MARIJUANA/ALCOHOL DRIVING PERFORMANCE STUDY
A SUMMARY OF PRELIMINARY FINDINGS

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SYNOPSIS

Approximately 100 volunteer male marijuana and alcohol users received 1 of 4 experimental treatments: (1) marijuana; (2) alcohol; (3) marijuana and alcohol; or (4) double placebo. After consumption, each subject drove a vehicle over a test course which simulated a number of real-world driving conditions. Four post-drug runs were involved, separated by 1-hour intervals. The subject's performance was rated by an in-car examiner, outside observers, and computerized vehicle measurements. Blood and urine specimens were extracted after each run to establish levels of THC and alcohol. A variety of multivariate statistical techniques were applied in evaluating treatment effects. Both marijuana and alcohol had significant effects on driving performance; the effects were particularly detrimental under the both-drugs treatment.

INTRODUCTION

This alcohol and marijuana driving performance study utilized a 3-factor independent groups design with repeated measures over 1 variable (Reeve et al., 1981). Subjects were randomly assigned to 1 of 4 treatment conditions: (1) double placebo; (2) active alcohol/placebo marijuana; (3) placebo alcohol/active marijuana; (4) active alcohol and active marijuana. Useable data were collected on a total of 84 subjects, 21 subjects per group. The design utilized multiple performance measures from 6 measurement categories. These were: (1) subjective measures made by raters and observers; (2) objective video tape sensor measures; (3) California Highway Patrol (CHP) observer measures; (4) Critical Tracking Task (CTT) and brief interval time estimation (BITE) measures; (5) clinical measures; and (6) subject self ratings.

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This study was designed to determine:

1) The singular and combined effects of marijuana and alcohol on a number of measures of driving performance;

2) The relationship between the ranges of delta-9-THC (tetrahydrocannabinol) in blood and/or alcohol in breath and measures of driving performance;

3) The relationships between various driving performance measures, their differential susceptibility to marijuana, and alcohol ingestion; and

4) The relationship between the time following alcohol and/or marijuana ingestion and driving performance impairment.

This study is unique in combining the features of various previous experiments concerning alcohol, marijuana, and driving performance into a single investigation. The separate effects of alcohol and marijuana have been measured in the past, using a variety of laboratory and field performance tasks (Reeve et al., 1981). Several investigators have studied a combination of THC and alcohol, using laboratory (including simulator) performance measurements, and 2 studies involved actual driving after ingestion of both drugs. The present study, however, is the first in which actual driving performance and laboratory measures have been correlated with chemical monitoring of both THC and alcohol in the blood, over a series of repeated trials.

METHODS

Data Reduction

Through a series of factor analyses, the thousands of data points were reduced to 27 variables representing 5 measurement domains: I. 15 factors from the license registration examiners' sheets; II. 2 factors from the outside raters' sheets; III. 3 significant factors from the sensor data; IV. 3 dimensions from the 9 field sobriety tests; and V. miscellaneous variables consisting of the CHP-car following rating, the CTT, and the BITE. Performances on these 27 variables following administration of the treatments were evaluated through a variety of multivariate techniques.

Statistical Analyses

The estimation and significance testing of the experimental treatment effects on performance were evaluated through a series of discriminant function analyses and related multivariate methods. In addition, univariate factorial analyses of variance (ANOVA's) , multiple regressions, and analyses of co-variance (ANCOVA's) were run on selected measures. Time-response gradients were evaluated through a series of analyses in which a discriminant function program was adapted to evaluate treatment differences in the patterns of rates of change on selected performance measures.

To test for bias in treatment group composition, we evaluated the 27 factors at baseline (Run 2) were evaluated through a multiple discriminant function analysis.

The post-treatment differences between the groups on the same 27 variables were then evaluated within each run (Runs 3-6) and on the composite of these runs through a stepwise discriminant function procedure. Using a significance level of p is less than .25 and a requirement that a performance variable discriminate on at least 2 runs, we included a total of 12 variables in the final pool of discriminators. The discriminant analyses were then rerun to derive optimal functions on this common pool of 12 variables.

RESULTS

The multivariate test for bias at Run 2 was nonsignificant, indicating that the 4 groups were essentially equivalent prior to treatment.

Of the discriminant functions resulting from the 12 variable on total composite run performance, the first 2 functions were statistically significant at p less than .01 and p less than .07, accounting for 64.3% and 22.3% of the explained variance, respectively (Table 1).

Table 1

Standarized Discriminant Functions--Total Composite Runs

Variable	Function I	Function II
Stanchions Touched	-0.72	0.81
Estimated Chicane (Deviation)	-0.87	0.41
S MPH (Speed Covered)	0.68	-0.28
Attempts (Risk Task)	0.62	-0.19
Cognit	0.46	0.03
Urban Failures	0.41	-0.10
Stanchions Down	-0.28	.02
Position Stop	0.16	0.93
Stopping Errors	0.15	0.59
Bipolar Skill	0.21	0.17
CTT	-0.15	-0.19
Bipolar Speed	-0.09	0.45
Variance Explained (%)	64.3%	22.3%
Canonical Correlation	.69	.49
Significance Level (p)	greater than .01	greater than .07

A 2-dimensional plot of the group centroids (Table 2) shows that the first function separated the placebo (P) from the both-drug group (B), with the marijuana (M) and alcohol (A) groups showing intermediate values. The second function separated the placebo from the 3 drug groups. Inspection of the means and structure matrix confirmed that on most variables, the placebo was associated with good performance and the drugs with poorer performance.

The structure matrix for the first 2 functions for all variables yielding correlations of .30 or higher (many other variables yielded lower, but significant correlations and are not shown for reasons of parsimony) provided comprehensive information on what each function is really measuring (Table 3); the structure matrix represents the correlation between the discriminant function scores of the subjects and their scores on all of the variables measured in the study. Note, incidentally, that these correlations have more powerful causal implications than ordinary correlation coefficients because they represent correlations with that part of the total score variance which has been causally affected by the treatments (the between treatment variance). Note, also, that the signs for some variables in the structure matrix are different from their signs in the discriminant function equation (e.g., chicane speed). This indicates that the direction of a variable's "unique" influence in the context of other variables differs from its simple direct response to the treatments. Such "suppressor" relationships must be evaluated carefully to avoid misinterpreting the results.

The total treatment effects across the 4 runs were highly significant. As expected, the effects were largest at Run 3 (Table 3) but, surprisingly, were almost as large at Run 6 (Table 4).

Table 3

Structure Matrix for First Two Discriminant Functions--Composite Runs (correlations less than .30; p greater than .003)

Function I			Function II		
Chicane Deviation Score	=	.52	Stop Position	=	.69
Speed (MPH)	=	.45	Stop Position (Bipolar)	=	.37
Bipolar Speed Control (Speedometer Covered)	=	-.42	Stopping Errors	=	.36
Detours Errors	=	-.41	Speed Control (Bipolar)	=	.31
Chicane Speed (E.T.)	=	-.40			
Overall LRE Rating	=	-.38			

Accelerator Changes (E.D.)	=	+.34
Steering Control (Bipolar)	=	-.32
Speed Match (Speedometer Covered)	=	-.32
Lane Position (Speedometer Covered)	=	-.31
U-Drive Instruction Failures	=	-.31
Bite Run 4	=	.31
Total Errors (Except Stopping)	=	-.30
Urban Speed (E.T.)	=	-.30
Urban Stops (Bipolar)	=	.30
Bite-Run 5	=	.30
FST Finger Count	=	-.30

Table 4

Percent of Variance Explained by Treatments for Each Post Treatment Trial

Trial	Percent of Variance Explained--All Three Functions*
3	71.1
4	62.4
5	63.5
6	69.4
Total Trials ..	66.5

* - Wilk's Lambda.

The percentages of variance attributed to marijuana, alcohol, and their interaction on the composite total run multivariate analysis indicate that all main effects were highly significant, but not their interaction (Table 5). Thus, the drugs were largely additive in their effects on performance.

Table 5

Percent of Variance Due to Treatment Factors - All Post Treatment Runs Combined

Effect	Percent of Variance (Explained)	Significance
Marijuana	33.2	greater than .001
Alcohol	24.2	greater than .001
Alcohol & Marijuana Interaction	9.1	N.S.
Total	66.5	greater than .001

The multivariate main effects and interactions across runs show a gradual declining effect for marijuana but a relatively flat gradient for alcohol (Table 6). Again, the effects are primarily additive, with a suggestion of an interaction at Run 6. In contrast to the total composite run results (Table 4), these data show a larger main effect for alcohol than for marijuana. This reversal implies a significant treatment x trial interaction with respect to alcohol. That is, the pattern of relationships for alcohol varied over time, which was obscured somewhat by collapsing the runs into a composite measure. The average effects across runs, therefore, provide a better index of the effect magnitudes.

Table 6

Treatment Effects by Run
(Percent of Variance Explained)

TREATMENT	RUN 3	4	5	6	$\overline{X}$
Alcohol (A)	29.5	32.0	31.5	32.5	31.4
Marijuana (M)	29.5	25.0	23.5	24.5	25.6
A x M Interaction	7.0	7.0	7.0	13.0	9.5

Figures 1 through 8 present plots of treatment group performance on a small number of selected variables. Unless otherwise noted, the performance measures are on the total composite runs. In all cases, the baseline performance (Run 2) is shown as a single point based on the average of the 4 treatment groups combined. This procedure was adopted to simplify the plots and can be justified by the fact that the groups did not differ significantly on the baseline measures.

No attempt is made here to interpret each of the figures, other than to point out that they reflect some of the findings shown in the preceding tables. In most instances, the placebo performed best, and the both-drug group performed poorest. Most of the figures show additive effects although there are some instances suggesting positive and negative interactions. Some of these data must be interpreted with caution due to the functional interdependency of the performance measurements. For example, Figure 1 indicates that marijuana resulted in a substantial improvement on the stanchions-touched variable. However, the results also indicate that marijuana caused subjects to drive more slowly through the chicane, which would tend to decrease the difficulty of the task. It is, therefore, difficult to interpret the substantive implications of such effects beyond concluding that marijuana intoxication causes one to drive more slowly and to make fewer errors in response to a difficult drive task.

Figure 9 shows the degree of impairment as judged by the subject, the license examiner, and the CHP officer who administered the Field Sobriety Test (FST). The 3 sets of results parallel each other quite closely with notable impairment evidenced only by the both group.

This study also included a measurement in which a CHP patrol car followed the subjects during the extended drive portion of the course and indicated whether or not the subject's driving appeared to be significantly impaired. All treatments were judged to be significantly more impaired than the placebo, and the size of the effects are quite extraordinary (Figure 10).

Figure 11 (A through I) illustrates the average blood/serum levels achieved by the subjects over the 4 treatment runs, along with performance on factors statistically related to treatment. Several of the trial-performance gradients tend to correlate with their respective serum gradients. For example, Figure 11B shows performance over trials on the primary factor underlying the field sobriety test (labelled "cognit"). We find that the marijuana and alcohol treatment means on this factor approximate the trends of the serum levels, whereas the placebo gradient is much flatter; note that both groups produced an unexpected increase in performance decrement at Run 6. The full implications of these data will require further study and the complete set is included without further comment.

DISCUSSION AND CONCLUSION

It must be emphasized that the above results represent only a small proportion of the data and the analysis of the findings. The final report will examine these data in more detail along with the total range of hypotheses addressed by the study. It appears safe, however, to conclude from these preliminary analyses that marijuana affects driving performance and that the effects are particularly detrimental in combination with alcohol.

Although there were a number of significant differences, there were also substantial similarities in the impact of marijuana and alcohol on driving performance. However, marijuana was more likely to cause excessive cautiousness on certain tasks than was alcohol. A significant association was found to exist between blood/serum levels of the drugs and performance, in that reductions in serum/blood levels across trials tended to be

associated with improved performance. Driving performance was affected for up to 4 hours following the use of marijuana, alcohol, or their combination. Although the effects declined with time, alcohol decrements existed longer than those of marijuana. Prior driving experience and drug use did not have an influence on treatment effects. Serum THC levels alone were not as good a predictor as the treatment condition. However, the combination of serum THC and carboxy metabolite levels accounted for slightly more of the marijuana-induced variation in performance than could be explained by the treatment condition alone.

While closed course driving is not necessarily indicative of spontaneous driving performance on the highway, the drive range did measure the important vehicle control and perceptual/motor integration components of the drive task. The major limitations involved in a closed drive range are the absence of dynamic traffic interaction responses and task situations involving a driver's assessment and response to accident risk. Since the measurements were obtained under daytime conditions, it is important to recognize that none of the results can be generalized to reduced visibility driving or night driving. We believe that impairment would probably be greater if measured under night-time conditions. Eventually, naturalistic behavior must be examined, using methods that are minimally constraining and generally unobtrusive. Rigorous epidemiological studies on the relative frequency of marijuana and marijuana-plus-alcohol in the blood and serum of fatal accident drivers are also essential.

The current study offers the opportunity to make a first approximation of the driving hazards inherent in marijuana intoxication, both alone and in combination with moderate amounts of alcohol. Hopefully, it will point the way to future efforts with respect to drugs and driving.

ACKNOWLEDGEMENTS

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County Criminalists Laboratory; the Veterans Administration Hospital in Palo Alto; Caltrans; the Research Consulting Corporation; Receptor Research Institute, Systems Technology, Inc.; the Insurance Institute for Highway Safety; Fail Safe, Inc.; SYVA, Inc.; Hoffman La Roche, Inc.; Research Triangle; Batelle Institute, North Carolina; and of Dr. Jim Ketchum, M.D., of the Veterans Administration Hospital in Palo Alto. The support of these agencies and the many individuals was essential to the success of the study. A major portion of the project was supported by a grant to the Department of Justice from the California Office of Traffic Safety (087902). Subsidiary support was provided through separate Office of Traffic Safety Grants to the Department of Motor Vehicles and the Foundation of the California State University, Sacramento. However, the conclusions are those of the authors and do not necessarily reflect the opinions of the Office of Traffic Safety, the National Highway Traffic Safety Administration, or any of the above-mentioned affiliations.

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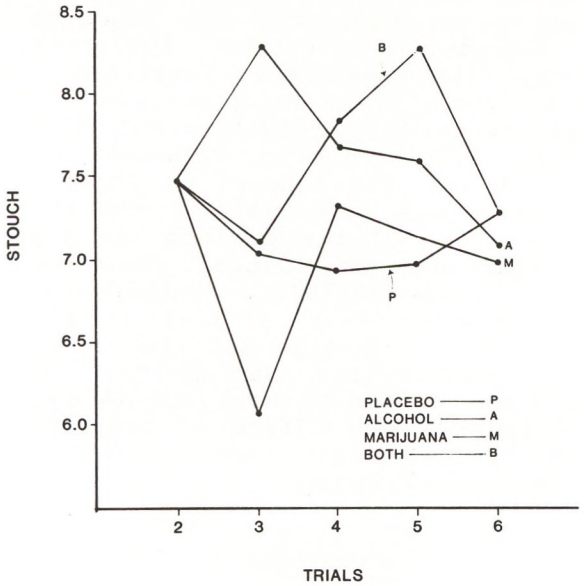


Figure 1. Stanchions Touched Factor.

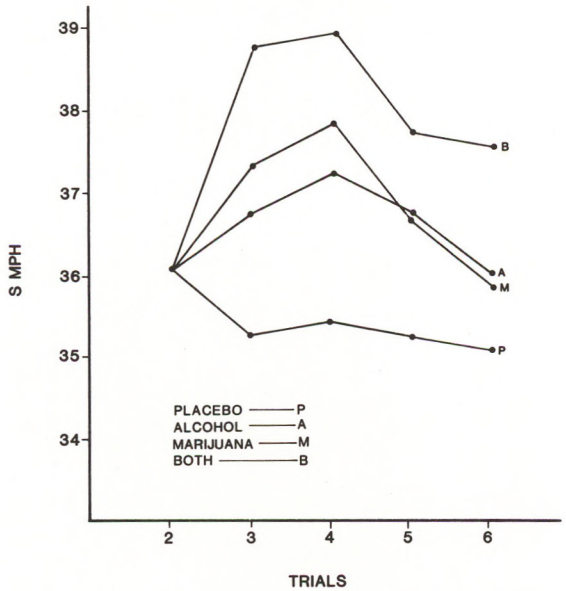


Figure 2. LRE Speedometer Covered MPH Factor.

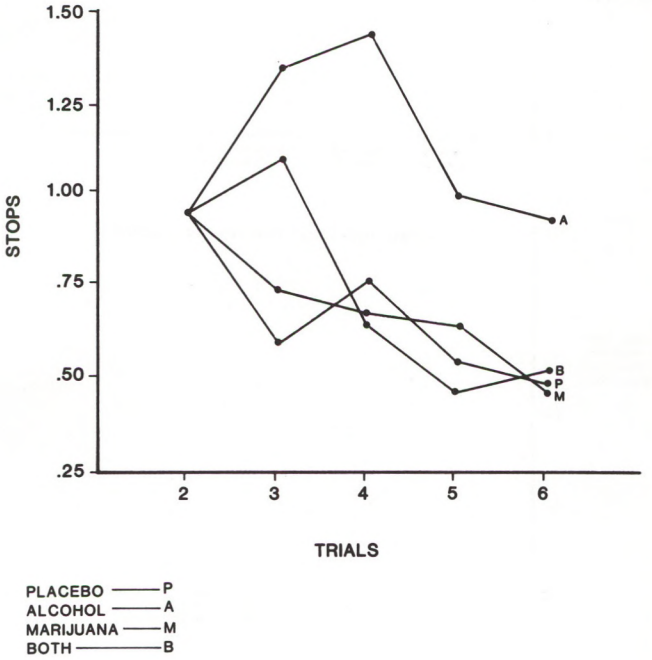


Figure 3. LRE Stop Control Factor.

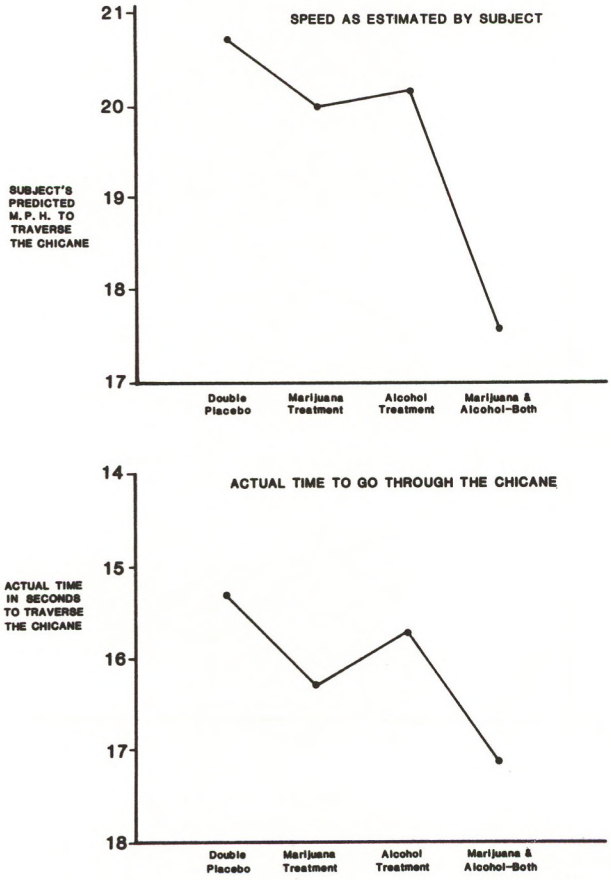


Figure 4. Speed and time measurements on the chicane.

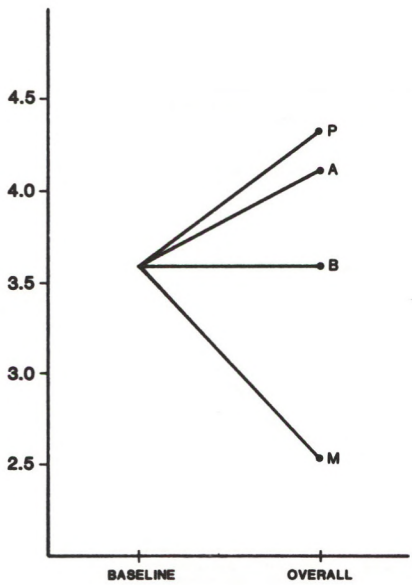


Figure 5. Chicane accelerator sensor.

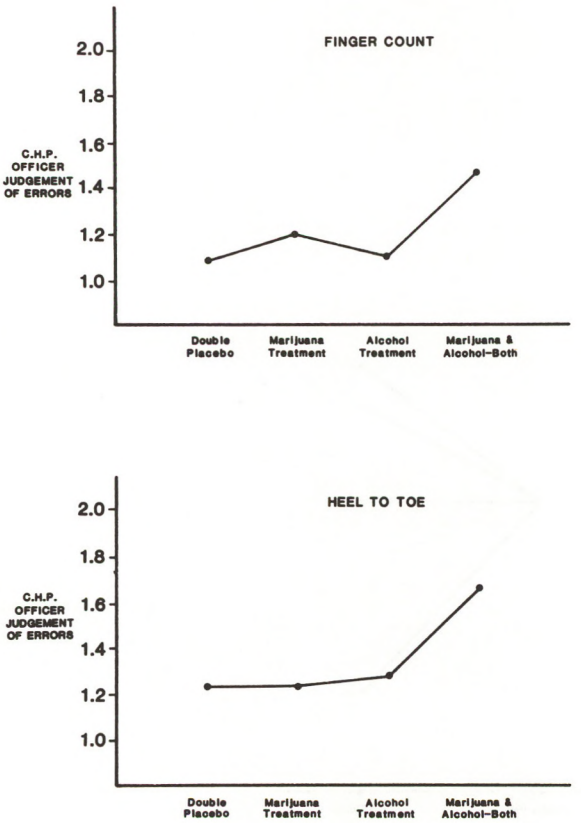


Figure 6. Two field sobriety tasks.

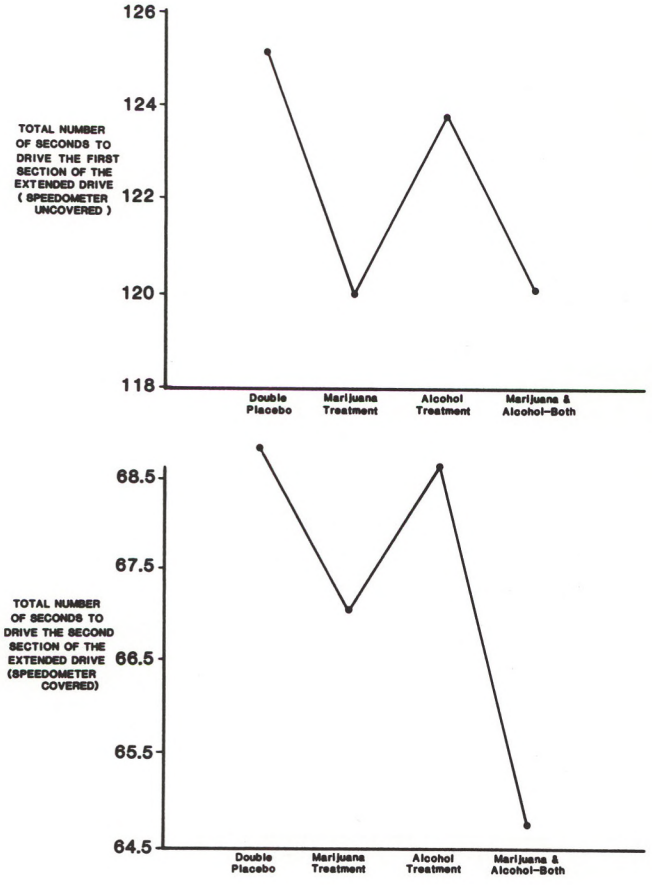


Figure 7. Overall time on extended drive.

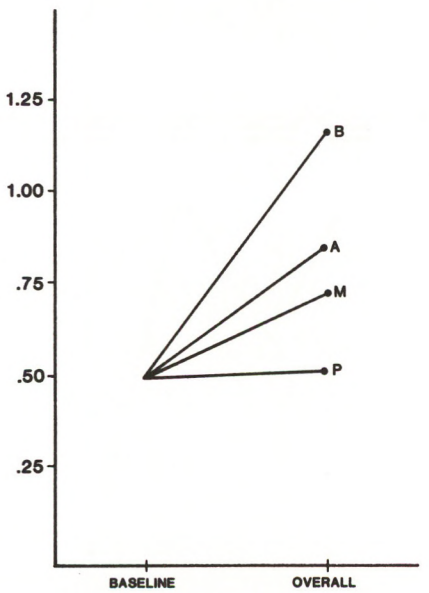


Figure 8. Estended drive speedometer covered: LRE speed control rating.

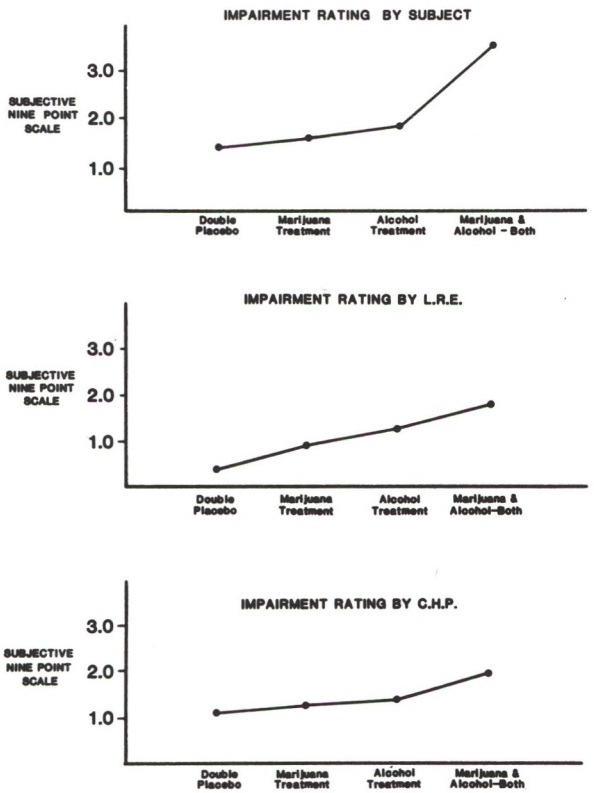


Figure 9. Subjective impairment ratings.

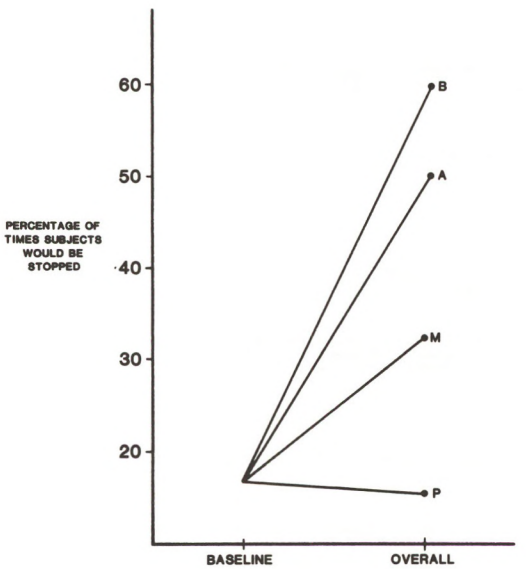


Figure 10. Following car on extended drive: C.H.P. rating.

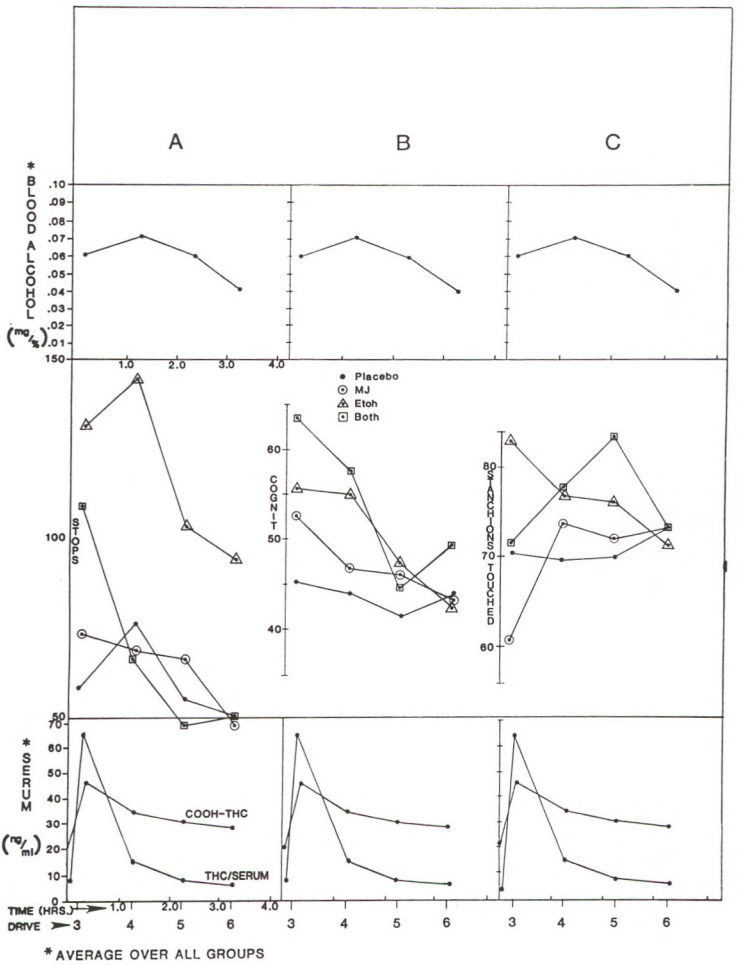
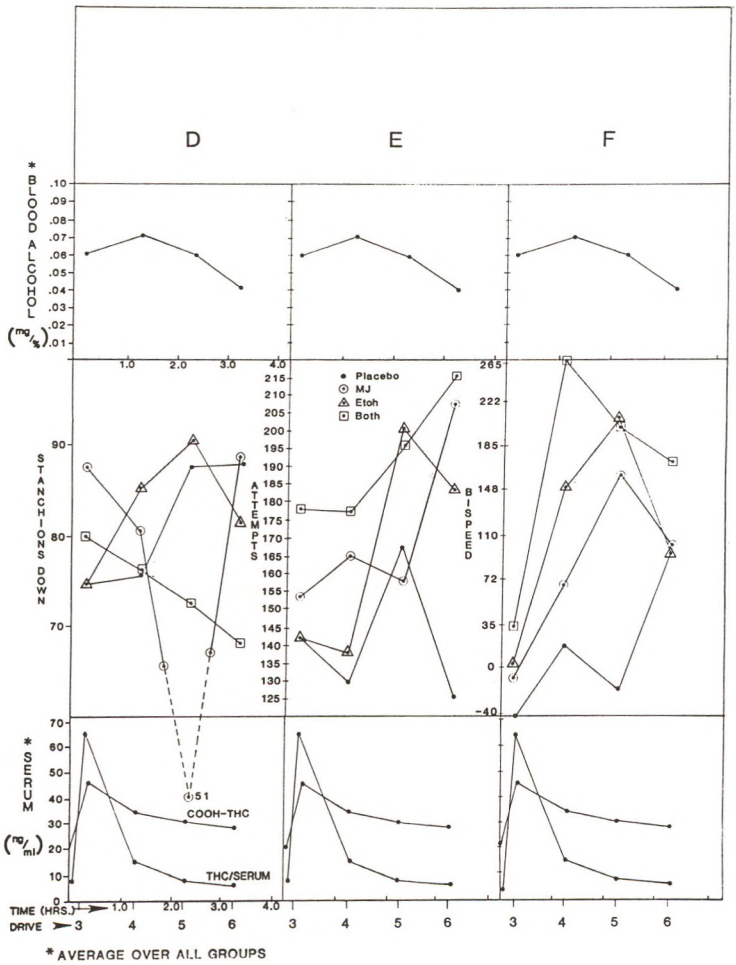


Figure 11. Performance Factors, by levels.



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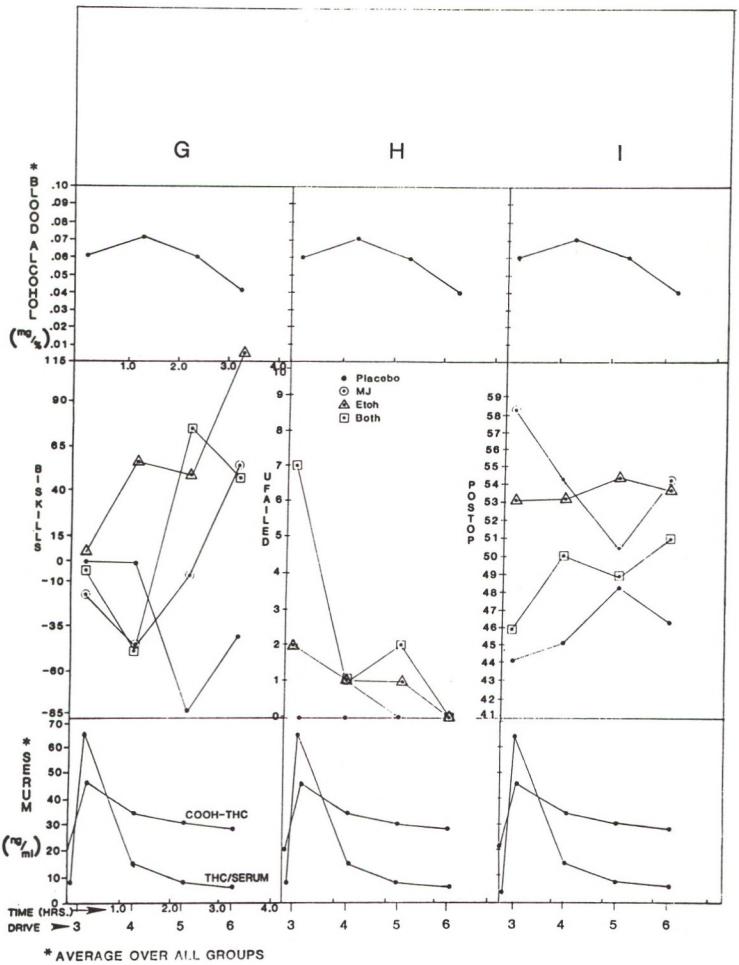

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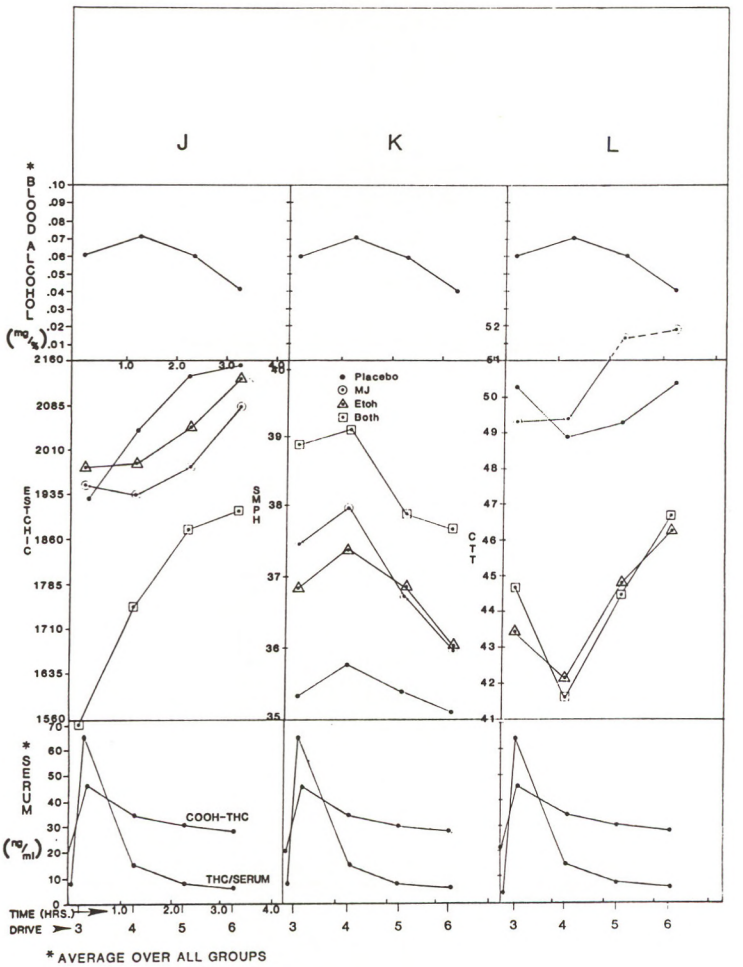

Figure 11. Performance Factors, by levels.

TABLE 1

STANDARDIZED DISCRIMINANT
FUNCTIONS--TOTAL COMPOSITE RUNS

Variable	Function I	Function II
Stanchions touched	-0.72	0.81
Estimated chicane (deviation)	-0.87	0.41
S MPH (speed covered)	0.68	-0.28
Attempts (risk task)	0.62	-0.19
Cognit	0.46	0.03
Urban failures	0.41	-0.10
Stanchions down	-0.28	.02
Position stop	0.16	0.93
Stopping errors	0.15	0.59
Bipolar skill	0.21	0.17
CTT	-0.15	-0.19
Bipolar speed	-0.09	0.45
Variance explained (%)	64.3%	22.3%
Canonical correlation	.69	.49
Significance Level (p)	< .01	< .07

TABLE 2

Overall Discriminant
Functions
By Group Centroids

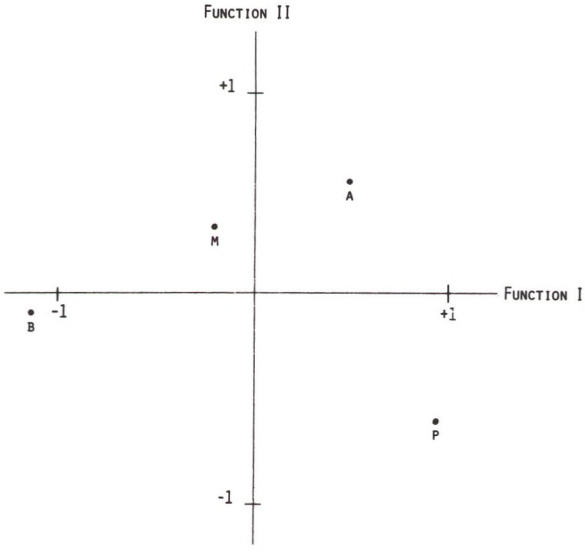

TABLE 3

STRUCTURE MATRIX FOR FIRST TWO DISCRIMINANT FUNCTIONS--COMPOSITE RUNS (CORRELATIONS $\geq$ .30, P $\leq$ .003)

Function I		Function II	
Chicane deviation score	= .52	Stop position	= .69
Speed (MPH)	= .45	Stop position (bipolar)	= .37
Bipolar speed control (speedometer covered)	= -.42	Stopping errors	= .36
Detours errors	= -.41	Speed control (bipolar)	= .31
Chicane speed (E.T.)	= -.40		
Overall LRE rating	= -.38		
Accelerator changes (E.D.)	= +.34		
Steering control (bipolor)	= -.32		
Speed match (speedometer covered)	= -.32		
Lane position (speedometer covered)	= -.31		
U-Drive instruction failures	= -.31		
BITE-Run 4	= .31		
Total errors (except stopping)	= -.30		
Urban speed (E.T.)	= -.30		
Urban stops (bipolar)	= .30		
BITE-Run 5	= .30		
FST finger count	= -.30		

TABLE 4

Percent of Variance Explained by Treatments for Each Post Treatment Trial

Trial	Percent of variance explained--all three functions*
3.....	71.1
4.....	62.4
5.....	63.5
6.....	69.4
Total trials..	66.5

*1 - Wilk's Lambda.

TABLE 5

PERCENT OF VARIANCE DUE TO TREATMENT FACTORS - ALL POST TREATMENT RUNS COMBINED

EFFECT	PERCENT OF VARIANCE EXPLAINED	SIGNIFICANCE
MARIJUANA.....	33.2	<.001
ALCOHOL.....	24.2	<.001
ALCOHOL X MARIJUANA INTERACTION.....	9.1	N.S.
TOTAL.....	66.5	<.001

TABLE 6

TREATMENT EFFECTS BY RUN
(PERCENT OF VARIANCE EXPLAINED)

TREATMENT	RUN				
	3	4	5	6	$\bar{X}$
ALCOHOL (A)	29.5	32.0	31.5	32.5	31.4
MARIJUANA (M)	29.5	25.0	23.5	24.5	25.6
A x M INTERACTION	7.0	7.0	7.0	13.0	9.5