December 1984
Final Report
DOT-HS-806-6 71

U.S. Department of Transportation
National Highway Traffic Safety Administration

IDENTIFICATION AND TESTING OF COUNTERMEASURES FOR SPECIFIC ALCOHOL ACCIDENT TYPES AND PROBLEMS - VOLUME IV: APPENDICES

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Contract No. DOT-HS-9-02085
Contract Amt. $423,713

Government Sponsors' Addendum

The Volume I report summarizes work conducted on a study to identify and test promising countermeasures for specific kinds of alcohol related accidents. During this study, two experiments--described more fully in Volume 2--were conducted to test the effects of selected roadway countermeasures on the driving behavior of motorist-subjects who either were sober or had been drinking. In addition, literature and accident data on the magnitude and nature of alcohol involvement in drivers of heavy trucks were examined and described in a separate volume (Volume 3).

Experiment I

Experiment I was designed to determine the effect of rumble strips and raised lane delineators on measures of driver performance (e.g., speed and lane position control) for drivers who were sober or had been drinking. An instrumented vehicle driven over a closed course was used. Due to problems listed below, the reader is cautioned about accepting the contractor's conclusion that: "The overall evidence supporting the effectiveness of the rumbling treatments was positive although not strong." (Volume 2, page 191)

- Although there was one anecdotal report of a driver losing control of his vehicle after contacting the rumbling treatment, no formal data were collected or presented on such occurrences. For example, no data were presented on whether drivers "overcorrected" after contacting the rumbling treatment and drove into an opposing lane of traffic.

- Examination of Volume 2, Table 16 indicated that more rather than less lane deviations occurred in the presence of the rumbling treatments when subjects were sober. An adequate explanation of this unexpected negative finding was not presented.

Experiment II

Experiment II used a driving simulator to evaluate the effects of continuous treatments (standard and wide edgelines) and spot treatments at curves (e.g., post delineators, flashing beacons added to curve warning signs), on the driving behavior of subjects who had been drinking. In spite of positive results for edgelines (i.e., a reduction in several measures of alcohol impairment of between 30 and 46 percent for subject-motorists at the highest alcohol level), the contractor did not recommend implementation of the edgeline countermeasure nor even that additional research be conducted. Based on the results of this study, further examination of this potential countermeasure is warranted. It should be noted that the FHWA is currently conducting a research study designed to examine the effects of standard and wide edgelines on the accidents of drinking and non-drinking motorists.

The reader is cautioned about interpreting results from a number of tables presented in Volume 2. Tables 42-44 and 46, 47 (as summarized in Table 48) in Volume 2 are incomplete as only "significant two-way interactions" are presented. Other more complex effects among the six factors investigated were not presented. As an hypothetical example, if each of two types of roadway countermeasures (e.g., edgeline presence and post delineators) did not dramatically reduce the amount of weaving for drinking drivers, but their combination did, this finding would not have been presented.

Fatigue

The contractor recommended (Volume 2, page 194), that studies of accident data be conducted "... to determine if fatigue-related accident types can be identified." However, the findings from this study do not support a fatigue effect. First, only behavioral data (e.g., on vehicle position, speed) were obtained, analyzed and reported. Information on whether or not subjects were, in fact, tired was not collected, and information on heart rate, and EEG to measure the subjects state of arousal, although collected in Experiment I, were found to be too variable for use. Second, the effects of "fatigue" appeared to yield different kinds of results in the two studies. For example, in Experiment I, examination of Figures 17 and 18 shows a reduction in mean velocity (speed) for both straight and curved roadways during the second hour (segments 3 and 4). On the other hand, curve entry speeds increased during the second hour in Experiment II (Table 58). In addition, an overall measure of driving performance (i.e., pay) increased during the second hour in Experiment II. Thus, the data from this study do not suggest a fatigue-related accident type.

Heavy Truck Alcohol Problem

The Volume 3 report presents information pertaining to the magnitude and nature of the heavy truck alcohol problem. As indicated by the contractor (Volume 3, page 1), this report was largely completed by 1979. Since that time, the National Center for Statistics and Analysis has published reports* containing more recent FARS data regarding alcohol involvement in heavy truck accidents. The reader should be aware that there are data that support the contractor's findings regarding the magnitude of the problem. (The May 1984 report contains data that are nearly identical in magnitude to those reported in Volume 3, Table 13, for the High Test States.)

The reader should be cautious when making comparisons among various study findings in Section 2 of the report as it appears that the definition of "heavy truck" may have differed from study to study. For example, on page 23, the FARS definition of heavy truck--i.e., single unit vehicles above a given weight and all multi-unit trucks--was different from the one used in the Baker study and Simpson study, i.e., tractor-trailers only.

*Alcohol Involvement in Traffic Accidents: Recent Estimates from the National Center for Statistics and Analysis DOT-HS-806-269, NHTSA Technical Report, May 1982, page A3.

Fatal Accident Reporting System 1982: An Overview of U.S. Traffic Fatal Accident and Fatality Data Collected in FARS for the Year 1982. DOT-HS-806-566, May 1984, page 17 - Figure 6.

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. DOT-HS-806-671	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Identification and Testing of Countermeasures for Specific Alcohol Accident Types and Problems - Volume IV: Appendices		5. Report Date December 1984 6. Performing Organization Code
7. Author(s) Thomas A. Ranney and Valerie J. Gawron, Ph.D.		8. Performing Organization Report No. 6551-Y-1
9. Performing Organization Name and Address Calspan Field Services, Inc. 4455 Genesee Street Buffalo, New York 14225		10. Work Unit No. A26 11. Contract or Grant No. DOT-HS-9-02085
12. Sponsoring Agency Name and Address National Highway Traffic Safety Administration Federal Highway Administration U.S. Department of Transportation Washington, D. C. 20590		13. Type of Report and Period Covered Final Report May 1979 - October 1983 14. Sponsoring Agency Code

15. Supplementary Notes

NHTSA Contract Monitor - Marvin Levy, NRD-42
FHWA Contract Monitor - Richard Schwab, HSR-10

16. Abstract

This report summarizes work conducted to investigate the feasibility of developing effective countermeasures directed at specific alcohol-related accidents or problems. In Phase I, literature and accident data were reviewed to determine the scope and magnitude of the driver-alcohol problem among vehicle drivers in general and heavy truck drivers in particular. Single vehicle accidents, head-on collisions, and to a lesser extent, rear-end collisions, were identified as alcohol collision types.

In Phase II, prospective countermeasures were identified and evaluated according to their expected effectiveness, state of development, and potential for empirical evaluation. Roadway treatments were selected for evaluation in Phase III, which consisted of two experiments. Experiment I evaluated a simulated rumbling shoulder treatment combined with a simulated raised pavement marker. An instrumented vehicle driven over a closed-course was used. The results indicated strong and consistent effects of alcohol on driving performance, including increases in lane position errors and vehicle control variability. Effects of the rumbling treatments were positive although not strong.

Experiment II used a driving simulator to evaluate continuous (standard and wide edgelines) and spot treatments for curves (herringbone patterned pavement markings, flashing beacons added to curve warning signs, chevron alignment signs, and post delineators). Alcohol effects were evident primarily on measures of tracking behavior and overall scenario performance. Edgeline presence improved tracking as well as overall performance. Wide edgelines were associated with additional, although non-significant benefits. The effects of spot treatments were relatively weak and equivocal Based upon the results, recommendations for additional research and development are presented.

The final report is published in four volumes:

Volume I - Executive Summary
Volume II - Problem Analysis and Preliminary Evaluation of Selected Roadway Countermeasures for the General Driver Alcohol Problem
Volume III - The Heavy Truck Alcohol Problem
Volume IV - Appendices

17. Key Words Accidents, alcohol, closed-course driving, countermeasures, curve negotiation, driving performance, driving simulator, roadway delineation, rumble strips	18. Distribution Statement Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
None	None	70	

Form DOT F 1700.7 (8-69)

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APPENDIX A

INSTRUMENT TO OBTAIN INFORMED CONSENT - EXPERIMENT

I, ____, have been informed by Texas Transportation Institute (TTI) that I have been selected to participate in a study "An Experimental Evaluation of Impaired Drivers."

1. I have been given an explanation of the procedures to be followed, including an identification of those which are experimental.
2. I have been given a description of the attendant discomforts and risks, which include: up to 5 hour sessions at night, operating a vehicle while in an intoxicated condition, use of physiological measurement sensors.
3. I have been given a description of the benefits to be expected.
4. I have been given a description of appropriate alternative procedures that would be advantageous to me.
5. I have been offered an answer to any inquiries concerning the procedures.
6. I have been instructed that I am free to withdraw my consent and to discontinue participation in the project or activity at any time.
7. I understand that in the event of physical injury resulting from the research procedures described to me that only acute, immediate, or essential medical treatment is available and monetary compensation is available for wages lost because of injury, through special insurance coverage.
8. I have not been requested to waive or release the institution, its agents or sponsors from liability for the negligence of its agents or employees.

I, the undersigned, have understood the above explanations and give my consent to my voluntary participation in TTI's research project.

____

Signature of subject

Date: ____________________

Location: ________________

APPENDIX B

CURRENT ALCOHOL USE QUESTIONNAIRE (QFV)

Subject Name ____________________

Current Alcohol Use (past two months)

PUT ONE CHECK IN EACH COLUMN:

	Wine	Beer	Whiskey Liquor	Any kind of drink
3 or more times a day				
2 times a day				
Once a day				
Nearly every day				
3-4 times a week				
Once or twice a week				
2-3 times a month				
About once a month				
Less than once a month . . . . but at least once a year . .				
Less than once a year				
*Never had it				

How often do you have as many as 5 or 6 glasses (or cans)?

	Wine	Beer	Whiskey Liquor
*Nearly every time			
*More than half the time . . .			
Less than half the time . . .			
Once in awhile			
Never			

How often do you have as many as 3 or 4 glasses (or cans)?

	Wine	Beer	Whiskey Liquor
*Nearly every time			
*More than half the time . . .			
Less than half the time . . .			
Once in awhile			
Never			

How often do you have as many as 1 or 2 glasses (or cans)?

	Wine	Beer	Whiskey Liquor
*Nearly every time			
*More than half the time . . .			
Less than half the time . . .			
Once in awhile			
Never			

*Proceed to next beverage

Score: ____________________

6551-Y-1

APPENDIX C

INSTRUCTIONS FOR USING QFV

The QFV (Quantity - Frequency - Variable) gives a rough estimate as to the drinking habits of the potential subject. The respondent is classified as either an Abstainer, Infrequent, Light, Moderate, or Heavy drinker. It is a useful tool in selecting participants for alcohol studies, and in excluding certain classes of drinkers (i.e., Heavy) from drug studies.

The questionaire will be administered as a part of the telephone interview.

1. For each of the three categories of beverage (wine, beer, whiskey-liquor), the respondent will be asked how often he usually drinks that beverage. The time span in question should be about the past six months. For example the person might be asked — "On the average, how often would you say you drank wine?" If the person responds with a quantity instead of a frequency, he should be given an example of how to respond, i.e., "Do you drink wine every day? A couple times a week? Several times a month?" etc. A check mark is placed next to the frequency which corresponds to the person's answer. This is repeated for all beverages, and finally for all types of beverages combined (how often do they have some kind of alcoholic drink, regardless of type). The answer to this question must have a frequency at least as high or higher than the most frequently consumed beverage.

2. For each beverage that the person responded to with a frequency greater than "less than once a month," you must question him about the amount of each beverage that he drinks. The questioning would go as follows:

   When you drink wine, how often would you say you had as many as 5 or 6 glasses? Would it be —

   *Nearly everytime
   *More than half the time
   Less than half the time
   Once in awhile or
   Never

If the person responds with a quantity that is *'d, you may go on to the next beverage. If not, place a check mark next to the subject's response (i.e., 5-6 once in awhile), and continue with the next quantity (3-4).

Repeat this procedure for all beverages which the person drinks at least once a month.

To calculate the QFV:

1. Determine the QVC (Quantity Variability Class). Find the beverage in which the greatest quantity is drunk. It is probably a good idea to calculate QVC's for each of the three beverages until you can recognize which will give the highest QVC. The QVC for a particular beverage is composed of two parts.

    a. The Modal quantity (the amount drunk nearly every time or more than half the time).

    b. The Maximum quantity (the greatest quantity drunk at least once in awhile).

   Look on the QVC chart, find the modal quantity (the amount the person drinks more than 1/2 the time) in column 2, then find the maximum quantity in column 3 that corresponds to the greatest quantity of that particular beverage. You must find both the amount and frequency of the maximum, then go across to column 1 to get a numerical QVC. For example, if a person drinks 1-2 glasses of wine more than 1/2 the time (modal quantity), and 5-6 glasses of wine once in awhile (maximum) the QVC for wine would be 8.

2. From part one of the questionaire determine how often the person drinks. This is the highest frequency checked (3-4 X's per week in the example).

3. To determine the QFV, take the QVC for whatever beverage that is closest to or equal to 1. Look on the QFV chart and match the highest frequency in column 2 with the highest QVC (closest to 1) in column 3, then look across to column 1 to get the QFV. For example, the highest frequency of alcohol use is 3-4 X's per week, and the QVC closest to 1 is 1, the person is a heavy drinker.

QUANTITY-VARIABILITY CLASSIFICATION

Quantity-Variability Class	Modal Quantity	Maximum Quantity	
1	5-6	5-6	
2	3-4	5-6	less than 1/2
3	3-4	5-6	once in awhile
4	no mode specified	5-6	less than 1/2
5	3-4	3-4	
6	1-2	5-6	less than 1/2
7	no mode specified	5-6	once in awhile
8	1-2	5-6	once in awhile
9	1-2	3-4	less than 1/2
10	1-2	3-4	once in awhile
11	1-2	1-2	

Modal = amount drunk "nearly every time" or "more than 1/2 the time"

Maximum = highest quantity drunk

Q-F-V CLASSIFICATION

Q-F-V Group	Frequency (of any alcohol)	Quantity-Variability Class
Heavy	Three or more times a day	1 - 11
	Twice a day	1 - 9
	Every day/nearly every day	1 - 9
	Three/four times a week	1 - 5
	Once or twice a week	1 - 4
	Two/three times a month	1
Moderate	Twice a day	10 - 11
	Every day/nearly every day	9 - 10
	Three/four times a week	6 - 9
	Once or twice a week	5 - 9
	Two/three times a month	2 - 8
	About once a month	1 - 6
Light Drinkers	Every day/nearly every day	11
	One to four times a week	10 - 11
	Two/three times a month	9 - 11
	About once a month	7 - 11
Infrequent	Drank less than once a month but at least once a year	
Abstainers	Drank none of the three beverages as often as 1/year	

APPENDIX D

TTI HUMAN FACTORS
DRIVER PERFORMANCE STUDY
PHYSICAL EXAMINATION FORM

Name: ____
(Last) (First) (Initial)

Date of Birth: ____/____/____ Age: __________ Sex: __________

Address: ____

Weight: ______________ Height: ______________

HAVE YOU EVER HAD:		Yes	No
1.	Hepatitis or liver disorder	____	____
2.	Kidney disease	____	____
3.	Diabetes	____	____
4.	Heart trouble	____	____
5.	Convulsions or epilepsy	____	____
6.	Peptic ulcer	____	____
7.	Abnormal blood pressure	____	____
8.	Alcoholism	____	____

ARE YOU ON ANY DRUGS OR MEDICATION AT THIS TIME? __________

IF YES, LIST THEM ____

____

Blood Pressure: Systolic __________ Diastolic __________

Pulse: ____

Heart: ____

Urine: Alb. __________ Sugar __________

Date: ______________________ ______________________
Medical Examiner

APPENDIX E

SUBJECT INSTRUCTIONS - EXPERIMENT I

The study for which you have volunteered, involves driving while in or near a legally intoxicated state. This study will require you to attend seven driving sessions. These sessions will be conducted at night and may continue as long as four hours after sunset. No single session will be longer than five hours. At least one experimenter will remain with you during the entire session. A session will begin when an experimenter arrives at your home or office to drive you to the research annex where the actual study will be conducted. The session will end when the experimenter drives you to your home.

Because you will be required to drink alcohol for these sessions, it will be necessary that you be examined by a physician to determine if there is any medical reason for you not to participate in the study. We will arrange for you to receive the examination at the University Health Center at no expense. This physical examination must be completed before you can be scheduled for the first session. You will be asked to complete a questionnaire about your drinking habits and return it at the time of the physical examination. This information will be held in strictest secrecy and not released to anyone. The information will allow us to determine the proper dose of alcohol you must drink to obtain the desired blood alcohol level for a particular session.

During the driving sessions, it will be necessary for you to have physiological sensors placed in skin contact on your chest and scalp. These sensors allow the experimenter to monitor your condition and record physiological performance along with the other measurements being made by the instruments in the car. These sensors may feel uncomfortable at first but you will quickly adjust to them. They do not present any hazard to you and can be connected and disconnected in a short time. Measurements from these sensors will be obtained only for the time you are driving the car.

Before beginning to drive you will be required to consume a predetermined amount of alcohol to raise your blood alcohol level to the desired amount. This amount is determined by your body weight and drinking experience. A Breathalyzer identical to that used by many police agencies will be used to measure your blood alcohol levels, before, during and after each experimental session. Please do not eat for at least four hours before each session and do not drink any alcoholic beverages for at least 12 hours before each scheduled session.

While driving you will be following a 3.3 mile course marked on the pavement at the research annex. Your only task is to follow the course keeping the car in the right-hand lane and maintaining 40 MPH along the some of the turns. Contact with the experimenters will be kept to a minimum but the observer in the front seat can take control of the car if he feels your performance presents a hazard at any time. You should be able to complete the sessions with little or no interaction by the experimenters.

At predetermined times you may be asked to stop and perform certain psychomotor skills test or Breathalyzer tests to determine your level of impairment or blood alcohol level. These do not reflect on your abilities but occur at scheduled intervals to ensure that the desired levels are being maintained. You may be asked to consume some additional alcohol at this time to maintain the desired blood alcohol level.

Should any essential medical treatment be needed as a result of injury, the session will be terminated and medical assistance obtained. You will be covered by special insurance for injuries during the sessions. At the completion of the study all participants will be advised as to the results of the study and all questions about the study will be answered at that time. You are free to discontinue your participation at any time and are not waiving the liability of the institution for negligence by its agents. If you have any questions about the study or what is required of you, ask the experimenters and they will be glad to furnish you with that information. Thank you for your cooperation.

APPENDIX F

A Physical and Physiological Evaluation of A Simulated Versus Actual Ribbed Pattern Countermeasure For Alcohol Impaired Drivers

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Texas Transportation Institute
Texas A&M University System

Prepared for

Calspan Field Services, Inc.

January, 1982

INTRODUCTION

On the initial phases of an investigation of roadside countermeasures a simulation of the countermeasures has several advantages. The primary advantage is that no physical countermeasure need be applied to the roadway surface. This allows a more varied and extensive examination of other aspects of the problem including the arousal quality of the countermeasure concept itself. Thus, when an effort to investigate the feasibility of developing effective roadside countermeasures for alcohol impaired drivers accidents was proposed, simulation became an attractive method. If an adequate simulation could be developed for this effort it could easily be altered for use in future study of different types of countermeasures. Thus, it became necessary to evaluate the simulation approach proposed to determine that the physical and physiological effects produced were not significantly different from a physical "rib pattern" countermeasure.

The principal study will be a simulation of a rural, nighttime driving environment using an actual vehicle on a closed course for drivers at 3 different Blood Alcohol Levels (0, .075 and .12%). The evaluation was performed on the same course and used a procedure altered only in that the subject spent less time on the course and completed both sessions in a single evening. The course places minimal demands on the subject in terms of interaction with the driving public (none) or peripheral distractions. The course does demand a constant path guidance behavior of moderate levels. The evaluation used drivers in both sober and alcohol impaired conditions performing the same task of path guidance while encountering both actual and simulated "rib pattern" countermeasures. However, only the sober analysis is presented here. The subject was aware of the countermeasure location but not of its type.

METHOD

Design

The experimental design is presented in Figure 1. The independent measure for the 3 subjects was:

1. Countermeasure type, which was at three levels: Simulation, Actual and none (Control).

The subjects repeated their runs to obtain 24 observations per subject, 8 observations per cell. Thus, a within subject statistical analysis was used. The 8 observations per cell were counterbalanced using two sites for presentation of the countermeasures. The control sample was obtained at the same site for all observations. A repeated session at BAC = 0.12% was completed for some subjects.

The physiological response was measured by coefficient of variation of heart rate (CV_{HR}). This is a derived measure of the subjects' heart rates and was obtained from the heart rate data collected as shown in Figure 2. The coefficient was derived for the 5 second window beginning 1 second before the countermeasure onset and ending 4 seconds after onset. This window was selected as being the shortest period acceptable to observe changes while not allowing other events to confound the measurements (i.e. following curves). The coefficient was calculated as the ratio of the mean heart rate to the standard deviation of heart rate for this window. This measure was found to be sensitive to arousal level (O'Hanlon, et.al., 1974). The physical responses were measured using the dependent measure of change in velocity (ΔV) which is derived from the measure of vehicle velocity as shown in Figure 3. The change of velocity was obtained from the same window as CV_{HR} by subtracting the speed at the end of the window from the speed at the beginning of the window. Thus, ΔV represents a slowing down when positive. The change in velocity was used as a physical measure

Countermeasure

		Simulated	Actual	Control
Subjects	1	*		
	2			
	3			

*8 observations per cell

FIGURE 1

EXPERIMENTAL DESIGN

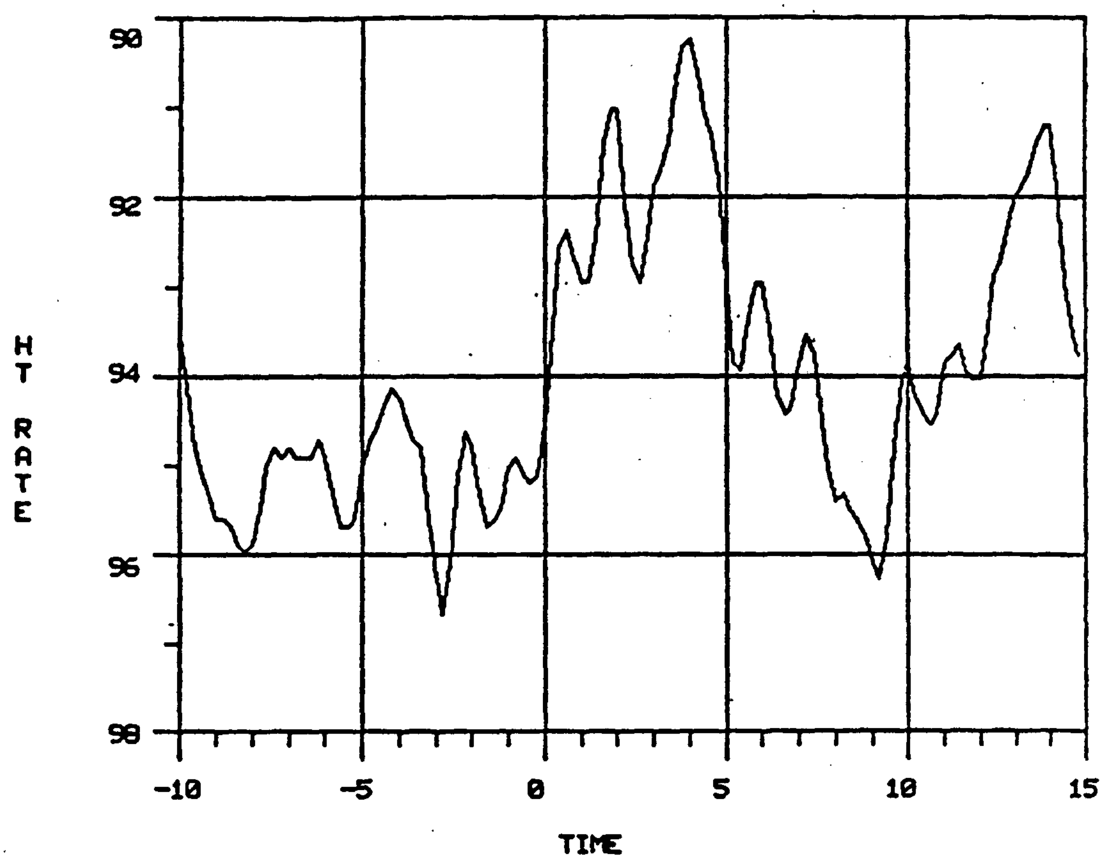

Figure 2

Example of Heart Rate (BPM) Over Time (Sec.)

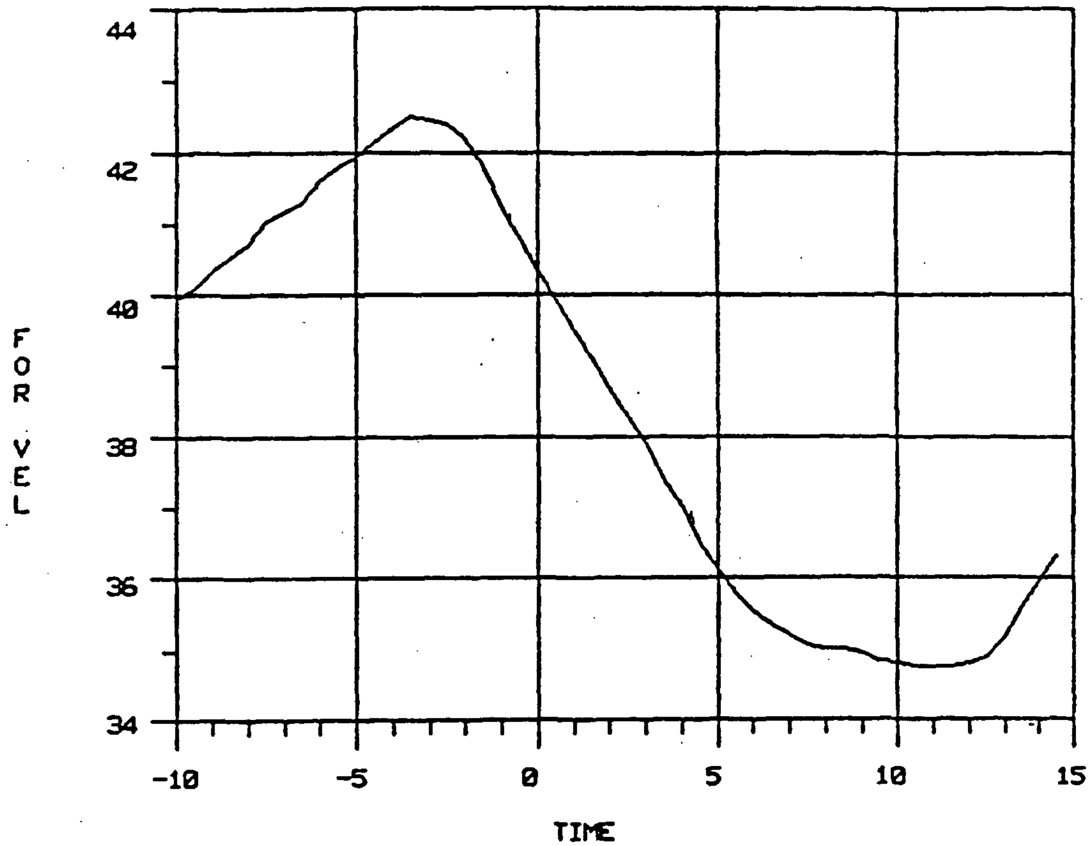

FIGURE 3

Example of Forward Velocity (MPH) Over Time (Sec.)

over other data because it was less sensitive to artifacts imposed by the presentation method. Since no path guidance input was required to avoid the countermeasure, it was our belief that traditional measures such as lateral acceleration, lateral deviation or steering reversal would not produce informative data. However, a change in velocity may be observed with no course alteration.

Subjects

The three subjects were male employees of The Texas Transportation Institute (TTI) recruited for this study by direct contact. They ranged in age from 32 to 53 and were administered physicals by the Texas A&M University Health Center to confirm that they were in good health. All had been determined to be moderate social drinkers by interviews conducted during recruitment and had taken part in previous (pilot test) sessions using the vehicle on the test course. Each subject was paid at his normal rate for the time of the session. The subjects were not informed of the experiment's purpose but were informed as to the total procedure including the encounters with the countermeasures. They were debriefed following the sessions where their performance and the study were discussed.

Apparatus and Procedure

The Driver Performance Measurement and Analysis System (DPMAS) is an instrumented vehicle capable of recording the measures outlined in Table 1., among others. The DPMAS performs some data reductioning and outputs the data file to an onboard digital magnetic tape recorder for analysis. A forward looking, roof mounted, video camera also makes a visual record of the session with selected data channels being superimposed on the display.

TABLE 1

DPMAS Sensor Channels

Filter Channel	Quantity	Symbol	HI/LOW Gain (Bias)	Sample Rate	Comments
1	Steering Position Ssw	DSW	$\frac{20.\text{deg}}{60.\text{v}}$	20/sec.	Positive-right
5	Steering Angle SwT	DWT	4.deg/v	20/sec.	Positive-right
6	Heading Angle Ψ	PSI	$\frac{5.\text{deg}}{20.\text{v}}$	20/sec.	Neg -10V  Pos +10
14	Lateral Acceleration α YI	AYI	.1 g/v	20/sec.	
22	Forward Velocity u_o	VEL	10 $\frac{\text{mph}}{\text{v}}$	2/sec.	Always Positive Stopped = 0
29	EEG Δ	EEG1	±10 v FS	5/sec.	
30	EEG θ	EEG2	±10 v FS	5/sec.	
31	EEG α	EEG3	±10 v FS	5/sec.	
32	EEG β	EEG4	±10 v FS	5/sec.	
35	Heart Rate HR	HR	20 bpm/v	5/sec.	
64	1) Parking lights 2) Not used 3) Brake lights 4) Radio 5) RT indicator 6) LT indicator 7) Hi beam 8) Low beam	PKLT NU BKLT RADI RTTI LTTI HIBM Lo BM	1-off,0-on	1/sec.	Decimal readout, convert to bianary to determine on/off
65	1) Horn 2) Windshield Wiper 3) Air conditioner 4) Oil Pressure indicator 5) Emergency brake 6) Seat pressure 7) Not used 8) Not used	HORN WWIP AIRC OILP EMBK SEAT NU NU	1-off,0-on	1/sec.	Decimal readout, convert to bianary to determine on/off

These channels are the real-time clock, keyboard input, heart rate, forward velocity and lateral acceleration. The electrocardiogram measures use the Driver Measures Unit which provides onboard processing of the drivers physiological state. The unit uses a portable Bio-Com biopac with bipolar pairs of silver/silver chloride electrodes with a neutral, non-irritating long-term electrode gel. The heartbeat rate is produced by on-line processing which measures the repetition of the ECG R-wave spike.

Some of the recorded variables are not suitable for use as dependent variables. Since no course adjustment was desired, steering position, steering angle, heading angle and lateral acceleration were not seen as being suitable as performance measures in this study. Lateral acceleration is suitable as a variable for comparison of the simulated to actual countermeasure in terms of vehicle dynamics. The EEG quantities were not used here because there was no reason to suspect that a change was going to occur during the short time the subject was being observed. The two binary groups did not present any quantity suitable as a performance measure. Thus, only some aspects of velocity and heart rate were seen as suitable for analysis. The velocity was converted to change of velocity (+ being a reduction). This was seen as the only performance variable available in the design. The heart rate variability measure of coefficient of variability had been demonstrated in previous studies as sensitive to moderate arousal levels.

The vehicle is also equipped with a servo steering input system which allows movement of the front tires independent of the drivers' steering wheel inputs. This movement is produced by an electrohydraulic servo actuator that extends a piston between the pitman arm and relay rod of the steering system. This system is shown in Figure 4. Activation of this servo is

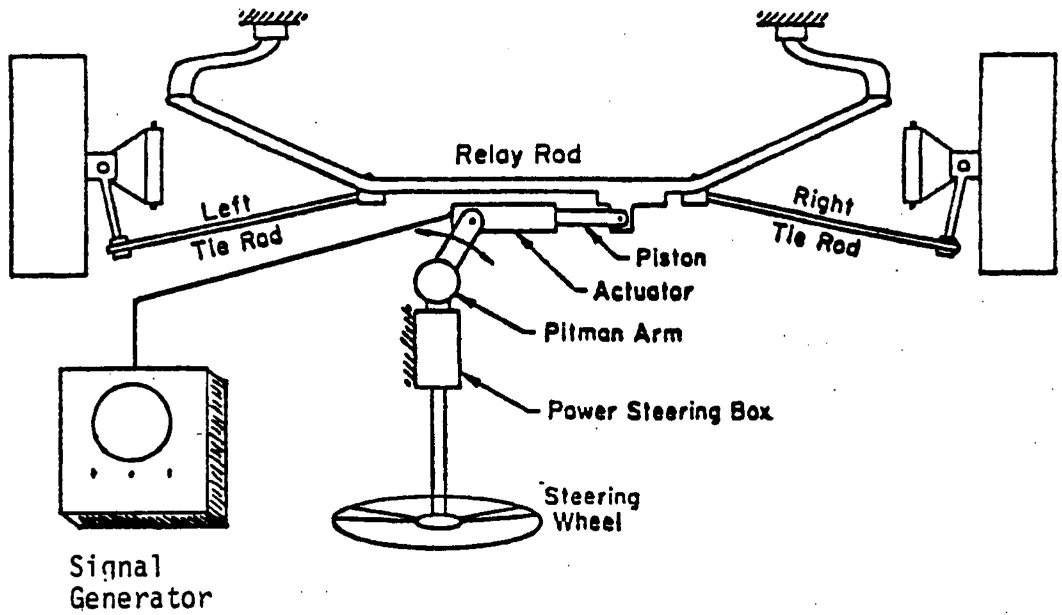

Figure 4

Servo Steering System

from an external sine wave generator which causes the servo to produce a series of equally spaced jerks to the steering system. The magnitude of these displacments is controlled by a variable gain circuit in the actuator circuit. The action manifests itself in a series of rapid, small changes in the front tire track, and an audible "shake" of the steering wheel.

The sine wave function was selected to be 10 HZ, a frequency which simulates crossing raised pavement on 1 foot spacing at 40 mph. Because the sine wave actually triggers a release of pressure in the piston, a deviation of 20° was introduced to the steering wheel which was released and restored by the action of the sine wave function input. The system had too much inertia to permit the entire 20° range of movement during any cycle, but it does attain about a 13° movement.

The physical countermeasures were 40 feet of 2 feet long, 1 inch high, 2 inch wide "ribs" placed laterally across the path on 1 foot center spacing. This pattern is consistent with a design used by the Texas State Department of Highways and Public Transportation. In addition, the sites were marked with a series of traffic cones denoting the 40 feet to the subject. The actual countermeasures were moved from one site to the other by secondary personnel using a second vehicle with no visable lights. This allowed the movement to be accomplished out of the subject's sight so that he was never certain as to which type of countermeasure was present until he reached the site.

The course, with sites marked, is shown in Figure 5. The course is a single 12 foot wide lane with white hashed edge marking. The sites were selected based on preliminary data as being sites of least lateral variability on continuous straight portions of the course. This was required to allow adequate sight distance by the subjects to discern the site and maintain his path through the countermeasure.

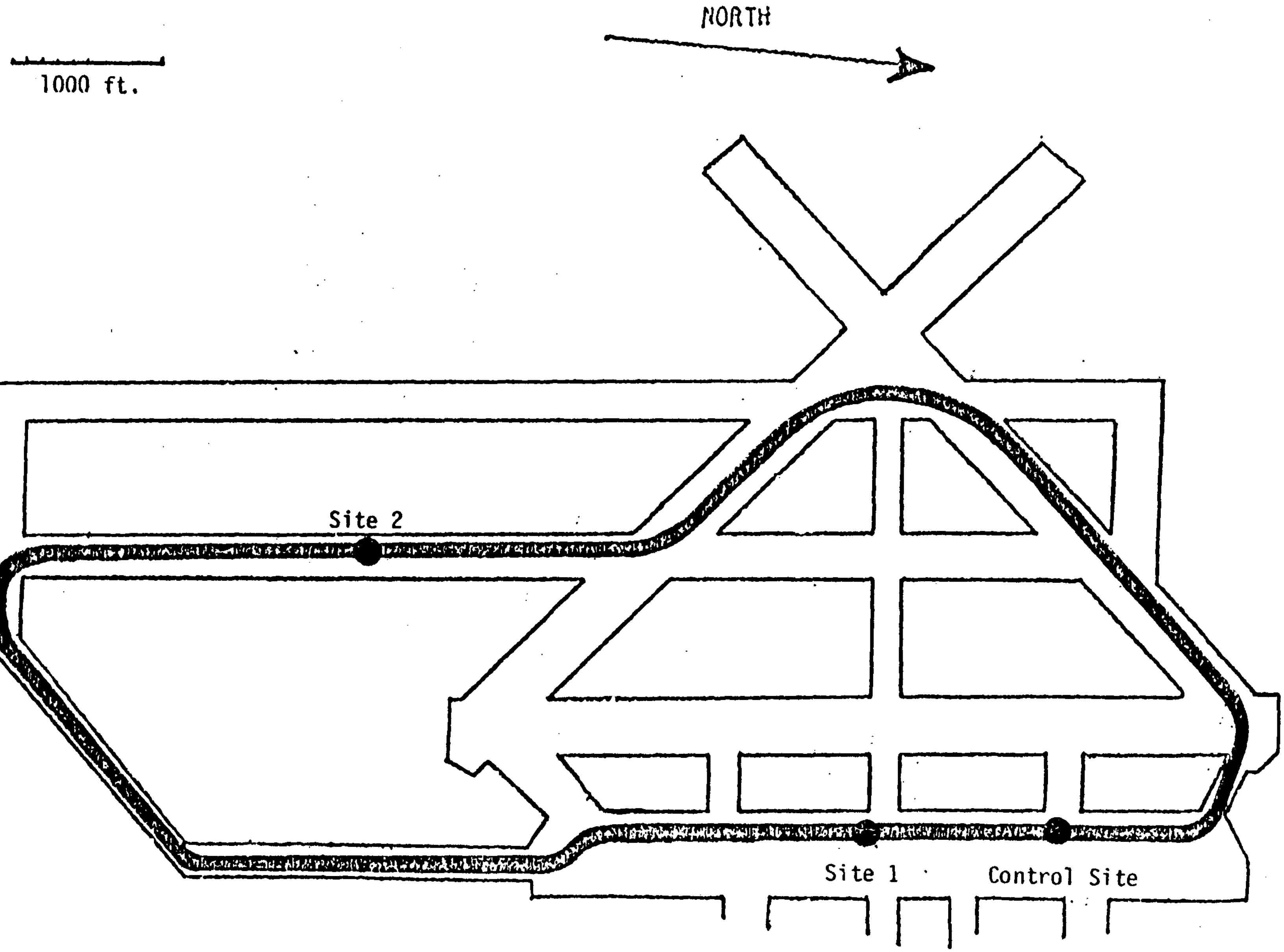

Figure 5

Course Layout

The subjects were instructed to eat only a light meal on the evening they were scheduled for their session. They were picked up at their home by one of the experimenters at about 6:00 p.m. and taken to the DPMAS housing facility at the Research and Extension Center of TTI. Upon arrival the subject was informed that the session would be in two parts, one with no alcohol and the second after ingestion of some alcohol. In addition, the subject was informed that his task was to negotiate the course at a speed not greater than 40 mph. He was also informed that there were two sites marked with cones where there might be some objects placed in his path which he was not to attempt to avoid. The subject was then tested for BAC level using a Breathalyzer Model 900. If the BAC level was 0.00% then the experimenters applied the electrodes. The subject was then placed in the vehicle and the system calibrated and checked for adequate electrode contact. The subject was then directed to the start of the course and allowed to complete 9 laps (approximately 45 minutes) during which he experienced both countermeasures at each site 4 times and had data recorded at the control site 8 times. This resulted in collection of 24 data points. The subject was then directed to return to the vehicle housing facility. The electrode leads were removed from the connection to the vehicle, but the electrodes were left in place. The subject was then taken to a waiting room.

The subject was furnished with 3 drinks over the next hour containing enough alcohol (100 proof vodka) for the subject to obtain the required BAC level of 0.12%. After a 30 minute wait the subject was tested for his BAC level and if the goal had been reached, he was returned to the vehicle. No subject failed to reach the required level. The subject was then reconnected by the electrode leads to the DPMAS vehicle. The vehicle was recalibrated and the subject completed 9 laps in a manner identical to the first half. The subject was then instructed to return to the vehicle housing facility where the electrodes were removed. The subject was allowed to rest in the waiting room and discuss the session, until his BAC level fell below 0.10%. This discussion did not replace the subject's debriefing. Approximately 2 hours after the end of dosing, the subject was returned to his home, escorted to the door and left with another occupant. The data tapes were collected and marked for analysis. After all subjects had completed their sessions, each was debriefed as to the purpose and expected use of the experiment and their data.

RESULTS

Because of data collection problems only the sober (BAC=0.00%) runs were analyzed. This analysis was conducted using two within-subjects analysis of variance designs, one for each measure obtained. The statistical model is:

$$X_{ijk}=\mu + \alpha_i + \delta_j + \alpha\delta_{ij} + \varepsilon_{k(ij)}$$

where

X_{ijk} = the value of the dependent measure for countermeasure i, subject j and error k.

μ = the population mean of the dependent measure

α_i = the effect of countermeasure type i where i=1,2 or 3

δ_i = the effect of subject j where j=1,2 or 3

$\alpha\delta_{ij}$ = the effect of the interaction of countermeasure type i and subject j

and $\varepsilon_{k(ij)}$ = the random error associated with countermeasure i and subject j.

The analysis was performed using SAS 79.5, a general statistical analysis package. The analysis used a General Linear Model (GLM) approach because some observations were lost due to data collection errors in the DPMAS. This produced an unbalanced (all cells do not have the same number of observations) analysis which is better handled by a linear regression approach. The results are consistent with a standard ANOVA approach and will be presented as such. All factors are assumed to be fixed. In the case of the subjects this is seen as justified by the small number of subjects not presenting a true picture of the continuous range of potential subjects (all drivers.)

The results of the analysis of heart rate variability are presented in Table 2. Only the effect of subjects was found to be significant. There was no significant effect due to the countermeasure type. The results of the analysis of change of velocity is presented in Table 3. In this analysis both the countermeasure type and subjects are significant. A Duncan's Multiple Range Test was performed on all significant main effects and these results are presented in Tables 4, 5 and 6. The cell means for both dependent measures is presented in Tables 7 and 8.

A Fast Fourier Analysis was performed on the lateral and vertical acceleration while encountering both the simulated and actual countermeasures for a 4 second window around the countermeasure. The longitudinal acceleration was not seen as being significant for analysis at this time. The results of these analyses are presented in Figures 6 and 7.

TABLE 2

ANOVA RESULTS

Dependent Measure = Coefficient of Heart Rate Variability (CV_{hr})

Source	d.f.	Sum of Squares	Mean Squares	F	Probability of F
Countermeasure	2	5.318	2.659	1.37	.2629
subject	2	101.561	50.781	26.10	.0001
Countermeasure x Subject	4	4.416	1.104	0.57	.6873
Error	59	114.792	1.946	-	-
Total	67	226.087	-	-	-

TABLE 3

ANOVA RESULTS

Dependent Measure = Change of Velocity (ΔV)

Source	d.f.	Sum of Squares	Mean Square	F	Probability of F
Countermeasure	2	7.796	3.898	8.44	.0006
Subject	2	3.383	1.692	3.66	.0316
Countermeasure x Subject	4	2.169	0.542	1.17	.3313
Error	60	27.710	0.462	-	-
Total	68	41.058	-	-	-

TABLE 4

Duncan's Multiple Range Test for Effect of Subjects on Coefficient of Heart Rate Variability

GROUPING	MEAN	N	SUBJECT
	3.976	24	3
	1.470	21	2
	1.366	23	1

TABLE 5

Duncan's Multiple Range Test for Effect of Countermeasure on Change of Velocity

GROUPING	MEAN	N	COUNTERMEASURE
	0.792	24	Simulated
	0.501	22	Actual
	-0.012	23	Control

TABLE 6

Duncan's Multiple Range Test for Effect of Subjects on Change of Velocity

GROUPING	MEAN	N	SUBJECTS
	0.769	21	2
	0.325	24	1
	0.242	24	3

TABLE 7

Coefficient of Heart Rate Variability Cell Means

		Countermeasure		
		Simulated	Actual	Control
	1	1.755 * 1.277 7	1.208 0.472 8	1.185 0.444 8
Subjects	2	1.330 0.746 8	0.977 0.412 6	2.052 2.992 7
	3	4.395 0.942 8	3.426 1.030 8	4.108 2.069 8

*mean/standard deviation/n

TABLE 8

Change of Velocity Cell Means

		Countermeasure		
		Simulated	Actual	Control
Subjects	1	0.431 * 0.921 8	0.359 0.595 8	0.185 0.101 8
	2	1.188 0.243 8	1.017 0.172 6	0.076 0.632 7
	3	0.756 0.805 8	0.256 1.154 8	-0.288 0.587 8

*mean/standard deviation/n

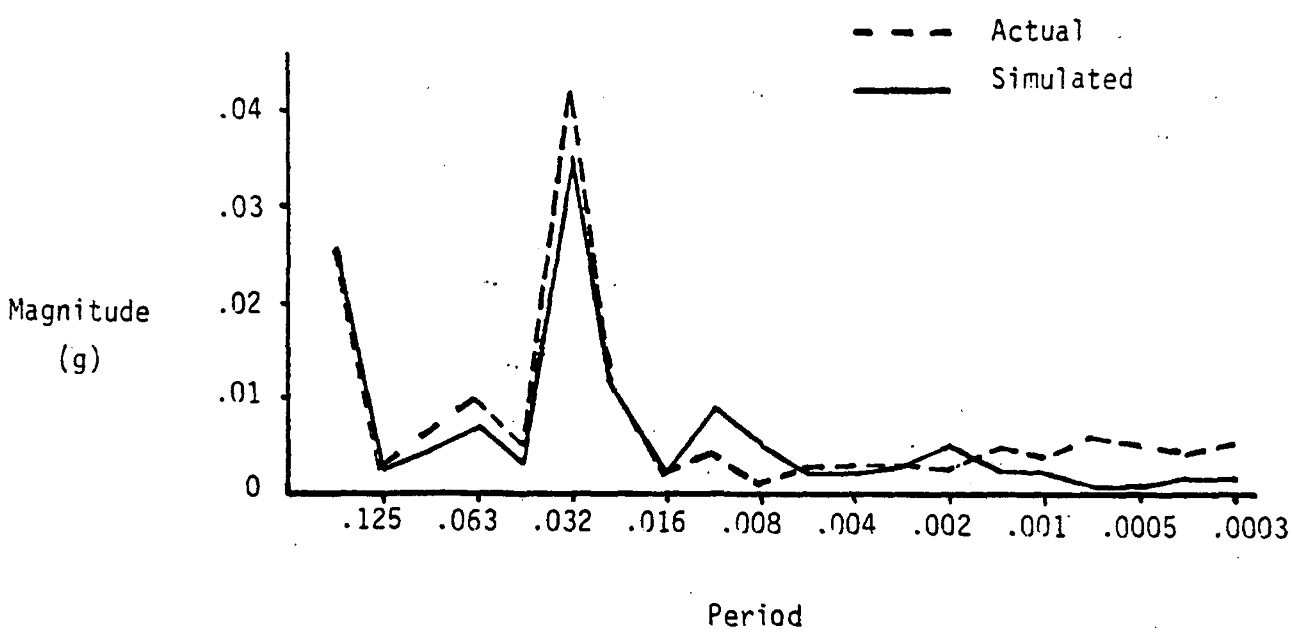

Figure 6

Results of Fast Fourier Analysis
of Vertical Acceleration

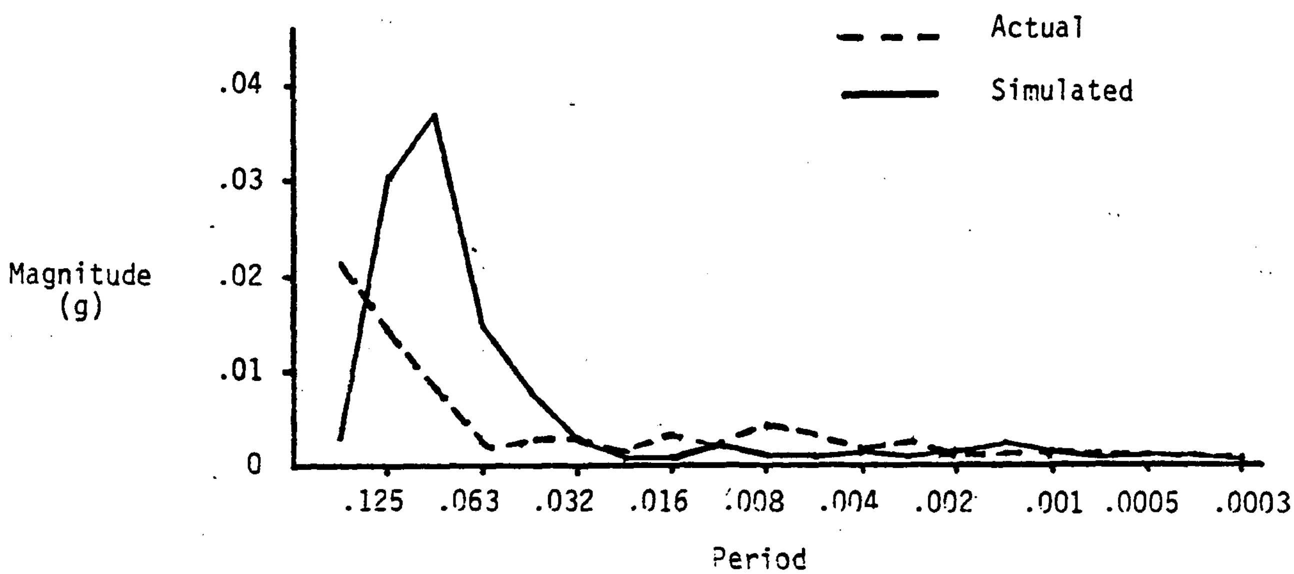

Figure 7

Results of Fast Fourier Analysis
of Lateral Acceleration

DISCUSSION

The nonsignificant results for countermeasure type using heart rate variability is discouraging on first glance. However, since the subjects were aware of the countermeasure location, no significant change in arousal level should be expected. The data may suggest trends in the desired direction, but the measures are not sensitive enough for this type of analysis under these conditions. This is seen as a significant effect of subjects but not countermeasure type. The results of the analysis of change in velocity are more encouraging. The Duncan's Test results indicate that the simulated and actual countermeasrues showed no difference across subjects, but both were different from the control. Some mention of the means is also warranted. The mean change of velocity for the control was about 0, as should be expected. Both countermeasures elicited a significant speed reduction. The results indicate that there is no reason to suspect that the drivers reaction to the simulated countermeasure is different from the actual countermeasure for these measures. The results indicate that the simulated vs. actual rumble strip countermeasures elicited about the same physical response by the driver. The nature of the assigned task, location known, made measures of physiological reaction nondiscriminating among the experimental conditions.

If the driver is not aware of where the countermeasures are (since he will only encounter one when he deviates from the roadway), level of arousal should be a more discriminating variable in the main study. Also, the measures used in the main study will include a composite EEG which should be more sensitive to changes in level of arousal than the heart rate measure used here. Lane deviation amount and recovery performance, of course, remain the principal criterion variable of interest in the main study.

The Fourier analysis is much as was expected. Both the simulated and actual countermeasure had componenet frequencies of the same period for the vertical acceleration. Thus the car bounces up and down in the same manner for both. The lateral acceleration is somewhat different. This should be expected since this was the impact force for the simulation. Thus the analysis for the simulation is centered on 10 Hz (.1 period) which was the input frequency. The actual countermeasure has a much slower frequency of vibration (<8 Hz). However this acceleration is still not much above the threshold of the driver and will be perceived as little more than "noise". This indicates that the vehicle behaves much the same for both the actual and simulated countermeasures.

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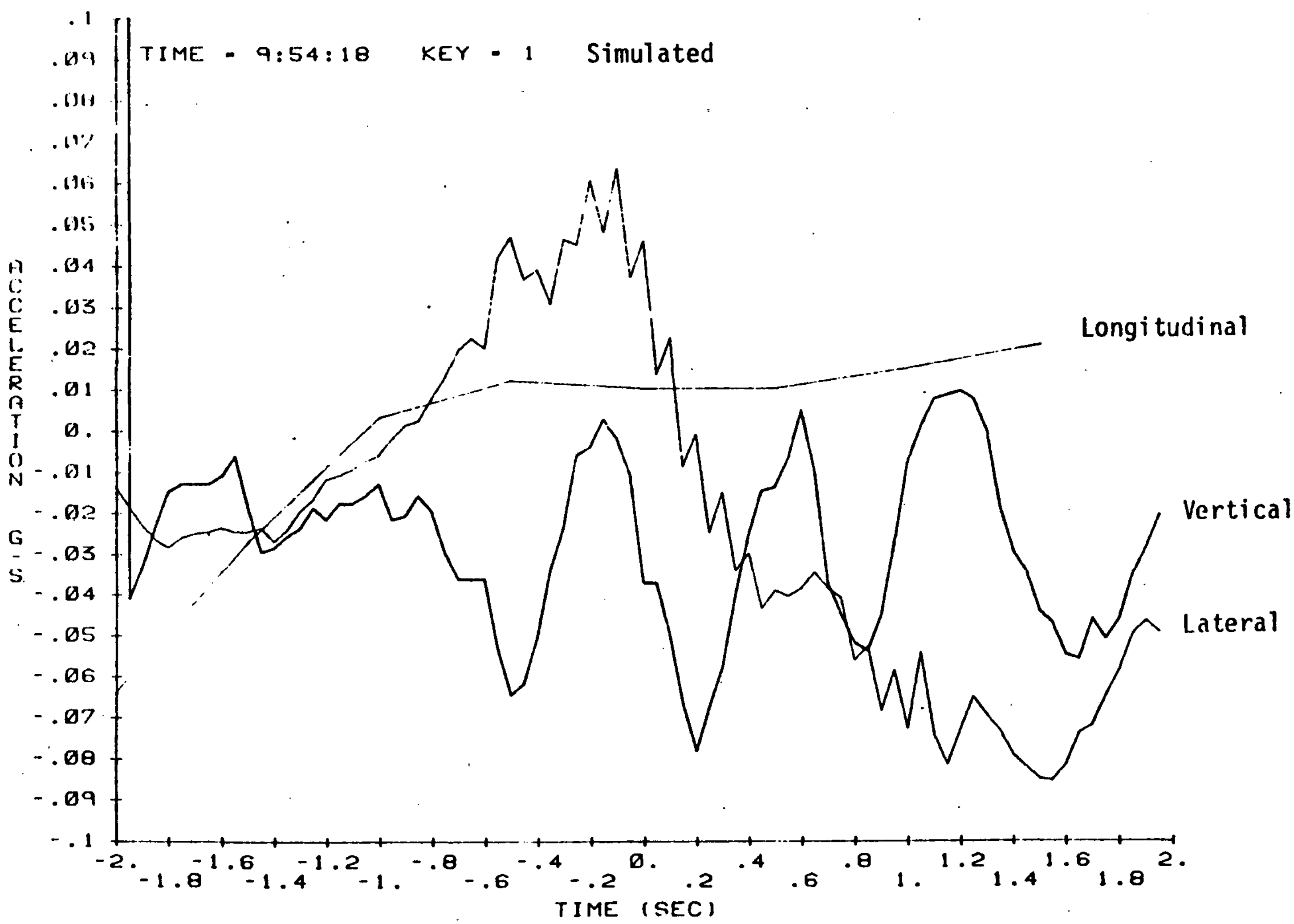
Klein, Richard H., Allen, R. Wade and Peters, Richard A. "Driver Performance Measurement and Analysis System (DPMAS), Volume 1 Description and Operations Manual", U.S. Department of Transportation, National Highway Traffic Safety Administration, Contract No. DOT-HS-359-3-733, 1976.

O'Hanlon, James F. and Kelley, Gene R. "A Psychophysiological Evaluation of Devices for Preventing Lane Drift and Run-Off-Road Accidents", California Department of Transportation, Division of Highways, Contract No. B-01-53, 1974.

APPENDIX I

ACCELERATIONS ACROSS COUNTERMEASURE



ACCELERATIONS ACROSS COUNTERMEASURE

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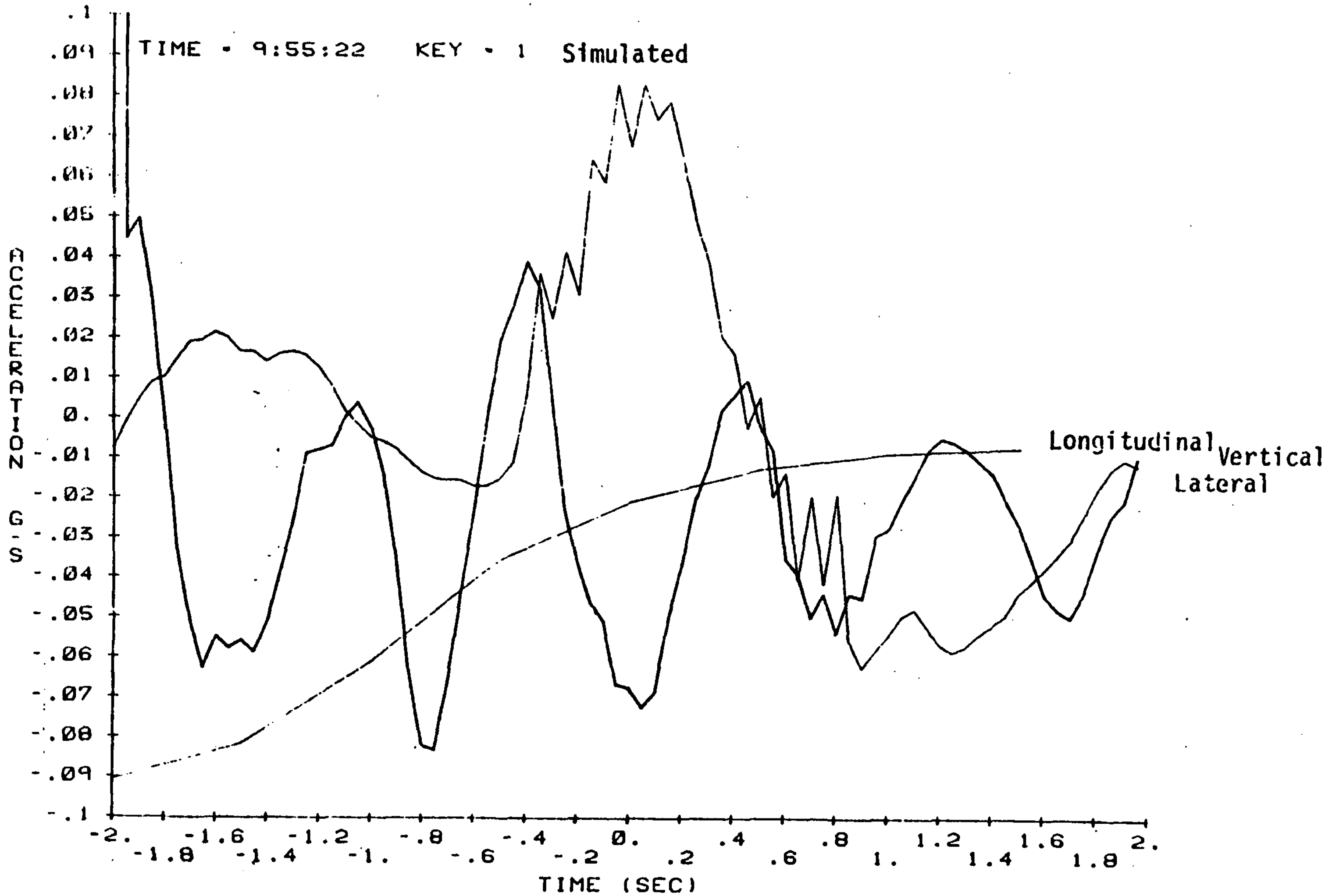

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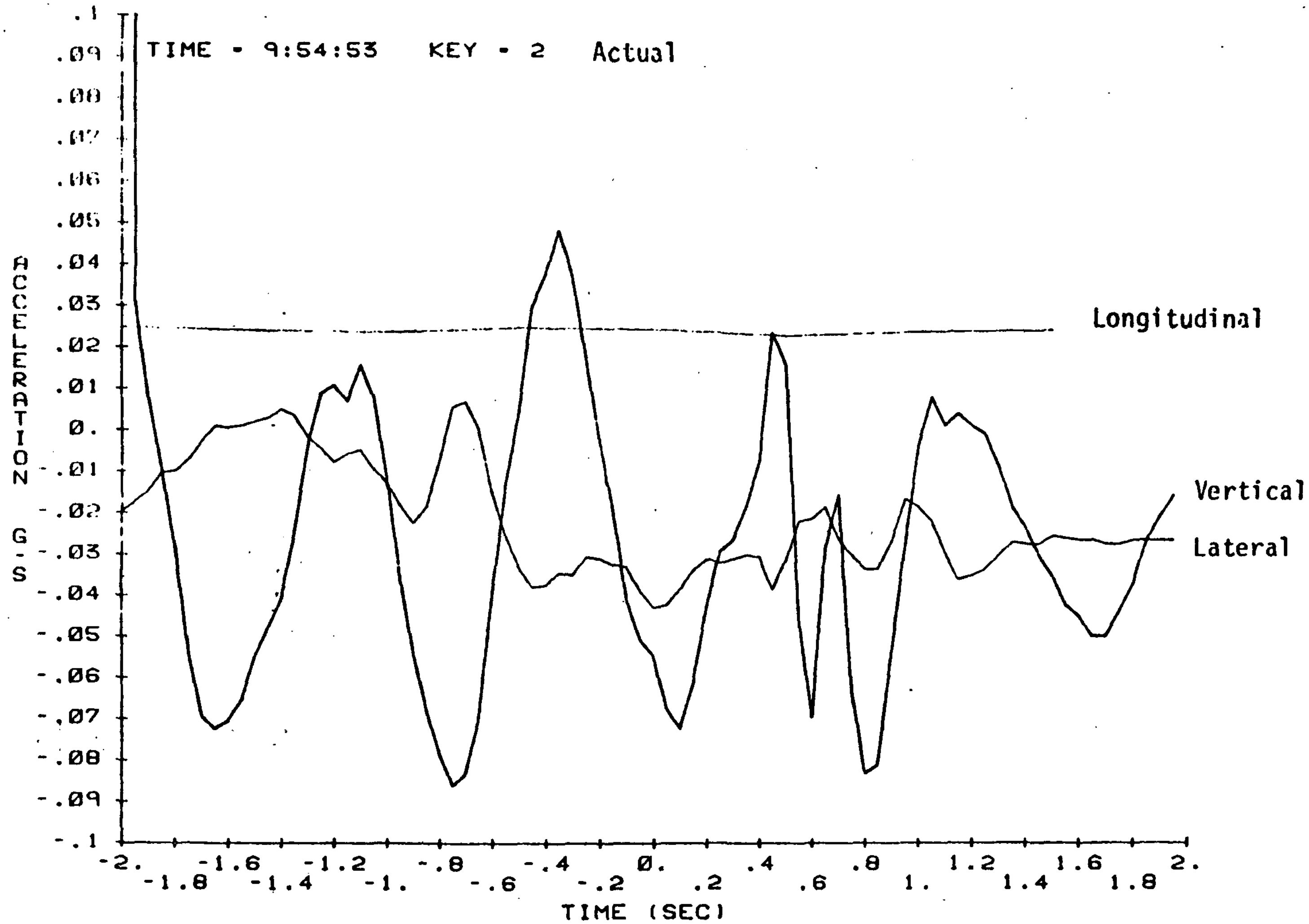

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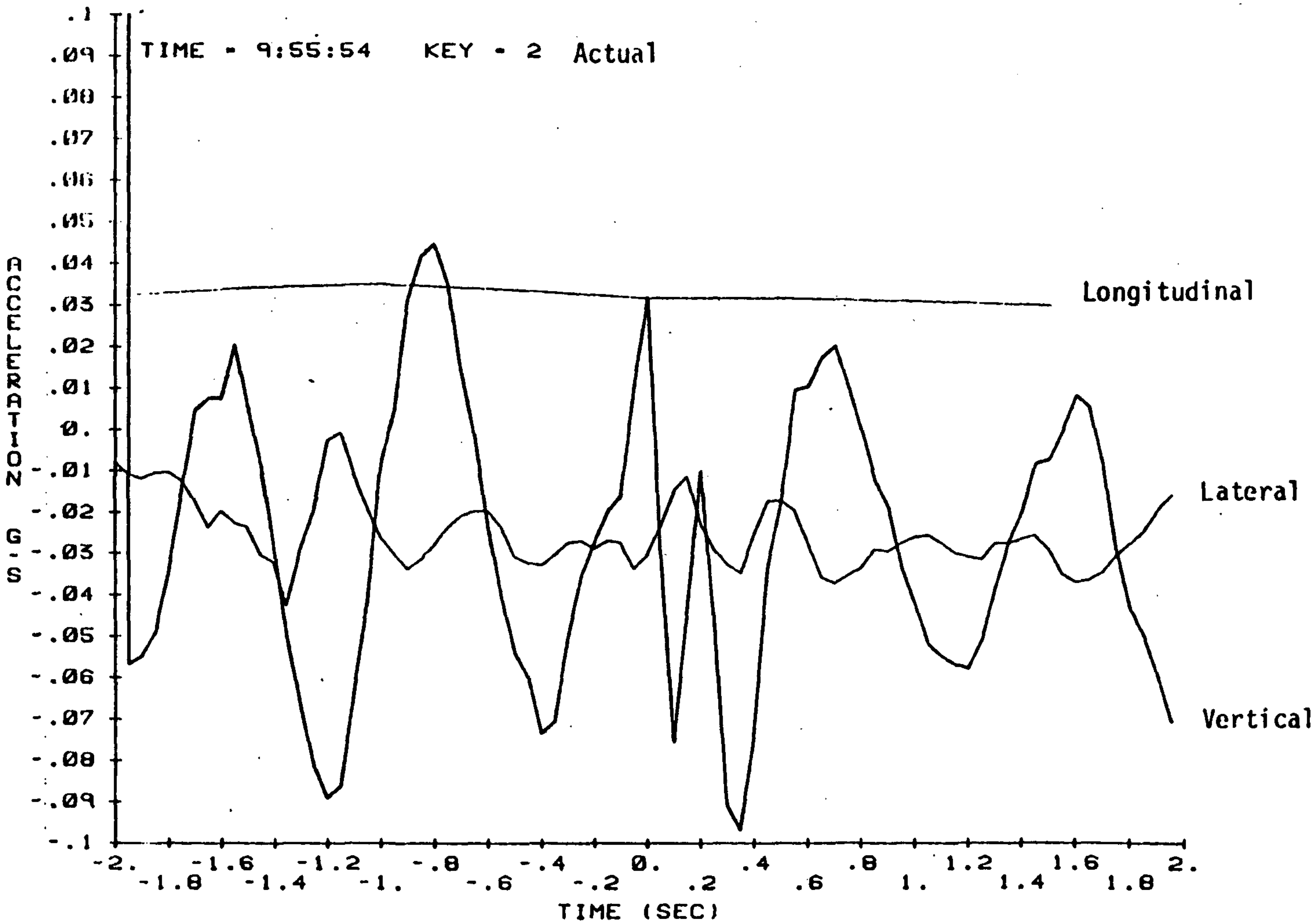

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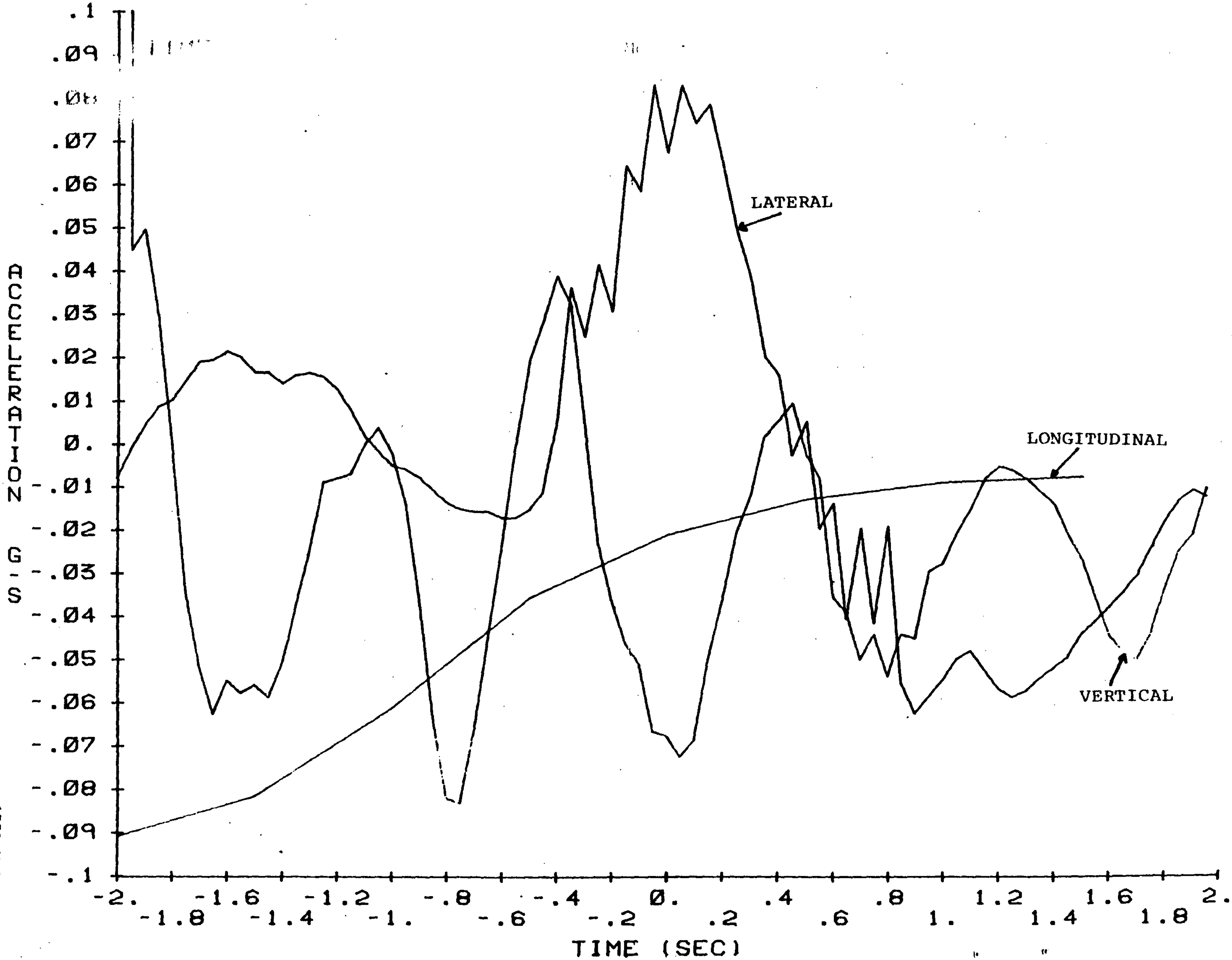
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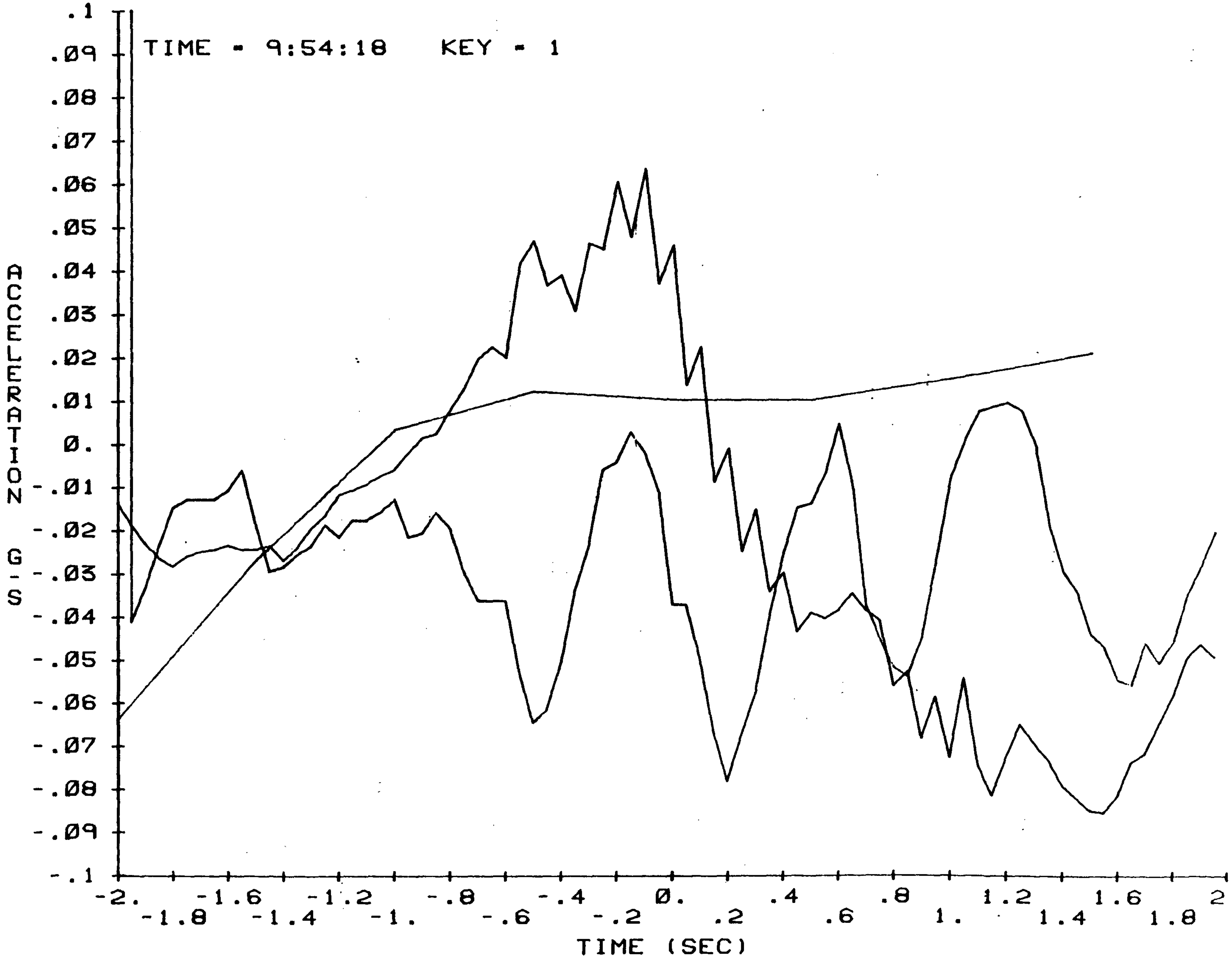
.08
.07
.06
.05
.04
.03
.02
.01
0.
-.01
-.02
-.03
-.04
-.05
-.06
-.07
-.08
-.09
-.1
-2. -1.6 -1.2 -.8 -.4 0. .4 .8 1.2 1.6 2.
-1.8 -1.4 -1. -.6 -.2 .2 .6 1. 1.4 1.8
TIME (SEC)
LATERAL
LONGITUDINAL
VERTICAL

40

6551-Y-1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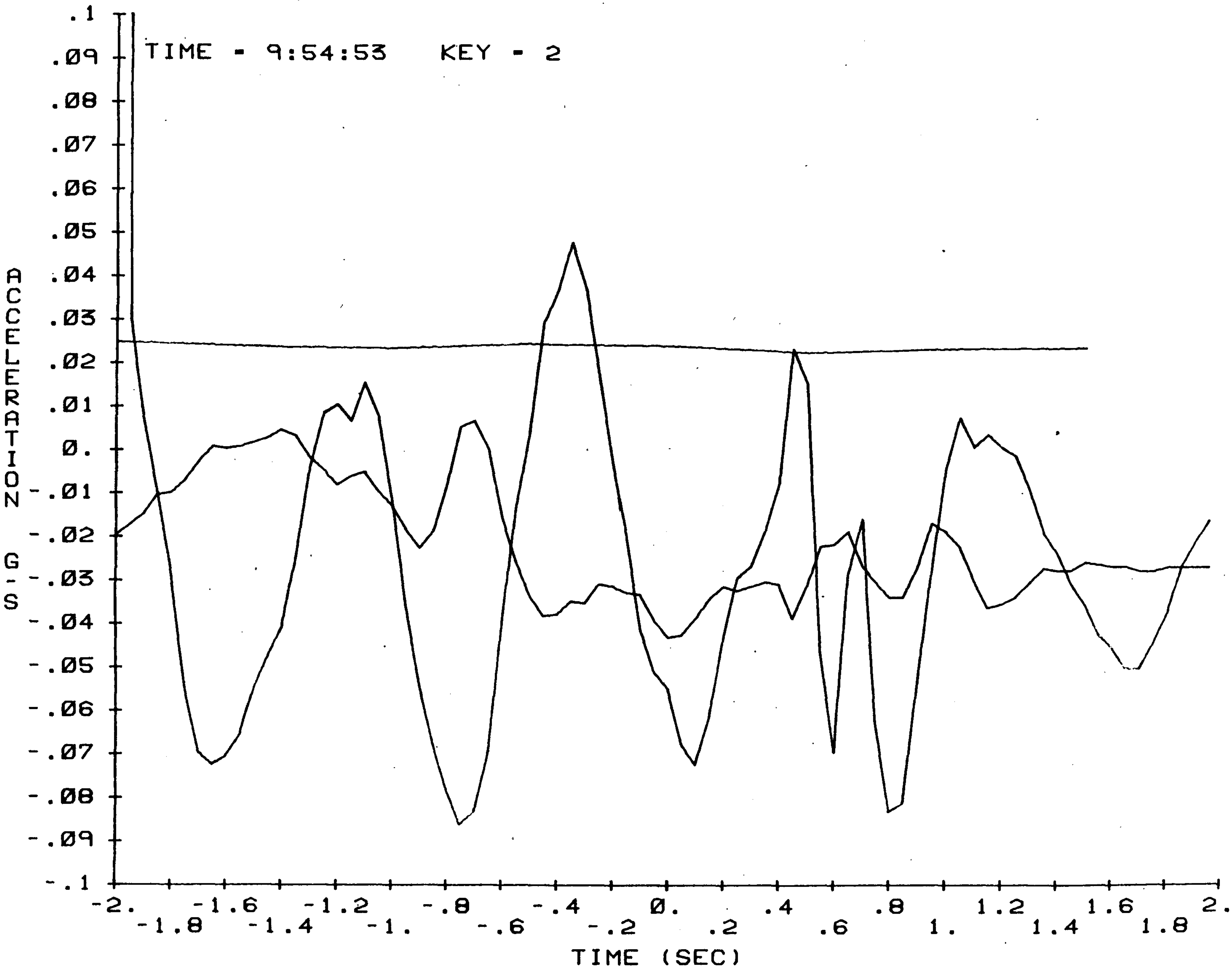
TIME (SEC)
.1 .09 .08 .07 .06 .05 .04 .03 .02 .01 0. -.01 -.02 -.03 -.04 -.05 -.06 -.07 -.08 -.09 -.1
-2. -1.8 -1.6 -1.4 -1.2 -1. -.8 -.6 -.4 -.2 0. .2 .4 .6 .8 1. 1.2 1.4 1.6 1.8 2.

6551-Y-1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.06
.05
.04
.03
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.01
0.
-.01
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-.03
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-.05
-.06
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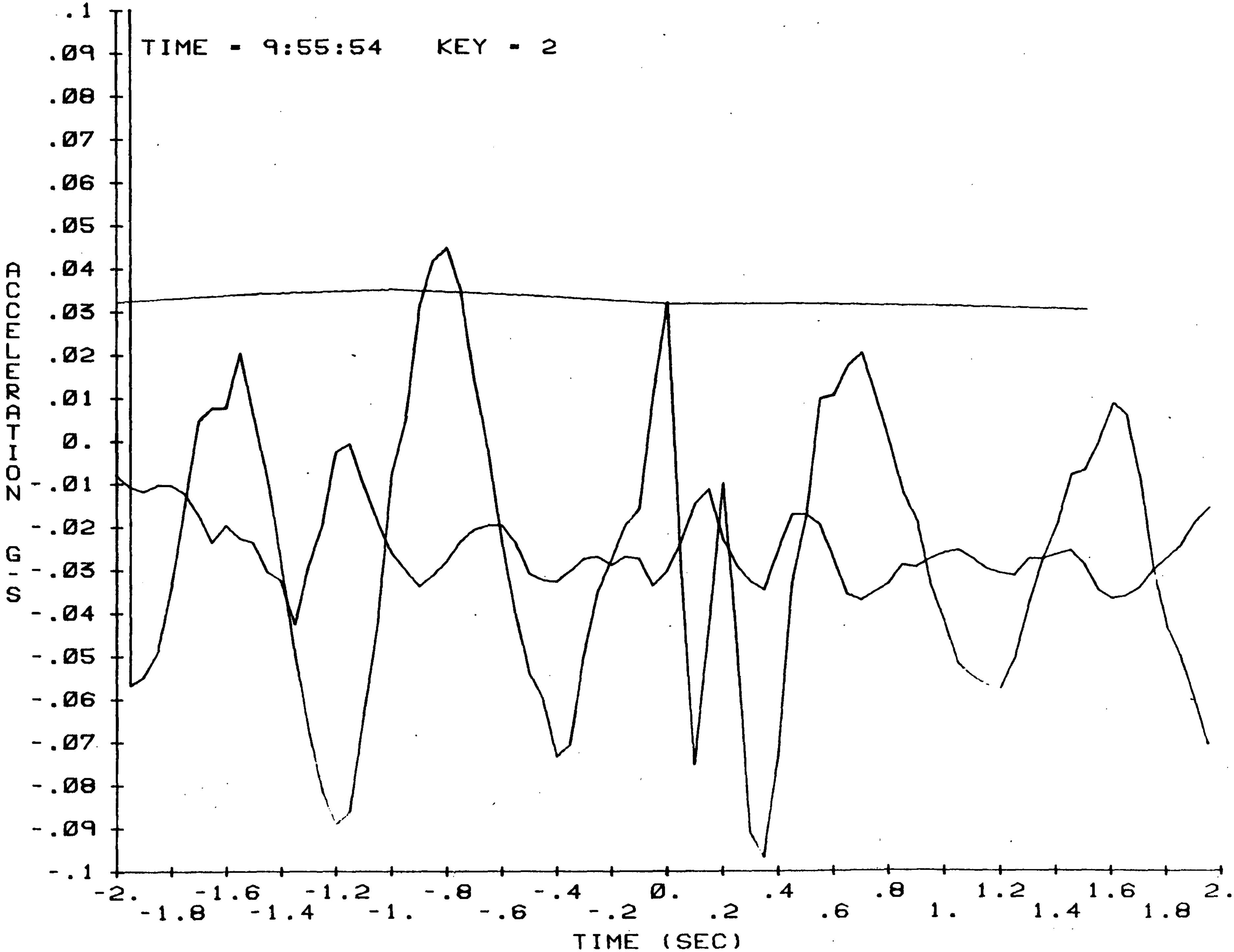
-.09
-.1
-2. -1.8 -1.6 -1.4 -1.2 -1. -.8 -.6 -.4 -.2 0. .2 .4 .6 .8 1. 1.2 1.4 1.6 1.8 2.
TIME (SEC)

6551-Y-1



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.08
.07
.06
.05
.04
.03
.02
.01
0.
-.01
-.02
-.03
-.04
-.05
-.06
-.07
-.08
-.09
-.1
-2.
-1.8
-1.6
-1.4
-1.2
-1.
-.8
-.6
-.4
-.2
0.
.2
.4
.6
.8
1.
1.2
1.4
1.6
1.8
2.

6551-Y-1

APPENDIX G

TELEPHONE SCREENING FORM - EXPERIMENT II

PERSONAL DATA

Name ______________________ Telephone No(s) ______________________

Address ____

Sex ________ Age ________ Birthdate ________ Height ________ Weight ________

Code ________

TELEPHONE SCREENING SHEET FOR POTENTIAL ALCOHOL/MARIHUANA TEST SUBJECTS

Date ______________ Time ______________ Code Number ______________

Source ______________________________ Accepted/Rejected ____________

Have you every been involved in an alcohol or drug related rehabilitation program? ____________

Present ______________________ Past ______________________

DRIVING DATA

Do you drive a car? Y / N How long have you been driving? ____________

Do you have a current driver's license? Y / N

Have you ever had an alcohol or drug related arrest? Y / N Explain: ____________

PHYSICAL CONDITION

Are you in good health? Y / N If no, explain ______________________

____

____

Do you have full use of both arms and legs? Y / N

Have you ever had ...	Yes	No
Diabetes		
Hepatitis		
Liver disease		
Kidney disease		
Heart trouble		
Convulsions		
Epilepsy		
Ulcers		
High or low blood pressure		
Respiratory problems . . .		

If the answer to any of these is yes, explain

____

____

____

____

Are you currently taking any drugs or medication? Y / N If yes, explain ____________

____

____

Are you colorblind? Y / N Do you have full vision in both eyes? Y / N If no, explain

____

Do you wear glasses or contact lenses? Y / N if yes, which? ____________

If glasses, how well can you see without your glasses? ____________

Code Number ____________

ALCOHOL AND DRUG DATA

What is your usual drink? ____________

If not hard liquor, do you drink hard liquor (whiskey, gin, etc.)? ____________

How much (of what) do you usually have when you drink? ____________

What is the most you ever drink? ____________

After drinking have you ever experienced:

Nausea ________ Vomitting ________ Dizziness ________

If yes, last time? ____________ How often? ____________

Have you ever had problems in school or on the job because of your alcohol or drug use? ____________

Have you ever used, when not prescribed by a doctor:

	Yes	No	Last Use?	How Often?
Cocaine				
Hallucinogens (LSD, peyote, mescaline)				
Barbiturates (Secanol, "reds," "downers")				
Amphetamines (Methadrine, Dexadrine, "speed")				
Tranquilizers (Valium)				
Opiates (heroin, opium, synthetics such as methadone				
Glue or aerosols				
Other drugs (What? ____________)				

Has your alcohol or drug use caused family problems? Past ____________ Present ____________

AVAILABILITY

If you are asked to take part in our alcohol/driving study, when would you be available? ____________

Specifically, on which days of the week, and for what times on those days, are you available?
Fill in table: ✓ = available; "no," "works," etc., if not available.)

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Morning							
Afternoon							
Evening							

How long will you be available on this schedule (specific dates)? ____________

APPENDIX H

INFORMED CONSENT FORM - EXPERIMENT II

Please read the following carefully.

The experiment in which you will participate is a investigation of the effects of alcohol upon performance in a driving simulator. At each session you will be asked to drink some liquid. The liquid which you will be asked to drink may or may not contain alcohol. If it does contain alcohol, the maximum does will be approximately 0.9 grams alcohol per kilogram body weight or about 6 ounces of whiskey for an average weight individual. Past experience with such doses, given at the rate we suggest for drinking, has usually produced no difficulties, although some subjects have occasionally experienced temporary discomfort. It should be noted that long-term use of large quantities of alcohol can lead to a variety of problems including alcoholism, liver and heart disease, and emotional problems.

The experiment in which you will participate will be directly supervised by Anthony C. Stein, our research psychologist. If any problem related to the experiment should arise which you or the experimenters feel requires assistance by a physician, a medical doctor will be available.

You will be given a list of persons to contact at any time after you leave our premises for assistance should you feel any discomfort.

It will be necessary for you to observe the instructions given to you pertaining to the experiment. Your participation will involve at least 10 hours/session and you should not make appointments which will require your presence until that time has elapsed or until the experimenter discharges you.

The data obtained from the investigation may be used for medical and other scientific purposes and may be made available for publication, but the identity of the subjects will not be revealed. You will be paid, but participation in the experiment cannot be expected to benefit you as an individual beyond the payment which you will receive. You will be free to withdraw from the experiment at any time without prejudice. If you have any questions, please feel free to ask them before or after you consent to participate.

I have read the foregoing information and received a copy.

Subject	Date
Witness	Date

APPENDIX I

RATIONALE FOR USING REWARD-PENALTY STRUCTURES

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Paper No. 223

USE OF REWARD-PENALTY STRUCTURES IN HUMAN EXPERIMENTATION

Anthony C. Stein
R. Wade Allen
Stephen H. Schwartz

For presentation at the
Eighty-seventh Annual Convention of the
American Psychological Association
New York, New York
1-5 September 1979

USE OF REWARD-PENALTY STRUCTURES IN HUMAN EXPERIMENTATION

Anthony C. Stein, R. Wade Allen, and Stephen H. Schwartz

Systems Technology, Inc.
Hawthorne, California

SUMMARY

This paper reviews the use of motivational techniques in human performance research and presents an example study employing a reward-penalty structure to simulate the motivations inherent in a real-world situation. The influence of motivation on human performance has been an issue since the beginning of behavioral science. Most often, motivation is controlled through procedures designed to minimize its influence as an uncontrolled variable. Driver behavior in a decision-making driving scenario was studied.

The task involved control of an instrumented car on a cooperative test course. Subjects were penalized monetarily for tickets and accidents and rewarded for saving driving time. Two groups were assigned different ticket penalties. The group with the highest penalties tended to drive more conservatively. However, the average total payoff to each group was the same, as the conservative drivers traded off slower driving times with lower ticket penalties.

INTRODUCTION

Reward-penalty structures have existed since the beginning of experimentation, and the effects of such structures have evolved into a separate area of research. As early as 1922, A. M. Johanson observed the effects of rewards and penalties on reaction times. These classic results (cited in Ref. 1) are shown in Fig. 1. Researchers have examined the motivational aspects (Refs. 2-6), looked at 'rewards' distracting effects (Refs. 7-10), and looked at the positive effects of rewards (Refs 11 and 12). What does this experimentation mean, and how can the researcher of today utilize the efforts of others?

Subject motivation is a primary concern in any experiment. "We want the subject motivated to come back for 12 experimental sessions;" or "we want the subject motivated to respond as quickly as possible;" or "we want the subject motivated to respond in a manner consistent with his or her normal behavior." Rewards and penalties play an important part in this motivation.

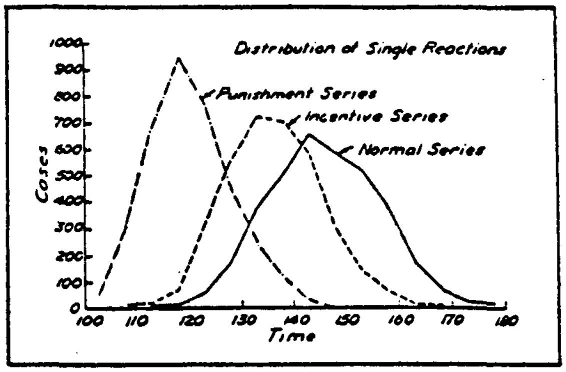

Figure 1. Change in the Distribution of Reaction Time Under the Influence of Incentives. Auditory stimulus. In the "incentive series" O was informed of his last RT; in the "punishment series" he received a shock in the finger when the reaction was at all slow. Each curve shows the distribution of 3600 single reactions obtained from three Os whose times were nearly the same. (Adapted from Ref. 1)

To assess reward-penalty structures with regard to their consequences, and to develop a structure for a given experiment, requires a basic knowledge of the literature, terminology, and present methodologies. This paper is a review of the present body of knowledge with an emphasis on reward-penalty design consequences for human performance research.

PREVIOUS RESEARCH

Definitions

The distinction between intrinsic and extrinsic motivation should be an important consideration when designing a reward-penalty structure. If a person chooses to work a series of complex mathematical problems because of personal enjoyment, then the "perceived locus of causality" (Ref. 6) is internal, and the task is intrinsically motivating. If, however, the person chooses to work the problems to gain an external reward, and the "perceived locus of causality" is external, then the task is extrinsically motivating (Refs. 3, 4, 6, 13-15).

Deci (Refs. 2 and 3), Deci, Benware, and Landy (Ref. 4), and Edwards (Ref. 16), all point out that reward-penalty structures can be designed to be either extrinsically motivating or neutral. If the experimenter chooses to have the structure of neutral influence on the subject, and at the same time achieve high subject motivation, it becomes necessary to use a task that has been, or can be, shown to be intrinsically interesting to the subject population. If the choice is to have a structure that makes the reward or penalty contingent on performance, or in some other way extrinsically motivating, then the choice of experimental task is of secondary consideration. It has been shown by Lepper and others (Refs. 3, 4, 13, and 14) that subjects performing tasks of high intrinsic motivation, receiving extrinsic rewards, perceive the locus of causality to be external, and show low intrinsic motivation.

Purpose of Rewards and Penalties

As pointed out by Edwards (Ref. 16), rewards and penalties can serve three purposes: 1) motivators, 2) information givers, and 3) instructions. If the subject is rewarded only for participation in an experiment, then the reward serves as a motivator; the subject will perceive the locus of causality as internal, and the experimental task will be intrinsically motivating. If the reward-penalty structure is changed, and task performance is rewarded the reward or penalty will serve as information, in addition to any motivating influence it has. If the experimental task is solving complex mathematical problems, and the subject is paid hourly for experimental participation, then task performance is unrelated to the reward, and the reward's purpose is that of a motivator. If the reward is increased as a function of problem completion time, or number of problems solved, the reward takes on the additional quality of an information giver. In this case it is important to note that correct response is not required.

If correct response is required for a reward increase, or incorrect response is punished, the reward also serves as an instruction. In this case the reward not only provides motivation and information, it now tells the subject the relative desirability of a specific response. Withholding the reward until the completion of the experiment does not alter its motivational or instructional qualities. Because the reward is performance related, withholding payment (or information about the reward "earned") only eliminates the informational feedback quality.

Form of Rewards and Penalties

Rewards and penalties can take many forms, and the type of reward or penalty chosen by the experimenter should be an important part of the reward-penalty design. The overall effect of the reward or penalty needs to be assessed prior to its introduction in the experiment. For example, Deci (Ref. 2) found that monetary rewards caused a decrease in intrinsic motivation, while rewards by use of verbal reinforcement caused an increase. McCloskey (Ref. 17), in her work with staff turnover rates, found that psychological rewards such as recognition, help from peers, and educational opportunities were more important in keeping an employee than salary or job benefits; and that money alone would not keep an employee. Viesti (Ref. 18) found that on an insightful learning task pay made no difference in performance.

One of the most commonly used rewards is money. Many researchers have examined the advantages and pitfalls of this reward form, and their findings can be of great assistance in developing a reward-penalty structure.

Money seems to provide the best balance between response and error rate. Daniels, et al.(Ref. 11), found that response speed remained constant, but a drastic reduction in error rate was observed when real instead of imaginary money was used. Slovic, Lichtenstein, and Edwards (Ref. 19) found that subjects employed simpler decision strategies in an imaginary incentive design than with real payoffs. Also Slovic (Ref. 20) found that when subjects made hypothetical choices, they maximized gain and discounted losses; however, when their choices had real consequences, the subjects were considerably more cautious.

The researcher should be cautioned by the work of Greenberg (Ref. 21) and Leventhal and Whiteside (Ref. 22), however. They have shown that monetary reward can be used to motivate performance, but that overreward is frequently employed. In some cases the overrewarding tendency was so strong that higher rewards were given to lower performing workers. Furthermore, Spence (Refs. 8 and 9), Miller and Estes (Ref. 10), and McGraw and McCullers (Ref. 7) point out that increased rewards may draw attention from the experimental task.

EXPERIMENTAL STUDY

The above research findings clearly show the need for appropriate reward-penalty designs, both in form and magnitude. The following examples, part of a study on alcohol-driver interaction, show how this information can be used to create a reward-penalty structure.

In a study concerning the effects of alcohol on drivers' decision making behavior, two separate experiments were conducted. The first was run in our fixed-base driving simulator (Ref. 23) and the second in an instrumented vehicle designed for the National Highway Traffic Safety Administration (Ref. 24).

In both experiments the subject was required to complete a driving scenario in both sober and intoxicated states. The following is a brief discussion of the requirements, design, and effects of variations in a motivational reward-penalty structure.

Reward-Penalty Structure

Driving in the real world is motivated by a variety of counteracting incentives. Drivers wish to minimize trip time but avoid tickets and accidents. Driving behavior is influenced by these motivations, particularly in risk-taking/decision-making tasks. In order to encourage real-world-like behavior we must attempt to simulate the real-world incentives. The problem with simulating typical driving incentives is that they include some difficult-to-quantify variables, such as the subjective value of time gained by driving faster and the subjective fear of low probability events such as auto crashes. Negative reinforcement with electric shock is a classical experimental technique and might serve to simulate the pain of an accident, but this technique is difficult to quantify and recent subject welfare guidelines make it unattractive. In a recent aircraft landing experiment involving pilot decision making (Ref. 25), the experimenters went so far as to inform their pilot subjects that they would be eliminated from the experiment in the event they crashed in order to make them as averse to crashes as they would be in real life. However, this approach would be logically awkward in this study because we would lose selected and trained subjects and, furthermore, the majority of driving accidents do not involve fatalities.

The traditional method of quantifying incentives for experimental control is to relate them to some well-defined variable with interval properties by measuring indifference curves (Refs. 26 and 27). The most well-defined, widely studied, and widely used norm is money, primarily because of its interval properties and interchangeability. Money has some limitations; for example, the decision-making behavior has been shown to be confounded by the subject's financial status. However, this can be experimentally controlled by controlling the knowledge of results (Ref. 28). In general, the additional experimental effort required to scale other disincentives (e.g., shock, loud noises, etc.) has led to widespread use of money for rewards and punishments in decision-making experiments.

In both experiments the reward-penalty structures had multiple requirements. A major concern was that the subject complete the driving scenario in a normal manner, with a reasonable motivation for timely progress and a desire to avoid tickets and accidents; that is, we wanted the subject to drive as if the driving situation were being experienced in the real world. A second requirement was that the subjects return for participation in six full-day experimental sessions. Finally, we chose to alter the penalty structure in the experiment to determine the behavioral effects of increased ticket penalty on the driver.

With the exception of ticket penalties, the reward-penalty structure for both experiments was the same. In order to provide a basic motivation to remain in the study, the subjects were paid an hourly wage. This payment was received by the subject irrespective of performance. To facilitate completion of the driving scenario, and to encourage normal driving behavior, we used an additional reward-penalty structure scaled to real world occurrences.

Rewards consisted of $10.00 for completing the driving scenario, and $2.00 for every minute of total elapsed driving time under 20 minutes. Assuming a real world situation of leaving a bar intoxicated, this rewarded the subject for making it home and for driving with the flow of traffic, thus avoiding detection.

In both experiments, crashes (i.e., hitting an obstacle or adjacent car, or running off the roadway) were penalized $2.00.

Tickets were given for running a red light or for speeding. Again to simulate a real world driving experience, the traffic police were present only 30% of the time. In experiment 1 (the simulation), tickets were either $1.00 or $2.00, depending on the group to which the subject was assigned. In experiment 2 (full-scale), tickets were either $1.00 or $4.00.

Subjects received immediate feedback if they crashed (buzzer), or received a ticket (siren and red lights), but total rewards and penalties were withheld until the completion of the experimental day. Again this simulates the real world, because the cost of a ticket or crash is rarely known when the incident occurs.

RESULTS AND DISCUSSION

To determine the suitability of our reward-penalty structure to the experiment, two criteria can be used. First, did all the subjects complete the experiments? In both experiment 1 and experiment 2 the answer was yes, indicating that we were able to keep the subjects sufficiently motivated to return. Second, to correlate our results with real world driving statistics, we compared our simulator and field test results with epidemiological data of over 7000 alcohol related traffic accidents. As evidenced in Fig. 2, the simulator results and the field results compare favorably with the actual accident data, thus indicating drivers motivated to take comparable risks.

Finally, in our investigation of the behavioral effects of a change in penalty structure, we found in experiment 1 no significant difference between the $1.00 ticket group and the $2.00 ticket group. Experiment 2, however, did show a significant difference between the $1.00 ticket group and the $4.00 ticket group.

In Fig. 3 we see that the high penalty group in the field study had on the average of one-third less tickets, with speeding tickets showing a greater sensitivity than signal light tickets. These results are statistically significant as shown in Table 1. Driving time differences between the two penalty groups were marginally significant (Table 1) and consistent with the ticket results, e.g, larger time and fewer tickets. Payoff was <u>not</u> significantly different between the penalty groups, however (Table 1), which indicates a compensatory tradeoff between driving time and ticket rate.

TABLE 1. ANALYSIS OF VARIANCE SUMMARY FOR OVERALL SCENARIO PERFORMANCE IN THE FIELD VALIDATION STUDY

SOURCE	ERROR TERM[a]	DEGREES OF FREEDOM	F RATIOS					
			PAYOFF	DRIVING TIME	ACCI-DENTS	SIGNAL TICKETS	SPEEDING TICKETS	ROUTE ERRORS
Day	DS(P)	1	19.33***	2.92	12.71**	2.09	13.96**	1.50
Penalty	S(P)	1	2.37	4.20†	1.92	10.80**	5.47*	1.33
Trial	TS(P)	2	10.44**	2.27	13.56**	4.72*	3.71*	1.41
DP	DS(P)	1	0.33	0.42	1.08	0.52	2.67	1.50
DT	DTS(P)	2	13.71***	1.0	11.55**	2.46	4.10*	1.26
PT	TS(P)	2	0.59	2.02	0.40	1.13	0.53	1.33
DPT	DTS(P)	2	1.40	1.65	1.27	2.08	0.90	1.49

Level of Significance: †$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

[a]Error term degrees of freedom: S(P) - 12, DS(P) - 12, TS(P) - 24, DTS(P) - 24.

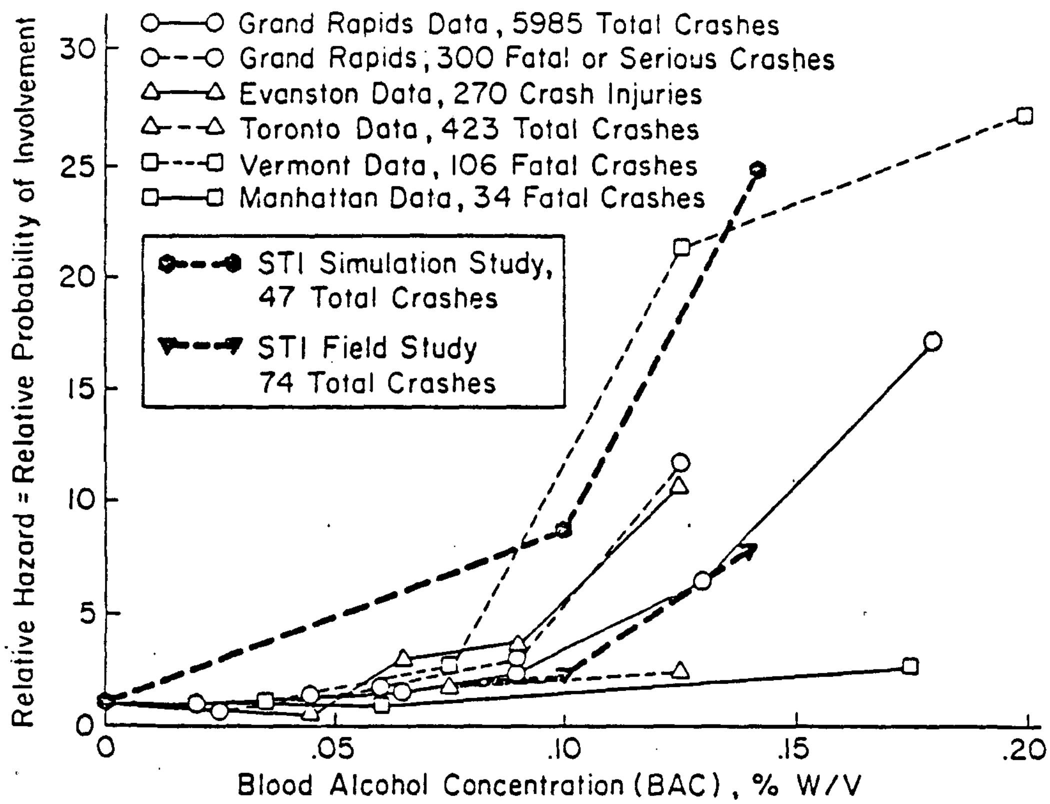

Figure 2. Relative Probability of Crash Involvement as a Function of BAC Where 1.0 = Relative Probability at Zero Alcohol (Adapted from Ref. 29)

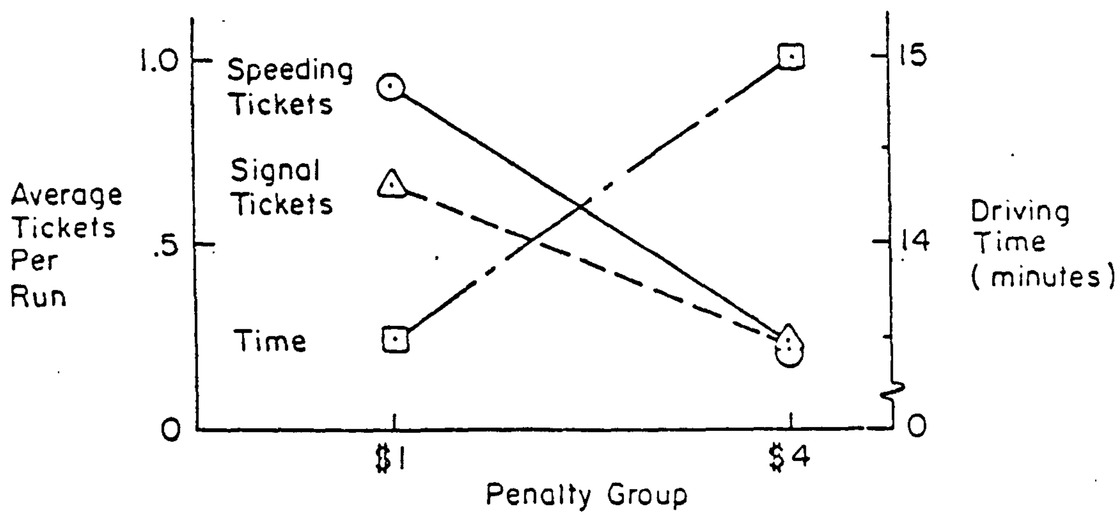

Figure 3. Penalty Effect on Ticket Rate and Total Time to Complete the Driving Scenario

Some insight into the ticket reduction with increased penalty can be gained from the signal light risk acceptance plot shown in Fig. 4 (Ref. 30). Here we see that the high penalty group perceived higher risks in signal failures (i.e., running the red light) and was willing to go less often. The combined effect was much more conservative behavior for the high penalty group, leading to better driving performance. The P(G) and SP(F/G) differences in Fig. 4 were statistically significant, but the SP_c difference was not. No group differences were observed for accident data in the experiment, and because of the magnitude of the ticket and P(G) group differences it is assumed that these are true penalty effects and not just between-group differences.

CONCLUDING REMARKS

The following conclusions were drawn with respect to the reward-penalty structure in our experiments:

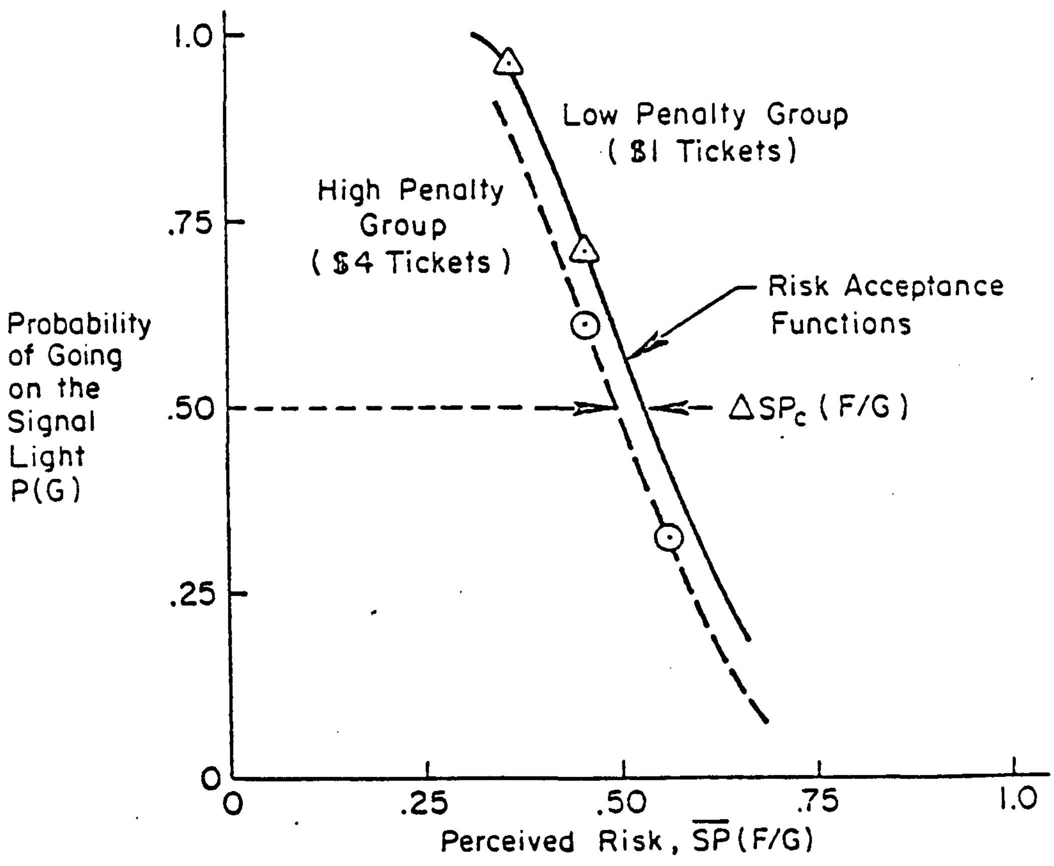

Figure 4. Mean Subjective Probability of Failure to Make It Through the Light If It Were Attempted

* Driving is not intrinsically motivating to the majority of the population, and in experimental tasks is even less so. Real-world Motivation incentives such as accidents, tickets, and desire to safe time, are extrinsic.

* Rewards and penalties must be tangible. Imaginary rewards and/or verbal reinforcement are not sufficient.

* Rewards and penalties should serve as general motivation, but not direct feedback in the driving scenario.

* Between runs in an experimental session, overall performance payoffs should be withheld in order to avoid feedback or reinforcement which might modify behavior on subsequent runs.

* Our results show that employing a specifically designed monetary reward-penalty structure provides sufficient extrinsic motivation to duplicate a "real world" driving situation.

These results on reward/penalty effects on driver risk taking might be extrapolated to real-world driving behavior. Perhaps drivers would drive more conservatively with increased and more evenly applied penalties for traffic violations.

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APPENDIX J

SUBJECT WELFARE COMMITTEE - EXPERIMENT II

Systems Technology, Inc., has continuing agreements with several members of the surrounding community to serve on subject welfare committees for various projects. A particular committee is formed from this "pool" and from STI staff to meet the particular needs of the project. For this project the committee will consist of the following individuals:

- Irving L. Ashkenas, M.S. Mr. Ashkenas is currently Vice President of Systems Technology, Inc. He has served as Technical Director for numerous studies involving human operators of ground, air, and sea going vehicles.
- Roland L. Coleman, Jr., J.D. Mr. Coleman is an attorney working for the State of California Department of Transportation, as well as in private practice.
- Choi Hokama. Mr. Hokama is the pastor of the Emanual Missionary Baptist Church.
- James C. Smith, Ph.D., Committee Chairman. Dr. Smith is a Senior Research Engineer at Systems Technology, Inc. His research experience includes studies on methodologies for reducing high blood pressure, as well as vast research in the areas of human neurophysiology and psychophysiology.

January 14, 1982

To Whom It May Concern:

I certify that the Subject Welfare Committee has reviewed the experiment described in STI Working Paper 2160-1 and has approved the stated procedures.

James C. Smith, Ph.D.
Committee Chairman
Subject Welfare Committee, Project 2160

APPENDIX K

SUBJECT INSTRUCTIONS (SIMULATOR DESCRIPTION) - EXPERIMENT II

TODAY YOU WILL BE DRIVING IN THE SIMULATOR AS PART OF YOUR PREPARATION FOR THE FORMAL DRINKING EXPERIMENT AT STI

The simulator operates in the following manner: you will sit in the driver's seat of a car cab facing a screen that depicts a roadway and a scenic horizon. When you step on the gas pedal, the screen shows forward motion of the car; if you step on the brake, the car "slows." When you move the wheel, the display shows the car moving down the road. In addition to the visual display, there is an engine noise that varies with car speed. We are simulating open highway driving conditions with no other interfering traffic.

You will be given a brief practice run and then you will participate in a 15-20 minute drive during which you will be required to follow the posted speed limit and to control the steering. During the run you will be presented with stationary and moving obstacles and curves. When you encounter a curve or an obstacle, please continue around it as safely as possible. If you exceed the roadway boundaries or hit an obstacle, you will have had an "accident." If you exceed the speed limit you run the risk of getting a ticket from our computer "cop," a siren that will be in operation approximately 30 percent of the time.

During the drive you will pass over sections of road with different pavement markings. Also, a series of road signs will be presented to you. You will need to respond to some of the signs by honking the horn. The experimenter will tell you which signs to respond to before you begin your "drive."

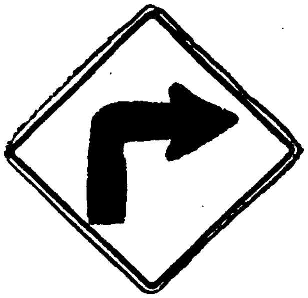
On experimental days the simulator drives will be two hours long. You will be paid $3.35 per your and an additional $20 for completion of the run. You will also receive $1 per each minute for beating a preselected completion time. Each ticket will cost you $1 and each accident will cost $2.

We have tried to make the simulator as real as possible. It might be helpful to imagine you are driving a rented or borrowed car. The experimenter can answer an questions you have regarding the simulation.

THANK YOU FOR YOUR PARTICIPATION

APPENDIX L

CURVE WARNING AND ADVISORY SPEED SIGNS - EXPERIMENT II



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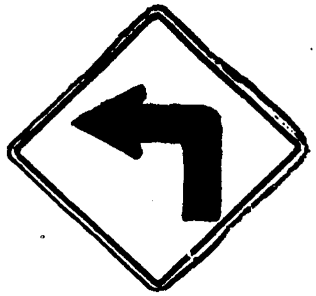

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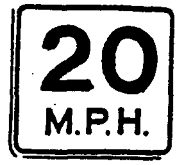

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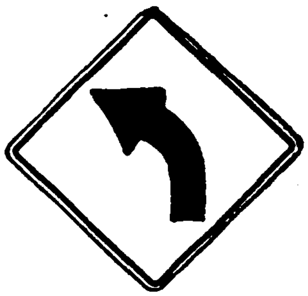
W1-2R



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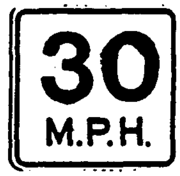

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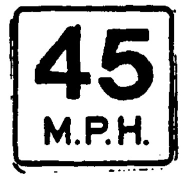

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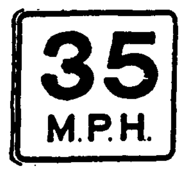
W1-4R

W1-4L



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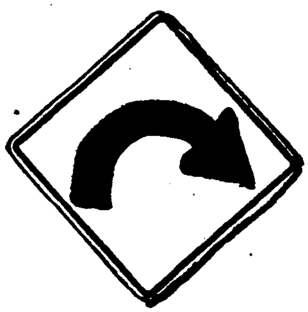
ST1-W1-L



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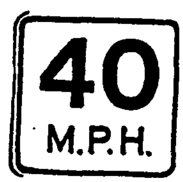
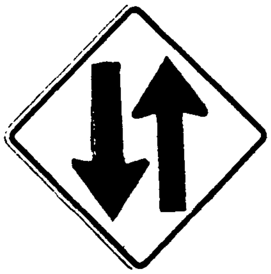


W13-1

APPENDIX M

SCENARIO SIGNS - EXPERIMENT II

A. Signs Requiring Response



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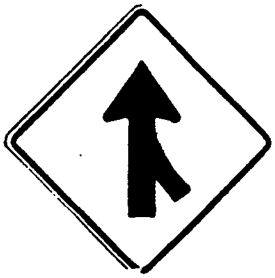

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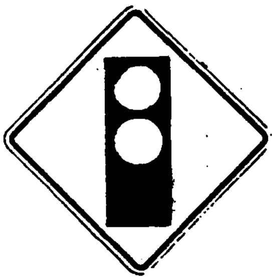
W11-2

S1-1



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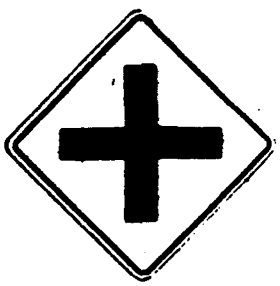
W11-3

W10-1

W11-9

W8-5



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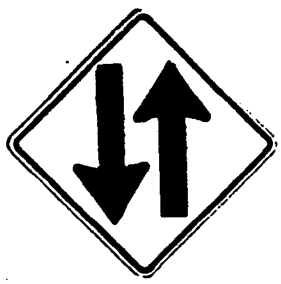
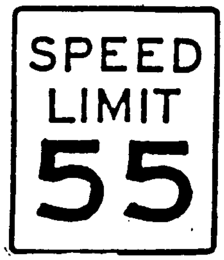


W6-3

W8-9a

B. Signs Not Requiring Response



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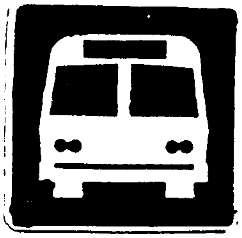
R3-4

R3-1

R9-39

R8-3a

R9-4a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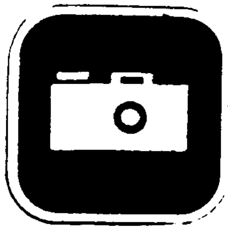
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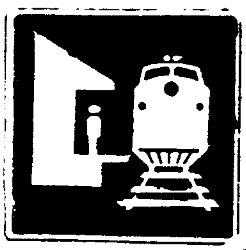
RS-022


D9-2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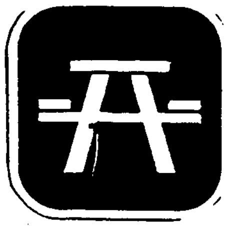
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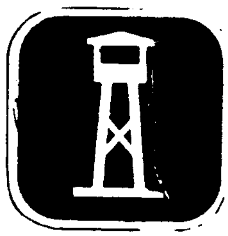
RS-047


D9-10


I-5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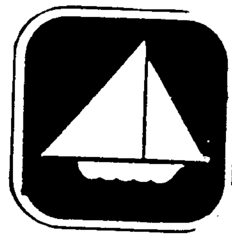
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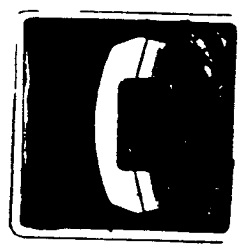
D9-6


I-14

MI-2

MI-1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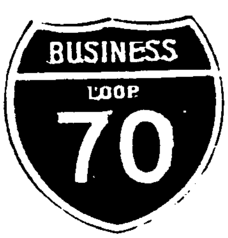
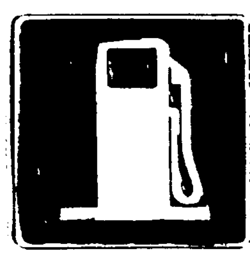


MI-2
Off-Interstate

E4-1

MI-1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