  2.74  +                                                                                                    +  2.74
        I2                          *         2                                                              I
  2.45  +                                                                                                    +  2.45
        I5               *          4                                                                        I
  2.16  +                                                                                                    +  2.16
        I4               6          5                                                                        I
  1.87  +                                                                                                    +  1.87
        I                                                                                                    I
  1.58  +15              2          *                  2                                                     +  1.58
        .+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+.
        1.58      1.85      2.13      2.40      2.68      2.95      3.22      3.50      3.77      4.05      4.32

PLOTTED VALUES -        51        EXCLUDED VALUES-         0         MISSING VALUES -        0
```

APPENDIX B: SELECTED ERROR PATTERNS ON THE CENTRAL ANGULAR MOVEMENT (CAM) TEST, AND THE THRESHOLD SCORED

The scoring difficulty is illustrated by the different patterns yielding the same score.

			Error Trials (Rate of movement - min. arc/sec)										
Case	Driver	Run	256	128	64	32	16	12	8	6	4	2	Scored Threshold
202	2	1					X	X					4
		2										X	
203	1	1						X			X	X	6
		2						X			X	X	
205	1	1								X	X		2
		2											
209	1	1						X			X	X	4
		2										X	
211	1	1										X	8
		2								X	X	X	
214	1	1										X	4
		2											
214	2	1									X		12
		2						X	X			X	
216	1	1								X	X		8
		2										X	
217	2	1							X	X	X		12
		2							X	X	X	X	

APPENDIX C: BASIC DEMOGRAPHIC QUESTIONNAIRE

Name: ______________________________

Social Security Number: ______________________

Sex:

_____Male
_____Female

Age:

_____Years Old

Education:

_____1-7 years
_____8-11 years
_____High School graduate
_____1-3 years of college
_____College graduate
_____Post-grad or professional degree
_____Vocational, technical or business school

Major current occupation: Give job title and brief description of work ______________________________
____
______________________________.

About how much was your total family income last year?

_____under $3,000
_____$3,000 to 5,999
_____$6,000 to 7,999
_____$8,000 to 11,999
_____$12,000 to 14,999
_____$15,000 to 19,999
_____$20,000 to 24,999
_____$25,000 or more

What is your present marital status?

_____Single
_____Married
_____Divorced or Separated
_____Other: ___________

Number of brothers and sisters you have? _____

APPENDIX D: DRIVING RECORD QUESTIONNAIRE

How long have you been driving? _____years

How many miles do you think you have driven in the last twelve month period? _____miles

How many accidents have you ever been involved in (include those in which you were not at fault)? _____

How many of these occurred in the last 5 years? _____

How many occurred in the last year? _____

In how many of the total number of accidents that you have been involved in were you at fault? _____

Briefly describe each accident you have been in during the last 5 years (in a sentence or two) and indicate whether there was anything you did that helped cause the accident.

Accident 1: Description________________________________
____
____

What was the main cause of the accident (put two checks by the main cause, and one check by any lesser important causes):

_____I wasn't paying attention, so I didn't see the danger until it was too late.
_____I was distracted by something, so I didn't see the danger until it was too late.
_____I didn't see any danger even though I thought I looked.
_____I didn't expect the other driver to do what he did.
_____I was going to fast.
_____I was driving recklessly or incorrectly.
_____I didn't evade the danger even though I could have.
_____I had trouble steering or controlling my car.
_____I was upset, under pressure, or in a hurry.
_____I was tired, not feeling well, or had been drinking.
_____I was not familiar with the vehicle, the road or with driving in general.
_____Other (please specify): ________________________

How much damage was involved in the accident?

_____No damage
_____Damage under $200
_____Damage over $200

APPENDIX D: Continued

How much injury was involved?

_____No injury or minor injury
_____Injury requiring hospitalization or repeated treatments.
_____Death

How many vehicles were involved? _____

(Repeat for further accidents.)

How many times have you been ticketed for any of the violations listed below?

_____speeding over the limit
_____reckless driving
_____driving while intoxicated
_____failure to observe a stop sign or light
_____Other (please specify all other tickets except for parking): ______________________________
______________________________.

How many times have you been ticketed for any of the violations listed below, in the past year (in the past 12 month period)?

_____speeding over limit
_____reckless driving
_____driving while intoxicated
_____failure to observe a stop sign or light
_____other (please specify all other tickets except for parking: ______________________________
______________________________.

APPENDIX E: ALCOHOL-DRUG USE QUESTIONNAIRE

How often do you take tranquilizers (prescription or non-prescription)?

_____About every day or every other day.
_____About once or twice a week.
_____About once to three time a month.
_____About once to several times a year.
_____Never.

How many cigarettes do you smoke on an average day?_____

How often did you have any alcoholic beverage during the past year?

_____About every day, or every other day.
_____About once or twice a week.
_____About once to three times a month.
_____About once to several times a year.
_____Never.

How many drinks did you usually have on those days or on those occasions when you drank? (By one drink we mean one 12-ounce bottle pf beer, one coctail, one four ounce glass of wine, etc.)

On an average day when I drank, I drank about_____ drinks at a sitting.

APPENDIX F: PERSONAL ADJUSTMENT QUESTIONNAIRE

Recent Events

Put a check mark next to each of the events listed below that happened to you within the past 12 months.

_____Got married, got engaged or started going with someone steadily.
_____Got separated or divorced from wife or husband, or broke-up with someone.
_____Had disturbing trouble with children, parents, in-laws or other family member.
_____Had disturbing trouble with close friend.
_____Job promotion (moved to higher position at work).
_____Job demotion (moved to lower position at work).
_____Troubles with boss or co-workers at my work. (Or trouble with teachers and fellow students at school.)
_____Fired or laid off from a job. (Or failed a course in school.)
_____Had problems finding a job.
_____Started a new type of work, changed to a different line of work or to a new job. (Or began new school, graduated or quit school or changed school.)
_____Considerable improvement in financial situation.
_____Took out a new loan or mortgage.
_____Fell behind in payments for loan, mortgage or finance.
_____Death of a close family member.
_____Death of close friend.
_____Been very sick or injured (other than in car accident).
_____Thought of committing suicide.
_____Been in fight.
_____Been so angry you threw or broke things.

Your Health

During the past year, have you suffered from any of the following?

_____Ulcers
_____Frequent headaches
_____Trouble falling asleep at night
_____Upset stomach, acid stomach, indigestion, gasses, heartburn, etc.
_____Fainting spells or dizziness
_____Frequent losses of memory
_____Attacks of nausea or vomiting
_____I sweat very easily even on cool days
_____My sleep is fitfull and disturbed
_____There seems to be a lump in my throat most of the time
_____My skin seems to be unusually sensative or itchy

APPENDIX G: TESTS OF PERSONAL ADJUSTMENT

Think of your behavior over the past six months. Indicate how often each of the following things characterized your behavior, for the past six months or so. If it happened almost never, circle 1; if it happened sometimes, circle 2; if it happened often, circle 3; if it happened almost always, circle 4.

Almost Never	Some- times	Often	Almost Always	
1	2	3	4	Acted as if I had no interest in things.
1	2	3	4	Was restless.
1	2	3	4	Just sat.
1	2	3	4	Felt that people didn't care about me.
1	2	3	4	Needed to do things very slowly to do them right.
1	2	3	4	Got angry and broke things.
1	2	3	4	Acted as if I had no control over my emotions.
1	2	3	4	Laughed or cried at strange things
1	2	3	4	Had mood changes without reason.
1	2	3	4	Had temper tantrums.
1	2	3	4	Got excited for no reason.
1	2	3	4	Acted as if I didn't care about other people's feelings.
1	2	3	4	Thought only of myself.
1	2	3	4	Was bossy.
1	2	3	4	Argued.
1	2	3	4	Got into fights with people.
1	2	3	4	Was cooperative.
1	2	3	4	Did the opposite of what was asked.
1	2	3	4	Cursed at people.

APPENDIX G: Continued

Almost Never	Some-times	Often	Almost Always	
1	2	3	4	Deliberately upset routine.
1	2	3	4	Was resentful.
1	2	3	4	Got annoyed easily.
1	2	3	4	Was critical of other people.
1	2	3	4	Lied.
1	2	3	4	Got into trouble with law.
1	2	3	4	Stayed away from people.
1	2	3	4	Was quiet.
1	2	3	4	Preferred to be alone.
1	2	3	4	Behavior was childish.
1	2	3	4	Moved about very slowly.
1	2	3	4	Was very quick to react to something someone said or did.
1	2	3	4	Was very slow to react.
1	2	3	4	Would stay in one position for a long period.
1	2	3	4	Acted confused about things; in a daze.
1	2	3	4	Acted as if I couldn't get certain thoughts out of my mind.
1	2	3	4	Talked without making sense.
1	2	3	4	Refused to speak at all for periods of time.
1	2	3	4	Spoke so low you could not hear me.
1	2	3	4	Talked about how angry I was at certain people.
1	2	3	4	Threatened to tell people off.
1	2	3	4	Said the same thing over and over again.
1	2	3	4	Talked about big plans I had for the future.
1	2	3	4	Gave advice without being asked.

Note - These demos are modified from the Katz Adjustment Scales.

APPENDIX G: Continued

Circle Yes or No for each question.

Yes	No	I find it hard to keep my mind on a task or job.
Yes	No	I certainly feel useless at times.
Yes	No	I work under a great deal of tension.
Yes	No	My daily life is full of things that keep me interested.
Yes	No	I seem to be about as capable and smart as most others around me.
Yes	No	Sometimes without any reason or even when things are going wrong I feel excitedly happy, "on top of the world".
Yes	No	I feel as good now as I ever have.
Yes	No	I enjoy many kinds of play and recreation.
Yes	No	I seldom worry about my health.
Yes	NO	I have a good appetite.

APPENDIX H: SOCIAL ADJUSTMENT QUESTIONNAIRE

How many times have you moved from one residence to another in the past 5 years?_____

How many years have you lived at your present address?_____

How many times have you changed jobs (or schools) in the last 5 years?_____

How many years have you been employed by your present employer? _____

Are you registered to vote? Yes____; No____.

How many times have you voted in the last four years?_____

Do you regularly attend church or other religious services? Yes____; No____.

When you were growing up did your parents regularly attend church? Yes____; No____.

In all, how many organizations or clubs do you pay dues to?_____

On the average, how many days a month do you spend at meetings of clubs or organizations to which you belong?

<u>Memberships</u>

Try to think of all the clubs or organizations that you belong to at the present time, and indicate how active you are in each by checking things you have done in each organization over the last five years.

Name of Organization	I am a member	I have gone to meetings	I have contributed money or dues	I have worked on projects	I have held an office
Church	____	____	____	____	____
Social, fraternal or charitable club	____	____	____	____	____
Union or professional organization	____	____	____	____	____
Political party or organization	____	____	____	____	____
Sports team or group	____	____	____	____	____

(List any others and indicate how active you are, e.g., church organizations, parent groups, scouts, etc.)

School

Based on your school experiences (junior high and high school) how often did each of the following events occur?

Event	1. Often	2. Sometimes	3. Rarely	4. Never
Played hooky.				
Wanted to drop out.				
Cut-up and was sent to the principal's office.				
Skipped classes I didn't like.				
Enjoyed school.				
Got Ds and Fs.				
Was suspended.				
Had academic problems.				
Received awards and honors.				
Belonged to school clubs or teams.				
Was well-liked.				
Had conflicts with my teachers.				
Went out on dates.				
Went to parties.				
Was a loner.				

General

Put a check mark (✓) beside each of the following things which has happened to you.

____Regular cigarette smoker before age 17.
____Had a full time job be (Excluding summer jobs.)
____Failed one or more grades before grade 8.
____Dropped out of school.
____Was arrested before age 18, for something other than driving.
____Was arrested after age 18, for something other than driving.
____Was convicted for some offense other than driving.
____Ran away from home as a child.
____Have gotten into trouble for not paying bills, or with a landlord over rent.

APPENDIX I: STANDARDIZED TESTS OF SOCIAL ADJUSTMENT

A number of controversial statements or questions with two alternative answers are given below. Indicate your personal preference by putting a check mark in front of the answer that is most attractive to you.

1. Taking the Bible as a whole, one should regard it from the point of view of its beautiful mythology and literary style rather than as a spiritual revelation.
   _____Yes
   _____No

2. Which of the following branches of study do you expect will ultimately prove more important for mankind?
   _____Mathematics
   _____Theology

3. When you visit a cathedral are you more impressed by a pervading sense of reverence and worship than by the architectural features and stained glass?
   _____Yes
   _____No

4. All the evidence that has been impartially accumulated goes to show that the universe has evolved to its present state in accordance with natural principles, so that there is no necessity to assume a first cause, cosmic purpose or God behind it.
   _____I agree with this statement
   _____I disagree with this statement

5. In your opinion, a man who works in business all week can best spend his Sunday in --
   _____trying to educate himself by reading serious books or go to an orchestral concert
   _____hearing a really good sermon

6. If you lived in a small town and had more than enough income for your needs, would you prefer to
   _____Help advance the activities of local religous groups
   _____Give it for the development of scientific research in your locality

7. Assuming that you are a person with necessary ability and that the salary of each of the following occupations is the same, would you prefer to be
   _____mathematician
   _____clergyman

APPENDIX I: Continued

8. Should one guide one's conduct according to, or develop one's chief loyalities towards
   _____ one's religous faith
   _____ ideals of beauty

Note-A longer, standardized version involves all 45 items from the Allport-Vernon Study of Values.

Circle Yes or No for Each Question

Yes	No	1.	My way of doing things is apt to be misunderstood by others.
Yes	No	2.	My parents have often disapproved of my friends.
Yes	No	3.	Before I do something I try to consider how my friends will react to it.
Yes	No	4.	I often think about how I look and what impression I am making on others.
Yes	No	5.	My table manners are not quite as good at home as when I am out in company.
Yes	No	6.	I get pretty discouraged with the law when a smart lawyer gets a criminal free.
Yes	No	7.	Even when I have gotten into trouble I was usually trying to do the right thing.
Yes	No	8.	Even the idea of giving a talk in public makes me afraid.
Yes	No	9.	It is pretty easy for people to win arguments with me.
Yes	No	10.	I have often gone against my parents' wishes.

Note-A longer, standardized scale consists of the following items taken from the California Psychological Inventory, Yes: 12, 36, 93, 94, 156, 164, 170, 182, 184, 214, 257, 302, 327, 336, 338, 339, 345, 369, 385, 386, 393, 396, 398, 405, 416, 420, 428, 431, 435, 436, 444, 457; No: 62, 123, 144, 168, 180, 192, 198, 212, 223, 245, 284, 317, 323, 334, 367, 373, 389, 394, 409, 429, 439. A longer, standardized scale consists of 50 items from the Pd scale of the MMPI.

APPENDIX J: IMPULSIVITY QUESTIONNAIRE

Driving Opinions

Circle Yes if you generally agree with the statement and No if you generally disagree with the statement. Try to answer all questions.

Yes	No	I find driving a form of relaxation which I use to relieve my tension.
Yes	No	Driving gives most teen-agers a feeling of being grown up.
Yes	No	It's fun to beat other cars at the getaway.
Yes	No	It's fun to maneuver through traffic.
Yes	No	During the past few months I have gone driving to blow off steam after an argument.
Yes	No	I feel pressure from people who have authority over me.
Yes	No	I find it difficult to go slowly when there is an open road ahead and the speed limit is 35 m.p.h.
Yes	No	Driving helps relieve pressure.
Yes	No	People are more likely to take chances if their friends are in the car.
Yes	No	It's fun to pass other cars on the highway even if you're not in a hurry.
Yes	No	I drive differently when other people are in the car.
Yes	No	It's a thrill to outwit other drivers.
Yes	No	Driving in traffic is no fun.
Yes	No	It's a thrill to beat other drivers at the getaway.
Yes	No	Driving at high speeds gives you a thrilling sense of power.
Yes	No	Most drivers should not be allowed to go over 60 m.p.h.
Yes	No	The desire for speed is just like a disease.
Yes	No	Most people would rather have a 400 horsepower engine in an old car than a low powered engine in a newer car.
Yes	No	Carelessness causes more accidents than speed.
Yes	No	When I am upset, driving helps soothe my nerves.
Yes	No	Speed limits are not needed in open country.
Yes	No	If speed limits are reduced any more, we might as well go back to the horse.
Yes	No	I feel perfectly confident in my own judgment of how fast to go under all conditions.
Yes	No	I'd rather have an old car with plenty of guts than a newer model with less power.
Yes	No	There is something about being behind the wheel that makes one feel bigger.
Yes	No	A good driver doesn't need the reminder of all the too many road signs.

APPENDIX K: TESTS OF IMPULSIVITY

Circle Yes or No for Each Question

Yes	No	1.	I have never done anything dangerous for the thrill of it.
Yes	No	2.	I often act on the spur of the moment without stopping to think.
Yes	No	3.	A person needs to "show off" a little now and then.
Yes	No	4.	I think I would like to fight in a boxing match sometime.
Yes	No	5.	I often do whatever makes me feel cheerful here and now, even at the cost of some distant goal.
Yes	No	6.	I like to go to parties and other affairs where there is lots of loud fun.
Yes	No	7.	I am said to be a "hothead".
Yes	No	8.	I keep out of trouble at all costs.
Yes	No	9.	Sometimes I feel like smashing things.
Yes	No	10.	I consider a matter from every standpoint before I make a decision.

Note-A longer, standardized scale consists of the following items taken from the California Psychological Inventory, Yes: 4, 20, 29, 42, 44, 48, 53, 54, 57, 66, 78, 81, 91, 93, 102, 104, 114, 115, 120, 132, 146, 151, 170, 173, 178, 183, 185, 191, 196, 208, 211, 231, 243, 248, 251, 257, 267, 275, 292, 294, 296, 297, 298, 300; No: 149, 168, 174, 223, 276, 286.

Circle a or b for Each Item

1. a. Many of the unhappy things in people's lives are partly due to bad luck. (X)
   b. People's misfortunes result from the mistakes they make.

2. a. One of the major reasons why we have wars is because people don't take enough interest in politics.
   b. There will always be wars, no matter how hard people try to prevent them. (X)

3. a. In the long run people get the respect they deserve in this world.
   b. Unfortunately, an individual's worth often passes unrecognized no matter how hard he tries. (X)

4. a. No matter how hard you try some people just don't like you. (X)
   b. People who can't get others to like them don't understand how to get along with others.

APPENDIX K: Continued

5. a. In the case of the well prepared student there is rarely if ever such a thing as an unfair test.
   b. Many times exam questions tend to be so unrelated to course work that studying is really useless. (X)

6. a. Becoming a success is a matter of hard work, luck has little or nothing to do with it.
   b. Getting a good job depends mainly on being in the right place at the right time. (X)

7. a. People are lonely because they don't try to be friendly.
   b. There's not much use in trying too hard to please people; if they like you, they like you. (X)

8. a. What happens to me is my own doing.
   b. Sometimes I feel I don't have enough control over the direction my life is taking. (X)

9. a. The average citizen can have an influence in government decisions.
   b. This world is run by a few people in power, and there is not much the little guy can do about it. (X)

10. a. As far as world affairs are concerned, most of us are the victims of forces we can neither understand nor control. (X)
    b. By taking an active part in political and social affairs the people can control world affairs.

Note-A longer, standardized scale consists of all 29 items from Rotter's Internal-External Scale. (Rotter, 1966)

APPENDIX L: TEST FOR CLERICAL ABILITY

Instructions: Below are given pairs of numbers. Put a check mark between the numbers <u>if they are not the same</u>. You will have 4 minutes.

78695____76895
67541____34621
88961____88961
76532____76532
90754____90745
67823____68723
54289____54289
00651____00671
21597____21957

etc.

APPENDIX M: IN-DEPTH HUMAN FACTORS FORM

In-Depth Human Factors Form

In-depth Case Number____ Drivers Name____________________ Number________

Address____________________ Phone________

Date of Collision__/__/__ Time__:__ AM PM

Location____________________

Interviewer____________________

Date of Interview__/__/__ Time__:__ AM PM

Location of Interview____________________ DPA ONLY: Date Rec'd___

Phase and Array Number	5 5 5	01 02 03
Number of: Traffic Units per Accident		04 05
On-Site, In-Depth Flag		06
On-Site Case Number		07 08 09 10
Traffic Unit Number		11 12
Card Number	0 1	13 14

DEMOGRAPHIC CHARACTERISTICS

1. Sex

__(1) Male
__(2) Female

15

2. Age ________ 16 17

Date of Birth: Month ________ 18 19

Day ________ 20 21

Year ________ 22 23

3. Height ______ (in inches______)
(in cm__________) 24 25

4. Weight ______lbs 26 27 28

(in kilograms__________)

5. What was the highest grade that you completed in school?

__(1) 1-7 years
__(2) 8-11 years
__(3) H.S. graduate
__(4) 1-3 years of college
__(5) College graduate
__(6) Post-grad or professional degree
__(7) Vocational, technical, or business school

29

6. Are you the main wage earner?

__(1) Yes (GO TO ITEM 9)

NO

__(2) respondent's spouse
__(3) respondent's parents
__(4) other (specify:________________
________________________)

30

7. What are you doing at the present time?

__(1) Housewife
__(2) Student
__(3) Retired
__(4) Other (specify:________________
________________________)

31

8. Do you have any kind of job - full-time or part-time - for which you receive pay?

__(1) full-time (Type of job:__________
________________________)

__(2) part-time (Type of job:__________
________________________)

__(3) None

32

In-Depth Human Factors Form

9. Now, regarding the main wage earner, how are you (or is he/she) employed? (Describe type of work ____________
________________________________)

__(1) Professional, technical, and kindred
__(2) Non-farm managers, officials and proprietors
__(3) Farmers and farm managers
__(4) Clerical and kindred
__(5) Sales workers
__(6) Craftsmen, foreman and kindred
__(7) Operatives and kindred
__(8) Private household workers
__(9) Service workers
__(10) Farm labors and foreman
__(11) Laborers, except for farm and mine
__(12) Housewife
__(13) Student
__(14) Other (specify: ____________
________________________________)

33 34

10. How long have you (or he/she) been with the present employer?

______years (in months______)

35

11. How many different employers have you (or he/she) worked for in the past five years?

____

36

12. About how much was your total family income last year? (List the combined incomes of the principal wage earners of the supporting household)

__(1) under $3,000
__(2) $3,000-5,999
__(3) $6,000-7,999
__(4) $8,000-11,999
__(5) $12,000-14,999
__(6) $15,000-19,999
__(7) $20,000-24,999
__(8) $25,000 or more

37

13. How many persons are living on this income? ____________

38

14. What is your present marital status?

__(1) single
__(2) married
__(3) divorced or separated
__(4) widowed
__(5) other (specify: ___________)

39

15. How many times, if any, have you previously been married?

__(1) never been previously married
__(2) once
__(3) two or more times
__(4) no response

40

16. Do you have any dependent children?

__(1) yes
__(2) no (GO TO ITEM 17)

How many of them presently reside with you in your home?

__(1) none
__(2) one
__(3) two
__(4) three or more

41

17. In the last ten years, how many times have you moved - moved from one address to another?

__(1) never (GO TO ITEM 19)
__(2) once
__(3) 2 or 3 times
__(4) 4 or 5 times
__(5) 6 or 7 times
__(6) 8 or more times
__(7) no response

42

18. About how far did you move the last move that you made? __________miles

43

PHYSICAL CONDITION

19. Were you feeling physically normal prior to the accident?

__(1) yes
__(2) no (explain: ________________
________________________________)

44

20. How is your general health?

__(1) excellent
__(2) good
__(3) fair
__(4) poor

45

21. Have you ever had a serious illness or injury that still bothers you?

__(1) yes (explain: ________________
________________________________)

__(2) no

46

In-Depth Human Factors Form

22. Are you disabled or do you have any physical handicaps?

__(1) Yes (explain:________________________________)

__(2) No

__ 47

23. Do you wear glasses or contact lenses?

__(1) Yes, wearing at the time of accident
__(2) Yes, not wearing at the time of accident
__(3) No

__ 48

24. Is your driver's license subject to any restrictions?

__(1) Yes, (specify:________________________________)

__(2) No

__ 49

25. Did you go to bed at your normal bedtime the evening prior to the accident?

__(1) Yes
__(2) No (explain:________________________________)

__ 50

26. How many hours of sleep did you get?

__________hours

__ __ 51 52

27. Were you sleepy or drowsy at the time of the accident?

__(1) Yes (explain:________________________________)

__(2) No

__ 53

28. Were you feeling unusually tired or fatigued from your day's activities?

__(1) Yes (explain:________________________________)

__(2) No

__ 54

PSYCHOLOGICAL CONDITION

29. Were you under any particular emotional strain before the accident?

__(1) Yes (explain:________________________________)

__(2) No

__ 55

30. Did you have any disagreements with a member of your family, a friend, or someone where you work before the accident?

__(1) Yes (explain:________________________________)

__(2) No

__ 56

Which of the following words best describes how often you (had an upset stomach) in the past year: often, sometimes, rarely, never? (Code 1, 2, 3 or 4, respectively and repeat for each condition)

31. __had an upset stomach __ 57

32. __had headaches __ 58

33. __felt nervous or tense __ 59

34. __worried about things __ 60

35. __felt depressed __ 61

How often have you found the following things to be annoying or troublesome: often, sometimes, rarely, or never? (Code 1, 2, 3, or 4, respectively and repeat for each condition)

36. __Conditions where you work (or go to school, or on last job if presently unemployed) __ 62

37. __Conditions around the neighborhood __ 63

38. __Conditions around home at the present time __ 64

39. __Conditions around your home while you were growing up __ 65

In-Depth Human Factors Form

SOCIAL PARTICIPATION

40. Do you belong to any organizations like civic groups, fraternaties, church groups, unions, and so on?

__(1) Yes (GO TO SPECIAL FORM, page 4A)
__(2) No

__ 66

DRIVING EXPERIENCE

41. How long have you been driving?

______years (in months______)

__ __ __ 67 68 69

42. How many miles do you think that you have driven in the last twelve-month period?

_________miles

(_________miles/100)

__ __ __ 70 71 72

43. Which of the following types of driver training have you successfully completed?

__(1) no driver training
__(2) high school course
__(3) college course
__(4) private driver school
__(5) other (specify:_______________

_____________________________)

__ 73

ACCIDENT/VIOLATION HISTORY

44. How many accidents prior to this one have you ever been involved in while driving?

_____________accidents

__ __ 74 75

45. How many of these occurred in the last 5 years?

_____________accidents

__ __ 76 77

46. How many of these occurred in the last two years?

_____________accidents

__ __ 78 79

47. How many of these occurred in the last year?

_____________accidents

__ 80

STOP

GO TO 02

48. In how many of the total number of accidents that you have been involved in were you judged at fault?

_______________accidents

__ __ 15 16

49. Has your car insurance ever been cancelled?

__(1) Yes (explain:_________________

_____________________________)

__(2) No

__ 17

How many times have you been ticketed for any of the following types of moving traffic violations?

○ Never been ticketed (GO TO ITEM 58)

50. __speeding over the limit __ __ 18 19

51. __reckless driving __ __ 20 21

52. __DWI __ __ 22 23

53. __other (specify:_______________

_____________________________) __ __ 24 25

How many times have you been ticketed for any of the following types of moving traffic violations in the past year?

○ Haven't been ticketed in the last year

54. __speeding over the limit __ __ 26 27

55. __reckless driving __ __ 28 29

56. __DWI __ __ 30 31

57. __other (specify:_______________

_____________________________) __ __ 32 33

58. Has your driver's license ever been suspended or revoked?

__(1) Yes (explain:_________________

_____________________________)

__(2) No

__ 34

In-Depth Human Factors Form

NAME OF ORGANIZATION	MEMBER	ATTENDANCE	FINANCIAL CONTRIBUTIONS	COMMITTEE MEMBER	OFFICES HELD
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
Total the number of checkmarks (✓) in each column					
	T_1	T_2	T_3	T_4	T_5

DIRECTIONS FOR USING THE SOCIAL PARTICIPATION SCALE

1. List the organizations with which the driver and spouse are affiliated (at the present time) as indicated by the five types of participation No. 1 to No. 5 across the top of the schedule. It is not necessary to enter the date at which the person became a member of the organization. It is important to enter L if the membership is in a purely local group, and to enter N if the membership is in a local unit or some state or national organization.

2. An organization means some active and organized grouping, usually but not necessarily in the community or neighborhood of residence, such as club, lodge, business or political or professional or religious organization, labor union, etc.; subgroups of a church or other institution are to be included separately provided they are organized as more or less independent entities. If applicable indicate with a checkmark (✓).

3. Record under attendance the mere fact of attendance or nonattendance without regard to the number of meetings attended. If applicable indicate with a checkmark (✓).

4. Record under contributions the mere fact of financial contributions or absence of contributions, and not the amount. If applicable indicate with a checkmark (✓).

5. Previous memberships, committee work, offices held, etc., should not be counted or recorded in computing the final score. Checkmark (✓) current committees or offices held.

6. Final score is computed by counting each membership as 1, each attended as 2, each contribution as 3, each committee membership as 4, and each office held as 5. If both driver and spouse are living together regularly in the home, add their total scores and divide the sum by two.

SOCIAL PARTICIPATION SCORE = $T_1 + 2T_2 + 3T_3 + 4T_4 + 5T_5$

$\rule{6cm}{0.4pt}$ = ___

RETURN TO PAGE 4, DRIVING EXPERIENCE

In-Depth Human Factors Form

VEHICLE FAMILIARITY

59. Is the accident vehicle your primary mode of transportation?

__(1) Yes (GO TO ITEM 60)
__No

If NO, what type of vehicle do you normally drive?

Year ______Make ______________________

Model ______________________

__(2) Full size (Buick Electra, Chevrolet Bel Air, etc.)
__(3) Intermediate (Chevelle, Charger, etc.)
__(4) Compact (Dart, Nova, etc.)
__(5) Subcompact (Vega, VW, etc.)
__(6) Sports Car (MG, Corvette, etc.)
__(7) Light truck (Pickup, Van)
__(8) Multipurpose Utility Vehicle (e.g., Jeep, Scout, Blazer, etc.)
__(9) Other (bicycle, etc.)
__(10) Don't usually drive

__ __ 35 36

60. How long have you driven the accident vehicle?

______years (in months______)

__ __ __ 37 38 39

61. How many miles have you driven it in the last twelve-month period?

______________miles

(____________miles/100)

__ __ __ __ 40 41 42 43

VEHICLE CONDITION

62. Has your vehicle had any repairs or new parts in the last 6 months?

__(1) Yes
__(2) No (GO TO ITEM 69)

__ 44

If YES, which of the following components was (were) affected? (Check all that apply and specify work done!)

63. __brakes ______________________

______________________ __ 45

64. __tires ______________________

______________________ __ 46

65. __power train ______________________

______________________ __ 47

66. __steering ______________________

______________________ __ 48

67. __suspension ______________________

______________________ __ 49

68. __other (specify: ______________________

______________________) __ 50

69. Did the vehicle have any unrepaired damage from previous accidents?

__(1) Yes (explain: ______________________

______________________)

__(2) No

__ 51

70. How do you determine when your vehicle will be serviced?

__(1) mileage-per owner's manual
__(2) mileage-per own judgment
__(3) when a problem arises
__(4) when maintenance person suggests a need
__(5) no particular method
__(6) other (specify: __________________)

__ 52

71. How many miles do you think you have driven since any of your brake shoes or pads were last replaced?

__(1) never replaced (GO TO ITEM 76)
__(2) less than 10,000 miles
__(3) 10,000 to 25,000 miles
__(4) 25,000 miles or more
__(5) don't know

__ 53

Which shoes or pads were replaced? (Check all that apply!)

72. __left front __ 54

73. __left rear __ 55

74. __right rear __ 56

75. __right front __ 57

In-Depth Human Factors Form

How long has each of your tires been in its present position?

76. Left front

__(1) less than 10,000 miles
__(2) 10,000-25,000 miles
__(3) more than 25,000
__(4) don't know

__ 58

77. Left rear

__(1) less than 10,000 miles
__(2) 10,000-25,000 miles
__(3) more than 25,000
__(4) don't know

__ 59

78. Right rear

__(1) less than 10,000 miles
__(2) 10,000-25,000 miles
__(3) more than 25,000
__(4) don't know

__ 60

79. Right front

__(1) less than 10,000 miles
__(2) 10,000-25,000 miles
__(3) more than 25,000
__(4) don't know

__ 61

80. Do you think all of your tires have sufficient tread?

__(1) yes
__(2) no (explain:________________
________________)
__(3) don't know

__ 62

81. When were your tire pressures last checked?

__(1) within the last week
__(2) more than a week but less than a month
__(3) more than a month
__(4) don't know

__ 63

82. Was there any part of the vehicle that was not working properly immediately before the accident?

__(1) Yes (explain:________________
________________)
__(2) No

__ 64

83. Was there anything in particular about the vehicle which may have contributed to the accident?

__(1) Yes (explain:________________
________________)
__(2) No

__ 65

TRIP/ROADWAY

84. Where did your trip originate?

__(1) home
__(2) work
__(3) shopping
__(4) school
__(5) recreation
__(6) friends or relatives
__(7) restaurant
__(8) personal business
__(9) cocktail/bar/wet party
__(10) other (specify:________________
________________)

__ 66

85. What was the intended destination of the trip?

__(1) home
__(2) work
__(3) shopping
__(4) school
__(5) recreation
__(6) friends or relatives
__(7) restaurant
__(8) personal business
__(9) cocktail/bar/wet party
__(10) other (specify:________________
________________)

__ 67

What was the purpose of this trip?

____

____

Approximately how far was the intended trip (origin to intended destination)?

________________miles

(in kilometers__________)

__ __ __ __
68 69 70 71

What time did you depart?

______________AM/PM

__ __ __ __
72 73 74 75

(24hr. time__________)

In-Depth Human Factors Form

How long did you expect the trip to take?

____________________________ __ __ 76 77

How long a time were you in the car before the accident happened?

____________________________ __ __ 78 79

86. How long have you been driving in this general area?

STOP

GO TO 03

______________years

(in months____________) __ __ __ 15 16 17

87. How often do you drive the road on which the accident took place?

__(1) daily
__(2) twice weekly
__(3) once weekly
__(4) twice monthly
__(5) once monthly
__(6) very infrequently
__(7) first time on road

__ 18

88. Were you confused in any way by the roadway or control devices?

__(1) Yes (explain:____________________________)

__(2) No

__ 19

RESTRAINT USAGE

89. Is your vehicle equipped with adjustable head rests?

__(1) Yes (specify their pre-crash adjusted position____________________________)

__(2) No

__ 20

90. Were you wearing a seatbelt at the time of the accident?

__(1) Yes (GO TO ITEM 91)
__No

If NO, which of the following best describes your reason for not using a seatbelt?

__(2) not available
__(3) inconveinent to use
__(4) uncomfortabel
__(5) forgot
__(6) not in habit
__(7) used only when traveling
__(8) don't believe in using them (explain:____________________________)
__(9) other (specify:____________________________)

__ __ 21 22

91. Were you wearing a shoulder harness at the time of the accident?

__(1) Yes (GO TO ITEM 92)
__No

If NO, which of the following best describes your reason for not using a shoulder harness?

__(2) not available
__(3) inconvenient to use
__(4) uncomfortable
__(5) forgot
__(6) not in habit
__(7) used only when traveling
__(8) don't believe in using them (explain:____________________________)
__(9) other (specify:____________________________)

__ __ 23 24

92. Is your vehicle equipped with a safety belt interlock system?

__(1) Yes (GO TO SPECIAL FORM Page 7A)
__(2) No

__ 25

In-Depth Case Number:

Safety Belt Interlock System

Traffic Unit Number:

PART I - VEHICLE INSPECTION

1. Was the interlock system operational before the crash?

    __(1) Unknown
    __(2) Yes (Disregard remaining questions in Part I)
    __(3) No
    15

2. Was any part of the system intentionally defeated?

    __(1) Unknown
    __(2) Yes
    __(3) No (GO TO QUESTION 10)
    16

If intentionally defeated, in what manner was it done? ◯ Unknown

3. __Belt buckled behind occupant 17
4. __Lap belt cut 18
5. __Shoulder belt cut 19
6. __Buzzer rendered inoperative 20
7. __Logic mechanism altered 21
8. __Logic mechanism by-passed by ignition circuit 22
9. __Other (explain):______________ 23
10. If questions 1 and 2 were negative, describe failure mode of the system.

    ____

PART II - DRIVER INTERVIEW

11. Have you or any other person ever attempted to defeat or "get around" any apsect of the starter interlock system? (Including warning buzzer, lights, switches, etc.).

    __(1) Unknown
    __(2) Yes
    __(3) No (GO TO QUESTION 37)
    24

Why was the attempt made to defeat the system? ◯ Unknown

12. __Took too long to start the car 25
13. __Do not like to wear restraints 26
14. __Passengers complained about being forced to wear restraints 27
15. __No objection to wearing restraints, but I will not be forced to do so in my own automobile 28
16. __Other:______________ 29

How was the system defeated? ◯ Unknown

17. __Unable to defeat the system (GO TO QUESTION 36) 30
18. __Wired around the system to the starter 31
19. __Disconnected the buzzer 32
20. __Shorted the seat sensors 33
21. __Tied the belts in knots 34
22. __Permanantly buckled the belts 35
23. __Tuck the belts under the carpet after starting the car 36
24. __Buckled the belt behind occupant after starting the car 37
25. __Cut the shoulder belt 38
26. __Cut the lap belt 39
27. __Altered the logic mechanism (If yes, explain):______________ 40
28. Other:______________ 41

Who accomplished this? ◯ Unknown

29. __Driver 42
30. __Owner (not driver) 43
31. __Automobile dealer 44
32. __Garage mechanic 45
33. __Relative 46
34. __Friend 47
35. __Other:______________ 48
36. Why were you unable to defeat the system?

    __(1) Unknown
    __(2) Too hard to get to
    __(3) Did not have proper tools
    __(4) Did not know enough about the system
    __(5) Other:______________
    __(6) N/A
    49

37. How many times has your vehicle failed to start when you went through the normal fastening routine?

    ______________ 50 51

38. Did you then attempt to defeat the system?

    __(1) Unknown
    __(2) Yes
    __(3) No
    __(4) N/A
    52

39. How many times has your vehicle started but then stalled after going through the normal fastening and starting routine?

    ______________ 53 54

In-Depth Human Factors Form

DRUG/ALCOHOL USAGE

Had you taken any medication or drug other than alcohol within 48 hours of the collision? (Check all that apply!)

( ) None (GO TO ITEM 102)

93. __stimulants - prescriptive/narcotic __ 26

94. __stimulants - nonprescriptive __ 27

95. __depressants - prescriptive/nartic __ 28

96. __depressants - nonprescriptive __ 29

97. __marijuana __ 30

98. __hallucinogens __ 31

99. __antihistamines __ 32

100. __other __ 33

Specify drug name(s), prescription Number(s), recommended dosage(s) and time taken.

NAME	PRESCRIPT.#	DOSAGE	TIME TAKEN
______		______	__/__/__
______	______	______	__/__/__
______		______	__/__/__

REFER TO PHYSICIAN'S DESK REFERENCE (PDR) FOR THE CLASSIFICATION OF A PARTICULAR DRUG

101. In your opinion, did the drug(s) impair your driving ability in any way?

__(1) Yes (explain:______________________

______________________________)

__(2) No __ 34

102. Had you consumed any alcoholic beverages within 24 hours of the accident?

__(1) Yes
__(2) No (GO TO ITEM 113) __ 35

How much of the following types of beverages did you consume? (Indicate quantity of each type)

103. __bottles of beer __ __ 36 37

104. __glasses of wine __ __ 38 39

105. __drinks containing hard liquor __ __ 40 41

106. Over what period of time did you consume these beverages?

__(1) one hour
__(2) two hours
__(3) three hours
__(4) four hours
__(5) five hours
__(6) six or more hours
__(7) don't know __ 42

107. How long before the accident did you consume your last drink?

__(1) less than one hour
__(2) 1-2 hours
__(3) 3-4 hours
__(4) 5-6 hours
__(5) more than 6 hours
__(6) don't know __ 43

108. In your opinion, was your drinking in any way involved in the accident?

__(1) Yes
__(2) No (GO TO ITEM 113) __ 44

If YES, in which of the following ways was it related? (Check all that apply!)

109. __impaired physical response __ 45

110. __impaired judgment __ 46

111. __impaired perception __ 47

112. __other (specify:________________

______________________________) __ 48

MISCELLANEOUS

113. Do you normally drive with one or both hands on the steering wheel?

__(1) left hand only
__(2) right hand only
__(3) both hands
__(4) either hand __ 49

In-Depth Human Factors Form

114. Which foot do you normally brake with?

__(1) right foot
__(2) left foot
__(3) either

50

115. Were all of your vehicle's windows and vents closed at the time of the accident?

__(1) Yes
__(2) No

51

116. Did you have your air conditioner, heater, or defroster operating at the time of the accident?

__(1) Yes (specify:________________)
__(2) No

52

117. Do you smoke?

__(1) Yes, but not smoking at the time of accident.
__(2) Yes, and smoking at time of accident.
__(3) No

53

118. Were you wearing sunglasses at the time of the accident?

__(1) Yes
__(2) No

54

119. Were you carrying luggage or cargo in the vehicle at the time of the accident?

__(1) Yes (describe its location and estimate its weight:______________
______________________________)
__(2) No

55

HAVE THE DRIVER FILL OUT THE DRIVER KNOWLEDGE AND DRIVER OPINION QUESTIONNAIRES.

ACCIDENT SUMMARY

120. How did the driver describe the traffic conditions at the time of the accident?

__(1) heavy
__(2) moderate
__(3) light
__(4) no other traffic present

56

121. Did the driver indicate that he/she was in a hurry?

__(1) Yes (explain:__________________
______________________________)
__(2) No

57

122. Did the driver indicate that his/her mind was wandering or preoccupied?

__(1) Yes (explain:__________________
______________________________)
__(2) No

58

Did the driver report any activity or occurrence inside the car that might have diverted his/her attention from the driving task? (Check all that apply!)

◯ no internal distractions

123. __talking 59

124. __listening to tape player or radio 60

125. __adjusting controls 61

126. __smoking 62

127. __eating 63

128. __other (specify:________________
______________________________) 64

Did the driver report anything outside the car that might have distracted his/her attention from the driving task? (Check all that apply!)

◯ no outside distractions

129. __other traffic 65

130. __pedestrians 66

131. __unusual event like loud noise 67

132. __driver-selected outside activity 68

133. __other (specify:________________
______________________________) 69

In-Depth Human Factors Form

Did the driver report anything that might have impaired or blocked his/her view of the area in which the accident took place. (Check all that apply!)

○ no view obstructions

134. __other traffic — 70

135. __curve(s) in road or hillcrest — 71

136. __trees or foliage — 72

137. __embankment — 73

138. __roadside structure — 74

139. __parked vehicle — 75

140. __other (specify:______________
______________________________) — 76

141. How fast did the driver say he was traveling prior to entering the collision sequence?

______________mph — 77

142. When was the first time the driver perceived the threatening situation? (Approximate distance in feet)

______________feet — 78 79 80

143. Pre-crash vehicle movement:

STOP

GO TO 04

__(1) straight ahead
__(2) turning, curve following
__(3) U-turn
__(4) reverse, backing
__(5) lane changing, passing
__(6) parked, stopped
__(7) entering/leaving private driveway - use #4 if backing in
__(8) starting to move
__(9) unknown

15

144. Character of vehicle movement:

__(1) straight ahead
__(2) straight ahead, road turned to left
__(3) straight ahead, road turned to right
__(4) off righthand-side of road
__(5) off righthand-side of lane
__(6) off righthand-side and back again
__(7) veered right
__(8) turned hard right
__(9) off lefthand-side of road
__(10) off lefthand-side of lane
__(11) off lefthand-side and back again
__(12) veered left
__(13) turned hard left
__(14) vehicle stopped
__(15) other (specify:______________
______________________________)
__(16) unknown

16 17

145. Did the driver attempt any kind of evasive action?

__(1) none (GO TO ITEM 147)
__(2) braked only
__(3) steered only
__(4) accelerated only
__(5) braked then steered
__(6) steered then braked
__(7) simultaneously braked and steered
__(8) other (specify:______________
______________________________)
__(9) unknown

18

146. Did the vehicle respond to the evasive action as the driver expected?

__(1) Yes
NO
__(2) fishtailed while skidding
__(3) lost steering control while skidding
__(4) lost control/not skidding
__(5) rolled over on roadway without collision
__(6) other (specify:______________
______________________________)
__(7) unknown

19

147. If evasive action could have been taken but was not, then why not?

__(1) none possible
__(2) delayed reaction
__(3) insufficient time
__(4) misjudgment
__(5) unsure of other driver's action
__(6) panic
__(7) other (specify:______________
______________________________)

20

In-Depth Human Factors Form

In the driver's opinion, could he have done anything differently that might have prevented or reduced the severity of the accident? (Check all that apply!) ◯ None

148. __could have gone slower or adjusted speed — 21

149. __could have accelerated to safety — 22

150. __could have steered to safety — 23

151. __could have applied brakes differently — 24

152. __could have been more alert or paid closer attention — 25

153. __could have signaled for turn, lane change, etc. — 26

154. __could have signaled other driver with horn — 27

155. __could have had related vehicle defect corrected or repaired — 28

156. __could have anticipated a potentially dangerous situation — 29

157. __other (specify:________________________________) — 30

158. How fast did the driver say he was traveling at impact?

________mph — 31 32

159. What were the driver's actions at impact?

__(1) unaware, no action
__(2) braced
__(3) covered face with hands
__(4) other — 33

160. What was the driver's post-impact position in the car?

__(1) normal driving position
__(2) thrown from normal driving position — 34

161. What were the driver's immediate post-impact actions?

__(1) no action
__(2) exited the vehicle
__(3) moved vehicle off road
__(4) assisted injured persons
__(5) other (specify:________________________________) — 35

162. Was an ambulance required for the driver or his/her passengers?

__(1) Yes
__(2) No — 36

163. How was the car removed from the scene?

__(1) towed
__(2) driven away — 37

164. Who notified the police of the accident's occurrence?

__(1) driver
__(2) other (specify:________________________________)
__(3) don't know — 38

165. Driver's opinion of police actions:

__(1) positive
__(2) negative (explain:________________________________)
__(3) no opinion — 39

166. Driver's assessment of principal human fault:

__(1) self
__(2) other driver
__(3) pedestrian
__(4) other (specify:________________________________) — 40

167. Driver's ranking of relative contribution of human vehicular and environmental factors (rank 1,2,3)

__(1) human — 41

__(2) vehicular — 42

__(3) environmental — 43

In-Depth Human Factors Form

168. Interviewer's general impression of respondent's attitude and demeanor:

__(1) hostile, uncooperative
__(2) suspicious, guarded
__(3) causal, impersonal
__(4) friendly, cooperative

__ 44

ENTER TEST SCORES WHERE APPLICABLE

169. __Driver Knowledge Test __ __ 45 46

170. __Pelz-Schuman Driver Opinion Questionnaire __ __ 47 48

171. __MAST __ __ 49 50

Describe anything that occurred during the interview that you think may have influenced the accuracy or completeness with which the respondent answered the questions.

Is there anything that you can add about his/her driving practices, his/her attitudes and his/her environment which may not be clear from the questionnaire? Please include any impressions that might help us do a better job of analyzing this accident.

NOTES:

In-Depth Human Factors Form: Status Review

TO THE INVESTIGATOR: Place a check mark (✓) in the appropriate square to the right of each attachment item to indicate its status. Be certain to code the in-depth case number and traffic unit number at the top of the 1st page of each supplementary form!

ATTACHMENT ITEM	Page(s)	Array	Card	From Column	To Column	Completed	Pending	Not Completed
Safety Belt Interlock System	7A	52	01	15	54			
Occupant Factors Form	A-1,2	24	01 02	15 15	80 49			
Driver Knowledge Test	B-1,2	53	01	15	34			
Pelz-Schuman Driver Opinion Questionnaire	C-1,3	50	01	15	64			
Dynamic Vision Test	D-1,2	54	01 02	15 15	75 32			
Michigan Alcohol Screening Test (MAST)	N/A	N/A	N/A	N/A	N/A			

TO THE CODERS:

<u>Completed</u> status means the data or tests are present and the results have been entered on the page(s) indicated, if applicable.

<u>Pending</u> status indicates that while the data is not yet in the file, it is expected to be <u>Completed</u> at some later time. The respective arrays should be left blank.

<u>Not Completed</u> status means that the particular data item was either not ascertained or inapplicable. Do not code the associated array for this traffic unit.

The data contained in each Attachment will be keypunched as a separate array beginning and ending in the card columns indicated. The data on the attached page(s) also applies to the traffic unit indicated on page one. Therefore, in keypunching the header information, only the array number will change.

In-Depth Case Number:

In-Depth Human Factors Form
Occupant Information

Traffic Unit Number:

Fill in the chart using the appropriate codes from below.
(Enter any additional information on back of page)

OCC. No.	SEAT POSITION	RE-STRAINTS USED	RE-STRAINTS AVAILABLE	AGE	SEX	AIS	HEIGHT	WEIGHT	AREAS OF OCCUPANT CONTACT
1									
2									
3									
4									
5									
6									
7									
8									
9									

SEX
1=Male
2=Female

Seated Position
01=Left front
02=Center front
03=Right front
04=Left rear
05=Center rear
06=Right rear
07=Left third seat
08=Center third seat
09=Right third seat
10=Bed of truck
11=Inside pickup camper
12=Other
13=Unknown

RESTRAINTS USED AND AVAILABLE
1=None
2=Lap belt only
3=Shoulder belt only
4=Lap and Shoulder belt
5=Unknown

AIS
0=No injury
1=Minor
2=Moderate
3=Severe injuries (not life-threatening)

AIS cont.
4=Severe injuries (life-threatening, survival probable)
5=Critical injuries
6=Fatality (one fatal lesion)
7-8-9: Review AMA codes
10=Unknown

CODES FOR AREAS OF OCCUPANT CONTACT

00=Unknown
01=Air conditioning or ventilation outlets
02=Glove compartment area
03=Hardware items (ashtray, instruments, knobs, etc.)
04=Heater or AC ducts
05=Instrument panel
06=Mirrors
07=Parking brake
08=Radio
09=Steering assembly
10=Sunvisors & fittings, and/or top molding (header)
11=Transmission selector lever
12=Windshield
13=Armrests
14=A-pillar
15=B-pillar

AREAS OF CONTACT CONT.

16=C-pillar
17=D-pillar
18=Courtesy lights
19=Hardware (sides)
20=Surface of side interiors
21=window frames
22=Window glass
23=Backlight (rear window)
24=Coat hooks
25=Roof or convertible top
26=Roof side rails
27=Console
28=Foot controls
29=Back of seats
30=Head restraints
31=Interior loose object
32=Other occupants
33=Restraint system hardware
34=Restraint system webbing
35=Hood
36=Objects exterior to car
37=Outside surface of car
38=Other
39=Backlight header
40=Other occupants
41=Flying glass
42=Tapedecks
43=Road surface
44=Eye glasses
45=Floors
50=No contact

In-Depth Human Factors Form

Occupant No.________________

1. This form should be filled out for each injured occupant. Add additional forms if necessary.
2. Check boxes to indicate type of injury to each body region, if known.
3. If you are reasonably assured that one or more specific components or areas contacted by this occupant resulted in an associable injury enter the proper code(s) in the starred (*) section. (See page A ((occupant injury)) for codes)
4. Describe specific occupant injuries on the back of this sheet.

BODY REGION	*ENTER CODE(S) FOR AREAS OF POSSIBLE CONTACT				CHECK TYPE OF INJURY									
	1	2	3	4	OVERALL INJURY TO BODY REGION	FRACTURE	LACERATION	CONTUSION	COMPLAINT OF PAIN	ABRASION	CONCUSSION	BURN	HEMORRHAGE	OTHER
Internal Organs						/					/			
Brain						/								
Face											/			
Head											/			
Neck (Cervical Region)											/			
Shoulder Girdle											/			
Right Upper Limb											/			
Left Upper Limb											/			
Chest & Upper Back (Thorax)											/			
Lower Back (Lumber Region)											/			
Abdomen						/					/			
Pelvic Girdle											/			
Right Lower Limb											/			
Left Lower Limb											/			
Whole Body						/					/		/	

In-Depth Case Number:

In-Depth Human Factors Form
Driver Knowledge Questionnaire

Traffic Unit Number:

Please read each question carefully and select the one response that you feel best answers it. Indicate your choice by placing an "x" in the corresponding blank on its left. Be sure that you answer every question and that you mark one and only one response!

1. Under normal conditions the top speed limit for driving in a business district is:

__(1) 15 mph
__(2) 20 mph
__(3) 25 mph
__(4) 30 mph ___ 15

2. If there are no painted lines on the road you:

__(1) May drive anywhere on your side.
__(2) Should drive as if there were lines.
__(3) Should drive wherever traffic is moving the fastest.
__(4) May drive in the center of the road. ___ 16

3. When driving at dusk or dawn, or on an unusually dark day:

__(1) Turn on your parking lights.
__(2) Keep your sunglasses on to cut down headlight glare.
__(3) Turn your lights on high beam.
__(4) Turn your lights on low beam. ___ 17

4. If your brakes are not holding because they are wet, you should:

__(1) Continue driving and they will dry off.
__(2) Keep one foot on the gas and one lightly on the brake until dry.
__(3) Stop on the side of the road and wait for them to dry.
__(4) Don't use your brakes until they are dry. ___ 18

5. For driving on sand or snow, the best forward traction can be attained:

__(1) By letting air out of the rear tires so they are several pounds below.
__(2) By letting air out of the rear tires and adding weight over the driving wheels.
__(3) By simply keeping the tires at their recommended pressure.
__(4) By adding weight over the driving wheels and keeping them at recommend or slightly higher pressure. ___ 19

6. When you want to make a right turn into a driveway you should:

__(1) Avoid stopping on the road.
__(2) Swing to the left before making the turn.
__(3) Signal after you begin to turn.
__(4) Signal the traffic behind you to pass ___ 20

7. If you come to an intersection that is hard to see around because of trees or buildings:

__(1) Proceed as if there was a yield sign at the intersection.
__(2) Stop near the center of the intersection and then continue when it is safe.
__(3) Slow down and blow your horn to warn drivers who cannot see you.
__(4) Stop at the intersection and edge forward slowly. ___ 21

8. The most dangerous time to drive in the rain is:

__(1) Just before the rain starts because it gets dark but most motorists have not slowed down yet.
__(2) Just after the rain starts because the rain mixes with road film making the roads slick.
__(3) After it has rained for about 30 minutes because the rain has washed away all the grit that gives you traction
__(4) Just after the rain stops because other motorists can see again, and start to drive faster but the streets are still wet. ___ 22

9. If brakes are applied continually, such as is necessary when coming down a long, steep grade, they may become very hot. When this happens:

__(1) The brake warning lamp on the dashboard will come on.
__(2) The brakes will loose their stopping ability.
__(3) The brakes will improve in effectiveness; brakes work best when hot.
__(4) The brakes should operate normally, since heat has very little effect on them. ___ 23

In-Depth Human Factors Form
Driver Knowledge Questionnaire

10. If you are driving at high speed and have a blowout, you should:

__(1) Let go of the steering wheel because the car will straighten itself automatically.
__(2) Step hard on the brakes to stop as quickly as possible.
__(3) Apply the brakes gently, with extreme caution.
__(4) Pull off the road first then slow down. 24

11. If the rear of your vehicle is skidding to the left you should:

__(1) Move the steering wheel back and forth in a zig-zag pattern.
__(2) Turn the top of your steering wheel to the left.
__(3) Hold your steering wheel from moving until out of the skid.
__(4) Turn the top of your steering wheel to the right. 25

12. If you cannot stop in time before hitting another vehicle, it is best to:

__(1) Gradually slow down and then hit the other vehicle.
__(2) Blow the horn and continue at normal speed.
__(3) Try to steer around the vehicle and avoid braking hard.
__(4) Remove your foot from the gas and put on the brake as hard as possible. 26

13. If you have locked your vehicle's brakes and you are sliding toward another vehicle, you should:

__(1) Attempt to steer around the vehicle.
__(2) Sound your horn and flash your lights.
__(3) Pump your brakes and attempt to steer around the vehicle. 27
__(4) Use your emergency brake.

14. If you know that you will soon be making a turn you should:

__(1) Look well ahead to locate the turning point.
__(2) Blow the horn several hundred feet before you turn.
__(3) Flash your bright lights to warn other traffic.
__(4) Speed up so as to avoid making other vehicles wait. 28

15. If the signal at a railroad crossing does not indicate that a train is coming you should:

__(1) Speed up and cross the track quickly.
__(2) Continue at the same speed and check for a train before crossing.
__(3) Slow down and look both ways.
__(4) Come to a complete stop before continuing across. 29

16. When passing a vehicle you should return to the right side of the road when:

__(1) You are 50 feet in front of the passed vehicle.
__(2) The other driver signals you to do so.
__(3) You have cleared the front bumper by a vehicle length.
__(4) You can see its entire front end in your rearview mirror. 30

17. It is best to check tire pressures:

__(1) After the car has been parked for a long time and the tires are "cold".
__(2) After the car has been driven vigorously and the tires are "hot".
__(3) Whenever convenient; it doesn't matter if the tires are hot or cold.
__(4) With the car on a lift, so that there is no weight on the tires. 31

18. When driving through fog at night, you should use your:

__(1) High beam headlights.
__(2) Parking lights.
__(3) Low beam headlights. 32
__(4) 4-way flashers.

19. Before leaving the road to avoid a head-on crash you should slow down by:

__(1) Pumping the brakes.
__(2) Applying constant pressure on the brakes.
__(3) Turning off the engine. 33
__(4) Shifting into neutral.

20. At night you should drive slow enough to be able to stop within:

__(1) 5 car lengths.
__(2) The distance lighted by your headlights.
__(3) The time it takes for a light to change from yellow to red.
__(4) 10 seconds from the time you hit the brake. 34

In-Depth Human Factors Form
Driver Opinion Supplement
Array 50

In-Depth Case Number: Traffic Unit Number:

DOS ONLY

1. What is your cummulative grade-point average (GPA) as a student?

__(1) A
__(2) B
__(3) C
__(4) D
__(5) Don't know

__(6) Check here if you are a high school graduate

15

Most drivers have to take a chance now and then -- such as passing on a winding road, driving fast on a wet road, or turning left in front of oncoming traffic.

Some drivers will be more likely to take a chance when other people are in the car; some drivers will be more likely to take a chance when driving alone. How about you?

CIRCLE ONE ANSWER IN EACH LINE

	More likely to take a chance	Less likely to take a chance	Same as alone	Don't drive with such a person	Never take chances	DOS ONLY
2. With a friend(s) in the car	1	2	3	4	5	16
3. With a date (or wife/ husband	1	2	3	4	5	17
4. With a parent(s) in the car	1	2	3	4	5	18

In this research we want to find out how people actually drive. Listed below are many things that people sometimes do when they drive. As you think back over the past month (or typical month), about how often would you estimate that you did each of these things?

CIRCLE ONE ANSWER IN EACH LINE

	Not at all	Once or twice	Each week	Almost daily	No idea	DOS ONLY
5. Drove with a radio or stereo on (or check here if no radio __)	1	2	3	4	5	19
6. Drove with one hand on wheel	1	2	3	4	5	20
7. Drove through a yellow light	1	2	3	4	5	21
8. Had a friendly race with another car	1	2	3	4	5	22
9. Kept up with traffic that was going 10 mph over the speed limit	1	2	3	4	5	23
10. Drove 15 mph or more over the prevailing traffic inside the city	1	2	3	4	5	24
11. Drove 10 mph or more over the prevailing traffic on an open highway	1	2	3	4	5	25
12. Dared or took a dare from another car	1	2	3	4	5	26

... Continued on next page ...

In-Depth Human Factors Form
Driver Opinion Supplement

DOS ONLY

In addition to driving at different times of day, and on different kinds of roads, people also drive when they are in different states of mind.

Again think of the past month, or if that was very different from your usual driving, think of a typical month. How often in that month did you drive in each state of mind listed below? A rough estimate is okay.

CIRCLE ONE ANSWER IN EACH LINE

	Not at all	Once or twice	Each week	Almost daily	No idea	
13. When I was tired or sleepy	1	2	3	4	5	27
14. When I was in a hurry	1	2	3	4	5	28
15. When I felt worried or depressed	1	2	3	4	5	29
16. In order to get away from people and be on my own	1	2	3	4	5	30
17. When I was smoking	1	2	3	4	5	31
18. When I was angry	1	2	3	4	5	32
19. After a couple of drinks	1	2	3	4	5	33

In a typical week last month, please estimate roughly how much time you spend driving for each of the following purposes (where you were the driver, not a passenger). Write your answer in hours. If you did no driving for some purpose, write "0". (Not time just sitting in the car, or at a store or a movie, but actually driving.)

Hours per week (rough estimate)

20. Driving to or from work, or as part of my job ____________ Hrs. 34 35 36

21. Driving to or from school ____________ Hrs. 37 38

22. For recreation, shopping visiting, etc. ____________ Hrs. 39 40 41

23. Sum of these = TOTAL HOURS driving per week ____________ Hrs. 42 43 44

Besides the time you were actually driving to and from places such as to work, school, stores, etc., how much time did you spend in an average recent week in these ways?

Hours per week

24. Working on cars (my own, or friends') -- repairing, testing, cleaning, etc. ____________ Hrs. 45 46 47

25. Being in an around cars for fun and entertainment such as at drive-ins, with friends, etc. ____________ Hrs. 48 49

Sum of these . . . . ____________ Hrs. 50 51 52

... Continued on next page ...

In-Depth Human Factors Form
Driver Opinion Supplement

DOS ONLY

Within the past year, how often have you felt or done the following things?

CIRCLE ONE ANSWER IN EACH LINE

	Not at all	Once or twice	Every month	Every week	Almost daily	DOS ONLY
26. Been mad enough to feel like smashing something, but didn't	1	2	3	4	5	53
27. Been mad enough so I actually did smash something	1	2	3	4	5	54
28. Felt like getting into a fist fight with someone but didn't	1	2	3	4	5	55
29. Actually got into a fight and hit somebody	1	2	3	4	5	56

At present, how much of the time do you feel pressure from other people who are trying to tell you how to run your life?

CIRCLE ONE ANSWER IN EACH LINE

Pressure From:	Hardly ever	Once in a while	Some of the time	Most of the time	Almost always	DOS ONLY
30. My parents or other older relatives	1	2	3	4	5	57
31. My wife (husband) or girlfriend (boyfriend)	1	2	3	4	5	58
32. Friends or relatives my own age	1	2	3	4	5	59
33. People who have authority over me	1	2	3	4	5	60

Sometimes, after an argument or quarrel, people go out for a drive to help them "blow off steam." During the past three months, how often have you gone driving to blow off steam after an argument?

CIRCLE ONE ANSWER IN EACH LINE

How often in three months:

After an argument with:	Not at all	Once or twice	Every month	Every week	Almost daily	DOS ONLY
34. My parent or other older relative	1	2	3	4	5	61
35. My wife (husband) or girlfriend (boyfriend)	1	2	3	4	5	62
36. One of my friends or relatives my own age	1	2	3	4	5	63
37. People who have authority over me	1	2	3	4	5	64

END, THANK YOU!

In-Depth Human Factors Form
Dynamic Vision Test

$\frac{5}{01}$ $\frac{5}{02}$ $\frac{4}{03}$ Duplicate columns 04-14 from page 1 from Array 55.

In-Depth Case Number: ___ Traffic Unit Number: ___

1. Static Acuity--No Glare: Normal

R	L	B	L	B	T
<u>175</u>	<u>150</u>	<u>125</u>	<u>100</u>	<u>85</u>	<u>70</u>
T	L	R	T	L	B
R	L	B	R	B	R
L	T	T	B	T	L
R	B	L	T	B	R
L	R	B	L	R	T
B	R	T	T	L	R

....

___ ___ ___ (15 16 17)

T	B	L	B	L	R	L	T	R
<u>85</u>	<u>70</u>	<u>60</u>	<u>50</u>	<u>40</u>	<u>35</u>	<u>30</u>	<u>25</u>	<u>20</u>
L	B	T	L	T	B	T	R	B
B	R	B	R	B	R	R	R	L
T	L	L	T	L	T	L	B	R
B	R	R	B	T	T	R	T	T
R	T	B	L	R	L	L	L	B
L	R	L	T	B	B	B	T	R

2. Central Angular Movement

(Practice: R L)

256	L	R
128	R	L
64	R	L
32	L	R
16	R	L
12	L	R
8	L	R
6	R	L
4	R	L
2	L	R

TOTAL: ___ ___ (18 19)

THRESHOLD: ___ ___ ___ (20 21 22)

3. Central Movement In-Depth

190	L	L
128	L	S
64	S	L
32	S	L
16	L	S
12	L	S
8	S	L
6	S	L
4	S	L
2	L	S

TOTAL: ___ ___ (23 24)

THRESHOLD:

SMALL: ___ ___ ___ (25 26 27)

LARGE: ___ ___ ___ (28 29 30)

4. Peripheral Angular Movement

(Practice: R L)

	<u>Left Eye</u>	<u>Right Eye</u>
256	L	R
128	R	L
64	R	L
32	L	R
16	R	L
12	L	R
8	L	R
6	R	L
4	R	L
2	L	R

TOTAL: ___ ___ (31 32)

THRESHOLD: ___ ___ ___ (33 34 35)

5. Peripheral Movement In-Depth

	<u>Right Eye</u>	<u>Left Eye</u>
190	L	L
128	L	S
64	S	L
32	S	L
16	L	S
12	L	S
8	S	L
6	S	L
4	S	L
2	L	S

TOTAL: ___ ___ (36 37)

THRESHOLD:

SMALL: ___ ___ ___ (38 39 40)

LARGE: ___ ___ ___ (41 42 43)

6. Peripheral Movement Tone Count

(Subtract total number of tones sounded in <u>BOTH</u> items 4 and 5 above from 40 and enter the resultant score in the columns to the right)

___ ___ (44 45)

7. Static Acuity--No Glare: Low Level

R	L	B	L	B	T
<u>175</u>	<u>150</u>	<u>125</u>	<u>100</u>	<u>85</u>	<u>70</u>
T	L	R	T	L	B
R	L	B	R	B	R
L	T	T	B	T	L
R	B	L	T	B	R
L	R	B	L	R	T
B	R	T	T	L	R

....

___ ___ ___ (46 47 48)

T	B	L	B	L	R	L	T	R
<u>85</u>	<u>70</u>	<u>60</u>	<u>50</u>	<u>40</u>	<u>35</u>	<u>30</u>	<u>25</u>	<u>20</u>
L	B	T	L	T	B	T	R	B
B	R	B	R	B	R	R	R	L
T	L	L	T	L	T	L	B	R
B	R	R	B	T	T	R	T	T
R	T	B	L	R	L	L	L	B
L	R	L	T	B	B	B	T	R

In-Depth Human Factors Form
Dynamic Vision Test

ORDER	8. Field of Vision		9. Detection, Acquisition, & Interpretation 90° Angle		10. Detection, Acquisition, & Interpretation 35° Angle	
	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye
1	L70		T70		R10	
2		R70		R70		L10
3	L90		L90		R20	
4	L70		L70		L30	
5		R80		T80		B15
6		R90		B90		R20
7	L80		R80		T15	
8		R90		L90		L35
9	L60		B60		B25	
10	L90		T90		R35	
11		R60		R60		B25
12		R70		L70		T30
13		R80		B80		L35
14	L80		R80		T35	
TOTAL	49	50	55	56	61	62
THRESHOLDS	51 52	53 54	57 58	59 60	63 64	65 66

11. Dynamic Visual Acuity 120° Angle

R T B L R T L L T B R

200 175 150 125 100 85 70 60 50 40 30

67 68 69

12. Static Acuity--Veiling Glare

R	L	B	L	B	T
175	150	125	100	85	70
T	L	R	T	L	B
R	L	B	R	B	R
L	T	T	B	T	L
R	B	L	T	B	R
L	R	B	L	R	T
B	R	T	T	L	R

70 71 72

T	B	L	B	L	R	L	T	R
85	70	60	50	40	35	30	25	20
L	B	T	L	T	B	T	R	B
B	R	B	R	B	R	R	R	L
T	L	L	T	L	T	L	B	R
B	R	R	B	T	T	R	T	T
R	T	B	L	R	L	L	L	B
L	R	L	T	B	B	B	T	R

13. Static Acuity--Spot Glare

R	L	B	L	B	T
175	150	125	100	85	70
T	L	R	T	L	B
R	L	B	R	B	R
L	T	T	B	T	L
R	B	L	T	B	R
L	R	B	L	R	T
B	R	T	T	L	R

73 74 75

T	B	L	B	L	R	L	T	R
85	70	60	50	40	35	30	25	20
L	B	T	L	T	B	T	R	B
B	R	B	R	B	R	R	R	L
T	L	L	T	L	T	L	B	R
B	R	R	B	T	T	R	T	T
R	T	B	L	R	L	L	L	B
L	R	L	T	B	B	B	T	R

STOP

GO TO 02

14. Simple Reaction Times

Trial Number One 15 16 17

Trial Number Two 18 19 20

Trial Number Three 21 22 23

15. Complex Reaction Times

Trial Number One 24 25 26

Trial Number Two 27 28 29

Trial Number Three 30 31 32

APPENDIX N: 24-PAGE DRIVER PROFILE SCORE QUESTIONNAIRE

Dear Respondent:

This questionnaire is part of a long-range project on driving conducted by Indiana University and the Institute for Research in Public Safety. It is intended to help develop programs that will prevent serious traffic accidents and injuries. We hope to gain a better understanding of what influences driving behavior by asking you about your driving, personal history and other related areas.

The information gathered in this questionnaire will be used for research purposes only. Your answers will be treated in strictest confidence and will be seen only by our research staff.

Please answer the questions as frankly and accurately as you can. Be sure to read each question carefully before answering it.

If you have any questions now or while working on the questionnaire, please feel free to ask for assistance.

We greatly appreciate your help in this research.

Yours sincerely,

Richard E. Mayer

Richard E. Mayer
Department of Psychology
Indiana University

Basic Information

1. Sex: Male______ Female______

2. When is your birthday? Month______ Year______

3. What is your marital status?

____Single
____Married
____Divorced or Separated
____Widowed
____Other (Please specify:_____________________)

4. Are you a student attending high school, college or university?

____No
____Yes, part time
____Yes, full time

5. What is your current occupation? (If you are not employed but your spouse is, give spouse's occupation. If you are not working because you are in school, give parrent's occupation.) Give job title and brief description of work:

____

____

6. What is your year in school?

____Freshman
____Sophomore
____Junior
____Senior
____Graduate Student
____Other (Please specify:_______________________)

7. What is your major (or expected major):____________________

8. What is your grade point average so far at IU? (If you no GPA at IU yet, give GPA from high school):__________

9. What were your SAT scores? (Please try to estimate if you cannot remember). Math SAT______ Verbal SAT______

10. At the present time, about what is your family income before taxes. If you are married inlcude whatever your spouse makes. If you are supported mainly by your parents give parents' income:

____Under $3,000
____$3,000 to $6,000
____$6,000 to $9,000
____$9,000 to $12,000
____$12,000 to $15,000
____$15,000 to $18,000
____$18,000 to $21,000
____$21,000 or over

11. How many brothers and/or sisters do you have?________

12. Do you have any step parents? Yes______ No______

****

Your Driving

1. When did you first receive your drivers' license?

   Month______ Year______

2. How many miles did you drive in the past 12 months. (If the past 12 months was not typical for you, indicate how many you normally drive in 12 months.)

____under 5,000
____5,000 to 9,999
____10,000 to 14,999
____15,000 to 19,999
____20,000 to 24,999
____25,000 or over

3. How many times have you ever been ticketed for any of the violations listed below? (Put number of tickets in each blank.)

____speeding over the limit
____reckless driving
____driving while intoxicated/driving under the influence
____failure to observe a stop sign or light
____illegal turn or maneuver
____other (please specify all the other tickets except for parking):

____

4. How many times have you been ticketed for any of the violations listed below, during the past 3 years. (Put number of tickets in each blank. By "past 3 years" we mean within 3 years of today.)

____speeding over the limit
____reckless driving
____driving while intoxicated/driving under the influence
____failure to observe a stop sign or light
____illegal turn or manuever
____other (please specify all other tickets during the past 36 months except for parking): ______________________________

____

5. Has your license ever been suspended or revoked?

Yes______ No______

6. How many accidents have you ever been involved in while being a driver (include those in which you were not at fault).

____

7. How many occurred within the past 3 years? _______________

8. In how many of the <u>total number of accidents</u> that you have been involved in as a driver were you judged to be at fault?

____

9. In how many of the accidents you were involved in as a driver <u>during the past 3 years</u> were you judged to be at fault?

____

10. Briefly describe each accident you have been involved in as a driver during the <u>past 3 years</u> including those not mainly your fault. Be sure to indicate whether there was anything you did (or didn't do) which helped cause the accident.

<u>ACCIDENT 1</u> (most recent one) Description:__________________

____

____

Approximate Date: Month______ Year______

(Even if the accident was not mainly your fault, put a check mark by what <u>you</u> did that contributed most to the accident.)

____I wasn't paying attention, so I didn't see the danger until it was too late.
____I was distracted by something, so I didn't see the danger until it was too late.
____I didn't see the danger even though I thought I looked.
____I didn't expect the other driver to be where he was or to do what he did.
____I was going too fast.
____I was driving a little recklessly or incorrectly.
____I didn't evade the danger even though I could have.
____I had trouble steering or controlling my car.
____I was upset, under pressure or in a hurry.
____I was tired, not feeling well, or had been drinking.
____I was not familiar with the vehicle, the road or with the driving in general.
____Other (Please specify):________________________________

____

How much damage was involved in the accident?

____No damage
____Damage under $200
____Damage over $200

How much injury was involved?

____No injury or minor injury
____Injury requiring hospitalization or repeated treatments
____Death

How many vehicles were involved?

____Just mine
____Two or more

ACCIDENT 2 (The second most recent one) Description:________________

____

____

Approximate Date: Month______Year_______

(Even if the accident was not mainly your fault, put a check mark by what you did that contributed most to the accident.)

____I wasn't paying attention, so I didn't see the danger until it was too late.
____I was distracted by something, so I didn't see the danger until it was too late.
____I didn't see the danger even though I thought I looked.
____I didn't expect the other driver to be where he was or to do what he did.
____I was going too fast.
____I was driving a little recklessly or incorrectly.
____I didn't evade the danger even though I could have.
____I had trouble steering or controlling my car.
____I was upset, under pressure or in a hurry.
____I was tired, not feeling well, or had been drinking.
____I was not familiar with the vehicle, the road or with driving in general.
____Other (Please specify):____

____

How much damage was involved in the accident?

____No damage
____Damage under $200
____Damage over $200

How much injury was involved?

_____No injury or minor injury
_____Injury requiring hospitalization or repeated treatments
_____Death

How many vehicles were involved?

_____Just mine
_____Two or more

<u>ACCIDENT 3</u> (Third most recent one) Description: ____________________

____

____

Approximate Date: Month______ Year______

(Even if the accident was not mainly your fault, put a check mark by what <u>you</u> did that contributed most to the accident.)

_____I wasn't paying attention, so I didn't see the danger until it was too late.
_____I was distracted by something, so I didn't see the danger until it was too late.
_____I didn't see the danger even though I thought I looked.
_____I didn't expect the other driver to be where he was or to do what he did.
_____I was going too fast.
_____I was driving a little recklessly or incorrectly.
_____I didn't evade the danger even though I could have.
_____I had trouble steering or controlling my car.
_____I was upset, under pressure or in a hurry.
_____I was tired, not feeling well, or had been drinking.
_____I was not familiar with the vehicle, the road or with driving in general.
_____Other (Please specify): ______________________________________

____

How much damage was involved in the accident?

_____No damage
_____Damage under $200
_____Damage over $200

How much injury was involved?

_____No injury or minor injury
_____Injury requiring hospitalization or repeated treatments
_____Death

How many vehicles were involved?

____Just mine
____Two or more

ACCIDENT 4 (Fourth most recent one) Description:________________

____

____

Approximate Date: Month______ Year______

(Even if the accident was not mainly your fault, put a check mark by what you did that contributed most to the accident.)

____I wasn't paying attention, so I didn't see the danger until it was too late.
____I was distracted by something, so I didn't see the danger until it was too late.
____I didn't see the danger even though I thought I looked.
____I didn't expect the other driver to be where he was or to do what he did.
____I was going too fast.
____I was driving a little recklessly or incorrectly.
____I didn't evade the danger even though I could have.
____I had trouble steering or controlling my car.
____I was upset, under pressure or in a hurry.
____I was tired, not feeling well, or had been drinking.
____I was not familiar with the vehicle, the road or with driving in general.
____Other (Please specify):____________________________________

____

How much damage was involved in the accident?

____No damage
____Damage under $200
____Damage over $200

How much injury was involved?

____No injury or minor injury
____Injury requiring hospitalization or repeated treatments
____Death

How many vehicles were involved?

____Just mine
____Two or more

Your Health

During the past year, have you suffered from any of the following?

_____Ulcers
_____Frequent headaches
_____Trouble falling asleep at night
_____Upset stomach, acid stomach, indigestion, gasses, heartburn, etc.
_____Fainting spells or dizziness
_____Frequent losses of memory
_____Attacks of nausea or vomiting
_____I sweat very easily even on cool days
_____My sleep is fitfull and disturbed
_____There seems to be a lump in my throat most of the time
_____My skin seems to be unusually sensative or itchy

How often to you take tranquilizers? (prescription or non-prescription)

_____About every day or every other day
_____About once or twice a week
_____About once to three times a month
_____About once to several times a year
_____Never

How many cigarettes do you smoke on an average day? _______

How often did you have any alcoholic beverage during the past year?

_____About every day or every other day
_____About once or twice a week
_____About once to three times a month
_____About once to several times a year
_____Never

How many drinks did you usually have on those occasions when you drank? (By one drink we mean one 12-once bottle of beer, one cocktail, one four ounce glass of wine,etc.)

_____one
_____2 or 3
_____3 or 4
_____4 or 5
_____6 or more

****

Your Activities

1. How many times have you moved from one residence to another in the past 5 years? ______

2. How many years have you lived at your present address? ______

3. How many times have you changed jobs (or schools) in the last five years? ______

4. How many years have you been employed by your present employer (or attending your present school)? ______

5. Are you registered to vote? Yes______ No______

6. How many times have you voted in the past four years? ______

7. Do you regularly attend church or other religious services? Yes______ No______

8. When you were growing up did your parents regularly attend church? Yes______ No______

9. In all, how many organizations or clubs do you belong to?______

10. On the average, how many days a month do you spend at meetings of clubs or organizations to which you belong? ______

****

Your Memberships

Try to think of all the clubs or organizations that you have belonged to during the past five years, including organized activities during high school or college (if within five years). Include social clubs, church, church clubs, philantropic organizations, scouts, 4H, sports teams, political groups, etc. Indicate how active you have been in each organization by checking things you have done in the last five years.

Type or Name of Organization	I am a member	Gone to meetings	Gave money	Worked on projects	Held office
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					

****

Your School Experiences

Based on your school experiences (junior high and high school) how often did each of the following events occur?

Often	Some times	Rarely	Never	Event
____	____	____	____	Played hooky
____	____	____	____	Received awards and honors
____	____	____	____	Was well-liked
____	____	____	____	Belonged to school clubs or teams
____	____	____	____	Wanted to drop out
____	____	____	____	Cut-up and was sent to the principal's office
____	____	____	____	Skipped classes I didn't like
____	____	____	____	Enjoyed school
____	____	____	____	Got D's and F's
____	____	____	____	Was suspended
____	____	____	____	Went to parties
____	____	____	____	Went out on dates
____	____	____	____	Had conflicts with my teachers
____	____	____	____	Had academic problems
____	____	____	____	Was a loner

****

Your Other Experiences

Put a check mark beside each of the following things which has happened to you.

____Regular cigarette smoker before age 17.
____Had a full time job before age 17. (Excluding summer jobs)
____Failed one or more grades before grade 8.
____Dropped out of school.
____Was arrested before age 18, for something other than driving.
____Was arrested after age 18, for something other than driving.
____Was convicted for some offense other than driving.
____Ran away from home as a child.
____Have gotten into trouble for not paying bills or with a landlord over rent.

****

Your Recent Events

Put a check mark next to each of the events listed below that happened to you within the past 12 months.

____Got married, got engaged or started going with someone steadily.
____Got separated or divorced from wife or husband, or broke-up with someone.
____Had disturbing trouble with children, parents, in-laws or other family member.
____Had disturbing trouble with close friend.
____Job promotion (moved to higher position at work).
____Job demotion (moved to lower position at work).
____Troubles with boss or co-workers at my work. (Or trouble with teachers and fellow students at school).
____Fired or laid off from a job. (Or failed a course in school).
____Had problems finding a job. (Or problems finding a school).
____Started a new type of work, changed to a different line of work or to a new job. (Or began new school, graduated or quit school or changed school).
____Considerable improvement in financial situation.
____Took out a new loan or mortgage.
____Fell behind in payments for loan, mortgage or finance.
____Death of a close family member.
____Death of close friend, or dear one.
____Been very sick or injured (other than in car accident).
____Thought of committing suicide.
____Got into a fight and hit someone.
____Been so angry you threw or broke things.
____Financial problems.
____Job problems
____School problems.
____Problems getting along with someone else.

****

Your Recent Behaviors

Think of your behavior over the past six months. Indicate how often each of the following things characterized your behavior, for the past six months or so. If it happened almost never, circle 1; if it happened sometimes, circle 2; if it happened often, circle 3; if it happened almost always, circle 4.

Almost Never	Some-times	Often	Almost Always	
1	2	3	4	Acted as if I had no interest in things.
1	2	3	4	Was restless.
1	2	3	4	Just sat.
1	2	3	4	Felt that people didn't care about me.
1	2	3	4	Needed to do things very slowly to do them right.
1	2	3	4	Got angry and broke things.
1	2	3	4	Acted as if I had no control over my emotions.
1	2	3	4	Laughed or cried at strange things.
1	2	3	4	Had mood changes without reason.
1	2	3	4	Had temper tantrums.
1	2	3	4	Got excited for no reason.
1	2	3	4	Acted as if I didn't care about other people's feelings.
1	2	3	4	Thought only of myself.
1	2	3	4	Was bossy.
1	2	3	4	Argued.
1	2	3	4	Got into fights with people.
1	2	3	4	Was cooperative.
1	2	3	4	Did the opposite of what was asked.
1	2	3	4	Was stubborn.
1	2	3	4	Cursed at people.

Almost Never	Some-times	Often	Almost Always	
1	2	3	4	Deliberately upset routine.
1	2	3	4	Was resentful.
1	2	3	4	Got annoyed easily.
1	2	3	4	Was critical of other people.
1	2	3	4	Lied.
1	2	3	4	Got into trouble with law.
1	2	3	4	Stayed away from people.
1	2	3	4	Was quiet.
1	2	3	4	Preferred to be alone.
1	2	3	4	Behavior was childish.
1	2	3	4	Moved about very slowly.
1	2	3	4	Was very quick to react to something someone said or did.
1	2	3	4	Was very slow to react.
1	2	3	4	Would stay in one position for a long period.
1	2	3	4	Acted confused about things; in a daze.
1	2	3	4	Acted as if I couldn't get certain thoughts out of my mind.
1	2	3	4	Talked without making sense.
1	2	3	4	Refused to speak at all for periods of time.
1	2	3	4	Spoke so low you could not hear me.
1	2	3	4	Talked about how angry I was at certain people.
1	2	3	4	Threatened to tell people off.
1	2	3	4	Said the same thing over and over again.
1	2	3	4	Talked about big plans I had for the future.
1	2	3	4	Gave advice without being asked.

Your Opinions

A number of controversial statements concerning problems facing our society are given below. There are two alternatives for each item. Indicate your preference by putting a check mark in front of the answer which is most attractive to you.

1. Concerning inflation,

____I think we have adequate means for preventing run-away inflation.
____There's very little we can do to keep prices from going higher.

2. Concerning special interest groups,

____Persons like myself have little chance of protecting our personal interests when they conflict with those of strong pressure groups.
____I feel that we have adequate means of coping with pressure groups.

3. In my opinion, a man who works in business all week can best spend his Sunday in,

____trying to educate himself by reading serious books or go to an orchestral concert.
____hearing a really good sermon.

4. If I lived in a small town and had more than enough income for my needs I would prefer to,

____Help advance the activities of local religious groups.
____Give it for the development of scientific research in my locality.

5. Assuming that I had the necessary ability and that the salary of each of the following occupations is the same, I would prefer to be a,

____mathematician.
____clergyman.

6. I believe that,

____A lasting world peace can be achieved by those of us who work toward it.
____There's very little we can do to bring about a permanent world peace.

7. Concerning world opinion,

____There's very little that persons like myself can do to improve world opinion of the United States.
____I think each of us can do a great deal to improve world opinion of the United States.

8. Concerning recent events,

____More and more I feel helpless in the face of what's happening in the world today.
____I sometimes feel personally to blame for the sad state of affairs in our government.

9. Taking the Bible as a whole,

____One should regard it from the point of view of its beautiful mythology and literary style rather than as a spiritual revelation.
____One should regard it literally as a spiritual revelation.

10. All the evidence that has been impartially accumulated goes to show that the universe has evolved to its present state in accordance with natural principles so that there is no necessity to assume a first cause, cosmic purpose or God behind it.

____I agree with this statement.
____I disagree with this statement.

11. Which of the following branches of study do you expect will ultimately prove more important for mankind?

____Mathematics
____Theology

12. People like myself can change the course of world events if we make ourselves heard.

____I agree with this statement.
____This statement is just wishful thinking.

13. When I visit a cathedral I am most impressed,

____By a rervading sense of reverence and worship.
____By the architectural features and stained glass.

14. I believe that,

_____This world is run by the few people in power and there is not much the little guy can do about it.
_____The average citizen can have an influence on governmental decisions.

15. A person should guide his life according to, and develop his chief loyalities towards,

_____his religious faith.
_____ideals of beauty.

****

Your Personality

Circle yes or no for each question. Please try not to leave any questions blank.

yes no 1. I find it hard to keep my mind on a task or job.
yes no 2. I certainly feel useless at times.
yes no 3. I work under a great deal of tension.
yes no 4. My daily life is full of things that keep my interested.
yes no 5. I seem to be about as capable and smart as most others around me.
yes no 6. My way of doing things is apt to be misunderstood by others.
yes no 7. My parents have often objected to the kind of people I went around with.
yes no 8. Before I do something I consider how my friends will react to it.
yes no 9. I often think about how I look and what impression I am making.
yes no 10. My table manners are not quite as good at home as when I am out in company.
yes no 11. I have never done anything dangerous for the thrill of it.
yes no 12. I often act on the spur of the moment without stopping to think.
yes no 13. A person needs to "show off" a little every now and then.
yes no 14. I think I would like to fight in a boxing match sometime.
yes no 15. I often do whatever makes me feel cheerful here and now, even at the cost of some distant goal.
yes no 16. I have often gone against my parents' wishes.
yes no 17. It is pretty easy for people to win arguments with me.
yes no 18. Even the idea of giving a talk in public makes me afraid.
yes no 19. Even when I have gotten into trouble I was usually trying to do the right thing.
yes no 20. I get pretty discouraged with the law when a smart lawyer gets a criminal free.
yes no 21. I consider a matter from every standpoint before I make a decision.
yes no 22. Sometimes I feel like smashing things.
yes no 23. I keep out of trouble at all costs.
yes no 24. I am said to be a "hothead".
yes no 25. I like to go to parties and other affairs where there is lots of loud fun.
yes no 26. I have a good appetite.
yes no 27. I seldom worry about my health.
yes no 28. I enjoy many kinds of play and recreation.
yes no 29. I feel as good now as I ever have.
yes no 30. Sometimes without any reason even when things are going wrong I feel excitedly happy, "on top of the world".
yes no 31. At times I have a strong urge to do something harmful or shocking.

yes no 32. I can easily make people afraid of me, and sometimes do for the fun of it.
yes no 33. I easily become impatient with people.
yes no 34. I have never been in trouble with the law.
yes no 35. I tend to be on my guard with people who are somewhat more friendly than I expected.
yes no 36. My conduct is largely controlled by the customs of those about me.
yes no 37. I have very few quarrels with members of my family.
yes no 38. My family does not like the work I have chosen (or the work I intend to choose for my life work).
yes no 39. At times I have very much wanted to leave home.
yes no 40. I believe I am no more nervous than most others.

****

Your Driving Opinions

Circle yes if you generally agree with the statement and no if you generally disagree with the statement. Try to answer all questions.

yes no 1. Besides actual driving, I spend 10 or more hours per week working on cars or being around cars for fun such as drive-ins.

yes no 2. I find driving a form of relaxation which I use to relieve my tension.

yes no 3. Driving gives most teen-agers a feeling of being grown up.

yes no 4 It's fun to beat other cars at the getaway.

yes no 5. It's fun to maneuver through traffic.

yes no 6. During the past few months I have gone driving to blow off steam after an argument at least once.

yes no 7. I feel pressure from people who have authority over me, or from my friends, relatives, parents or othe

yes no 8. I find it difficult to go slowly when there is an open road ahead and the speed limit is 35 mph.

yes no 9. Driving helps relieve pressure.

yes no 10. People are more likely to take chances if their friends are in the car.

yes no 11. It's fun to pass other cars on the highway even if you're not in a hurry.

yes no 12. I drive differently when other people are in the car, e.g., friends, parents, date or spouse.

yes no 13. It's a thrill to outwit other drivers.

yes no 14. Driving in traffic is no fun.

yes no 15. It's a thrill to beat other drivers at the getaway.

yes no 16. Driving at high speeds gives you a thrilling sense of power.

yes no 17. Most drivers should not be allowed to go over 60 mph.

yes no 18. The desire for speed is just like a disease.

yes no 19. Most people would rather have a 400 horsepower engine in an old car than a low powered engine in a newer car.

yes no 20. Carelessness causes more accidents than speed.

yes no 21. When I am upset, driving helps soothe my nerves.

yes no 22. Speed limits are not needed in open country.

yes no 23. If speed limits are reduced any more, we might as well to back to the horse.

yes no 24. I feel perfectly confident in my own judgment of how fast to go under all conditions.

yes no 25. I'd rather have an old car with plenty of guts than a newer model with less power.

yes no 26. There is something about being behind the wheel that makes one feel bigger.

yes no 27. A good driver doesn't need the reminder of all the too many road signs.

yes no 28. During a typical month, I have a friendly race with another car at least once.

yes no 29. During a typical month I drive 15 mph or more over the prevailing traffic inside the city at least once.

yes no 30. During a typical month I drive after a couple of drinks at least once.

****

FINDINGS "A's" PROBLEM

Do not look at this test until you are asked to do so.
Circle each word that has an "a" in it.

mention	running	morning	neighbor	dropping	stunned	ditch	recognize	notion
ladder	numerous	setting	strong	sixteen	vicinity	blown	christen	sewing
bench	promise	puzzle	door	instead	luckily	unfit	mercury	drowsy
theory	funny	witty	moon	moment	shudder	ought	disguise	bugle
further	skip	dryly	soothe	worker	nowhere	sirup	wearing	loiter
shutter	bloom	switch	quarrel	swift	subsist	knelt	counsel	spool
publish	perfume	fellow	spelling	joyful	countless	ridge	bouquet	belle
spread	monkey	blotter	wheel	comfort	sponsor	coral	inscribe	scent
deliver	eleven	melted	steam	fertile	profile	tomb	throttle	cease
remind	dismal	expense	sober	divide	faint	doze	zoning	blithe
improve	sponge	ringing	night	throng	bonfire	stroll	pewter	onset
forbid	history	durable	couch	velvet	refund	gushing	tyrant	lofty
pudding	biscuit	mixture	swell	readily	offense	preface	debris	epoch
sunrise	nobody	touch	correct	descent	custard	sputter	modest	whose
reward	temple	picnic	hear	chunk	recover	nicely	refine	knoll
progress	consist	whistle	window	sense	pitiful	reptile	fleecy	plural
intense	indeed	lemon	bitter	eight	homely	labor	enroll	siphon
bridle	distant	within	lively	grease	ruddy	boldly	leaves	mount
prize	scenery	shriek	engine	moist	citron	single	deluge	bungle
goose	jesting	riddle	compel	rocks	ignite	deport	hurled	wrung
indoor	howl	politics	twinkle	click	squeak	surrey	obscure	superb
winding	jump	leave	serene	empty	goblet	college	debtor	mildly
temper	figure	wintry	modern	freedom	propose	hoarse	quarter	double
message	depend	relish	revive	bottle	observe	browse	enforce	buried
virtue	race	yonder	fifth	report	seldom	inherit	pompous	steeple
endure	sprout	bread	study	demure	intrust	repose	burrow	ebbed
sixth	honey	sweep	boast	bushel	resume	behold	humbug	import
chalk	clock	prince	juicy	unfold	earnest	crouch	apple	woman
motor	duke	confide	scorn	found	croquet	deride	exploit	furrow
route	cliff	socket	mood	locket	empress	recoil	urgent	sturdy
syrup	four	fatigue	seize	merit	corrupt	caught	tumult	embers
gold	shawl	monster	ivory	general	emotion	slight	jewels	tempt
spicy	lunch	explode	renew	impulse	neither	invest	unfurl	impose
lion	crowd	million	colony	notch	endless	gross	grunt	idea
wool	extent	empire	loudly	pump	instead	inner	beech	secede
pine	guard	regular	horse	cruise	exempt	punch	sight	owner
sour	jolly	church	giant	drift	species	dizzy	horde	ravine
cork	upper	bulge	visit	tiger	corps	heed	throb	horror
pint	noon	timid	ounce	hilly	peril	chess	petty	crust
sheep	dough	plum	stone	happy	some	oven	numb	buzz
dusty	expect	moss	being	occur	crew	spurt	whom	seek
ostrich	supply	youth	rural	light	except	clothing	smoky	envy
period	double	fresh	color	notion	welcome	routine	birth	board
event	equip	wash	settle	uproar	struggle	shock	botany	time
middle	bottom	dress	fuel	ideal	word	numb	orderly	problem
right	green	storm	proper	foggy	blue	signal	content	trumpet
frozen	murmur	excel	outburst	gloss	orange	counter	breadth	powder
dodge	thrive	delight	puzzle	mutter	employ	quick	record	meadow
white	become	figure	furnish	crutch	sports	error	choice	opening
tough	collect	twist	grab	fiction	court	evening	splendid	crush
ocean	feeling	collect	sprout	house	humor	differ	splinter	forbid
crush	suspend	truth	connect	energy	great	ruler	ribbon	intense
grind	machine	precise	grumble	sooner	index	dislike	string	extent
cloud	yielding	design	position	impress	skilled	worship	linen	trinket
drawn	slight	cotton	forward	contest	discover	cluster	express	several
bulky	increase	resent	horrible	exclude	enormous	severe	picture	sleepy
desire	continue	stride	dense	sincere	secret	touch	fiery	group

GO ON TO NEXT PAGE

Circle each word that has an "a" in it.

tty	discount	button	civil	swimming	grind
tpour	buckle	street	through	struggle	stretch
oured	possible	tooth	wonder	poultry	outcome
iend	building	lusty	pump	journey	kindly
lode	trouble	corner	corn	opposite	thread
cline	exert	turn	bluff	wretch	frolic
dge	believe	throw	short	taught	bonds
gerly	source	protect	beach	slight	recite
roine	devote	defeat	keeper	curved	pulse
thmus	labor	nerve	cement	pretty	swamp
ough	reserve	trim	muddy	origin	crust
tern	hopeful	pulley	bulletin	behind.	shelter
lvan	penny	fortune	stumble	certain	choose
tly	learn	thistle	improper	shrink	part
osper	screen	collar	poverty	promise	using
dious	purse	esteem	courage	impulse	folder
lode	sketch	shell	bouquet	current	ceiling
lieve	quietly	broken	stencil	dismiss	theme
loin	mischief	feather	purpose	broader	surprise
der	revolt	clever	heartily	neglect	butcher
hen	flying	floor	question	conceit	plowing
ndense	precious	summit	receive	blunder	shingle
iled	similar	benefit	lesson	winter	trunk
tify	sullen	listless	towel	swallow	scheme
egar	grocery	inquire	past	bending	lumber
try	pottery	definite	rugged	conquer	between
iress	tumble	chicken	weight	praise	describe
tten	spoil	ticket	truck	design	distinct
der	ideal	posture	prompt	tinsel	merchant
oever	pledge	thrust	region	union	offering
rgeon	trust	formal	society	pride	steeple
isten	circle	hence	mental	follow	think
pter	other	become	crest	tower	known
turn	ease	coffee	field	sponge	relief
out	solid	heroism	press	uphill	purple
lb	bound	place	shower	vessel	mildly
ter	flood	courtesy	geese	policy	ready
oll	bright	pushing	likely	needle	flour
ter	scene	story	custom	persist	red
uff	office	gulf	title	verse	spend
em	help	plume	public	honor	whole
sis	enough	yellow	develop	instant	speech
eep	howl	blunt	combine	flower	worth

STOP. THIS IS END OF TEST.

Do not look at this test until you are asked to do so.

Enter an X on the line between the numbers that are <u>not</u> the same.

7573 _____ 7573

347820 _____ 349820

4951 _____ 4951

4573043 _____ 4571043

37501243 _____ 37501243

125093562816 _____ 125093562816

8350107234 _____ 8350107234

34861890172 _____ 3486170172

506915 _____ 596915

786071254329 _____ 786071255329

41345073 _____ 41345073

925660752 _____ 925660752

16719581023 _____ 16717581023

3965701745 _____ 3965701745

135299235126 _____ 135299235136

13897142 _____ 13897142

84215073506 _____ 84215073507

941856031194 _____ 941846031194

8041637 _____ 8071637

70317493 _____ 70317493

35789462805 _____ 35789462805

6312850394 _____ 6312850394

731497130631 _____ 731497130681

591137507 _____ 591127507

289414 _____ 289414

17906 _____ 17906

16719581024 _____ 16719581024

16719581024 _____ 16719581024

3965701746 _____ 3665701746

135299235127 _____ 135299235127

13897143 _____ 13897145

84215073508 _____ 84216073508

941856031195 _____ 941856431195

8041638 _____ 8041438

70317494 _____ 70317494

35789462806 _____ 35789562806

6312850395 _____ 6312850795

731497130632 _____ 731497130632

591137508 _____ 591167508

21553401284 _____ 21553401284

1251373807 _____ 1251373307

903148671504 _____ 903148671504

68794353108 _____ 68754354108

37501235 _____ 37501235

125093562817 _____ 125093562817

8350107235 _____ 8350107235

34861890173 _____ 34861840173

506916 _____ 506616

GO ON TO THE NEXT PAGE.

Enter an X on the line between the numbers that are not the same.

639 _____ 639
4714306 _____ 4715306
65382 _____ 65372
710 _____ 710
43210573 _____ 43210573
6182653905221 _____ 6182653905221
43270105338 _____ 43276105338
27109816843 _____ 27109816853
519605 _____ 519605
923452170687 _____ 923452170687
370543141 _____ 310543141
2570665292 _____ 2570665292
32018591670 _____ 32018691670
5471075693 _____ 5471075683
621532992531 _____ 621582992531
24179830 _____ 24179830
70537051248 _____ 70537057248
7361408 _____ 7361708
39471307 _____ 39471507
508264987503 _____ 508264987503
4930582136 _____ 4930582136
136031794137 _____ 136031794137
705731195 _____ 705736195
38210435512 _____ 38210535512

414982 _____ 415982
60971 _____ 60971
16253948 _____ 16253948
42018591760 _____ 43018591760
647107569 _____ 647107569
721532992531 _____ 721582992531
341798301 _____ 341798701
80537051248 _____ 80537051248
5911306581491 _____ 5911306581491
83614081 _____ 83614081
49471307 _____ 47471307
6082649875 _____ 6082647875
5930582136 _____ 5730582136
236031794137 _____ 236031294137
805731195 _____ 805131195
48210435512 _____ 48210435612
405176841309 _____ 405176841309
80145349786 _____ 80145349796
53210573 _____ 53210573
718265390521 _____ 718265390521
5327010538 _____ 5327010538
37109816843 _____ 37189816843
619605 _____ 619505
123452170687 _____ 123452190687

N-25 STOP. THIS IS END OF TEST.

*U.S. GOVERNMENT PRINTING OFFICE: 1979