SENSITIVITY OF A CRITICAL TRACKING TASK TO ALCOHOL IMPAIRMENT

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ABSTRACT

A first order critical tracking task is evaluated for its potential to discriminate between sober and intoxicated performances. Mean differences between predrink and postdrink performances as a function of BAC are analyzed. Quantification of the results shows that intoxicated failure rates of 50% for blood alcohol concentrations (BACs) at or above 0.1%, and 75% for BACs at or above 0.14%, can be attained with no sober failure rates.

A high initial rate of learning is observed, perhaps due to the very nature of the task whereby the operator is always pushed to his limit, and the scores approach a stable asymptote after approximately 50 trials. Finally, the implementation of the task as an ignition interlock system in the automobile environment is discussed. It is pointed out that lower critical performance limits are anticipated for the mechanized automotive units because of the introduction of larger hardware and neuromuscular lags. Whether such degradation in performance would reduce the effectiveness of the device or not will be determined in a continuing program involving a broader based sample of the driving population and performance correlations with both BACs and driving proficiency.

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I INTRODUCTION

It has become common knowledge that alcohol is involved in the majority of traffic fatalities (1), (2)*, and that casualties in terms of both human lives and material losses have reached phenomenal levels. Consequently, General Motors has been actively pursuing means of alleviating the problem through an alcohol countermeasures program.

Several technological approaches to the "driving while intoxicated" problem were discussed in Reference 3, having for common objectives the identification of the intoxicated driver through performance or chemical (breath) tests (4), (5). Two philosophies were distinguished: one where the identification process takes place prior to driving by a test—behavioral or chemical—of short duration, and the other involving the continuous monitoring of driver performance. The latter approach could involve warning mechanisms (e.g., hazard flashers), and the predriving test could involve the actual inhibition of the vehicle's starting through ignition interlocks.

A discussion of some of the drawbacks and advantages of the above approaches is in order. In the case of direct BAC measurement, it is well accepted that great individual variability in capabilities exists at equal BACs; and, although it is well established that as blood alcohol concentration rises basic performance capabilities deteriorate, the relationship between BAC and driving performance is not a perfect one. It is, for instance, often argued that experienced drinkers are less impaired than inexperienced drinkers at lower blood alcohol

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*Numbers in parentheses designate References at end of paper.

concentrations, and, that indeed, large individual differences do exist in tolerance to alcohol. On the other hand driving is a behavioral task, and a behavioral testing procedure seems, therefore, more logical than a chemical one for examining an individual's current ability to drive. This would be true even if alcohol were the only agent or condition that produced temporary driving impairment. It is not, of course, and to devise automatic chemical means of detecting other possible agents or any large subset of them has major technical drawbacks.

In the case of a predriving performance test, however, the intoxicated driver might on some occasions be able to "pull himself together" sufficiently to pass the predriving test even though his blood alcohol level exceeds legal limits and though his driving capability is impaired to the point of gravely increasing his probability of involvement in an accident.

The time involved for the absorption and metabolism of alcohol and the resulting delay in its effects on driving performance also deter from this approach. In addition, the implicit assumption that the performance task will be degraded by alcohol consumption in a similar fashion to driver performance must be justified. Nevertheless, an interlock system is designed not to keep people from drinking, but to keep them from driving when their abilities are impaired to the extent that their risk of having an accident is greatly increased.

Indeed, no predriving behavioral or psychomotor test provides the utopian system that could continuously monitor driving performance and bring the vehicle to a safe halt when performance impairment is detected (6). While it is believed necessary to devote efforts towards gaining a better understanding of the perceptual, decision, and motor response processes that comprise the driving task, and towards establishing quantitative means of assessing them on a continuous and passive monitoring basis, it is felt that the predriving identification of the unfit individual and temporary inhibition of his vehicle from starting by virtue of an interlock system promise more immediate benefits. Indeed, a recently completed Accident Causation Study at General Motors showed that an effective behavioral predriving task would be one of the highest payoff accident countermeasures available. Although General Motors has put more emphasis on this type of countermeasure, we are also pursuing the alternative approaches mentioned, namely, those based on breath test and on the continuous monitoring of driver performance.

II PREDRIVING PERFORMANCE TESTS

A. Objectives and Desired Characteristics

The main objectives for a predriving performance test implemented as an alcohol ignition interlock can be stated simply as follows:

- Large discrimination against intoxicated individuals *(positive rejection rates)*.
- No discrimination against sober individuals capable of driving* (false rejection rates).

While most programs to date were conducted primarily with the goal of quantifying individual test sensitivities to BAC by assessing the above rejection rates, the following additional characteristics are desired and must be considered in any comparative analysis:

- High correlation with driving ability.
- Short duration of test.
- *Rapid learning rate.*
- Easy integration in vehicle.
- Insensitivity to age, sex, intelligence, and social and educational backgrounds.
- Not easily compromised.
- Low cost.

Although the correlation between traffic accidents and rising BACs is well established, large variabilities in driving capabilities are attributed to different tolerances to alcohol. Therefore, performance on the predriving task should be correlated with driving ability, the main variable of interest. Consequently, the collection of such data would allow one to compare legal restrictions sought by many states, namely, *having a cutoff for driving according to BAC* (e.g., passing all below 0.10%) with having a performance check implying that one who is too intoxicated to pass should not be driving.

B. Operational Modes

There exist two distinct philosophies in selecting the design or test parameters for any behavioral task to be used as an alcohol interlock. One approach calls for universal thresholds, that is, fixed parameters for the entire driving population; the other allows for the individualization of the test parameters for each subject. The tradeoff here is primarily between cost and effectiveness.

It is clear that unless interlocks are to be directed only to a selected few offenders, individualization on a universal basis would be costly and complicated, since the baseline performance of each driver would have to be established. In most instances, however, the effectiveness of the test is greatly enhanced by individualization, since the variability in performance between subjects is eliminated.

**Tolerable false rejection rates* would depend on the application, with higher rates permitted if applied only to those with a driving while intoxicated record.

III A CRITICAL TRACKING TASK (CTT) AS AN ALCOHOL INTERLOCK SYSTEM

The CTT device as implemented in the automotive environment (7) utilizes existing systems on the car; namely, the steering wheel and a meter mounted on the instrument panel (the meter use could be shared with other systems, such as fuel measurement). The test consists of steering to keep the needle within a bounded area, just as one would steer his car on a bounded road. Figure 1 shows the current experimental system.

The test resembles somewhat the steering of a car on a slippery surface, such as ice, while the speed of the car gradually increases (without the driver's control). It involves controlling an unstable system which gradually becomes more unstable (8). If control is successfully maintained up to a preset level of instability (λ_r), i.e., in the analogy of driving on ice up to a certain speed, a green light comes on and the car can be started. If the needle wavers outside of the designated area, a red light comes on and the starter is immobilized. In this event he may be allowed additional trials. That is, whether the threshold value, λ_r, is reached or not determines whether the trial is a <u>success</u> or a <u>failure</u>. It appears that the initial value for the unstable mode, λ_{ic}, and $\dot{\lambda}$, can be selected to limit the duration of the test to approximately 10 seconds. The development and characterization of "critical tasks" are well documented in the literature (8), (9), and (10).

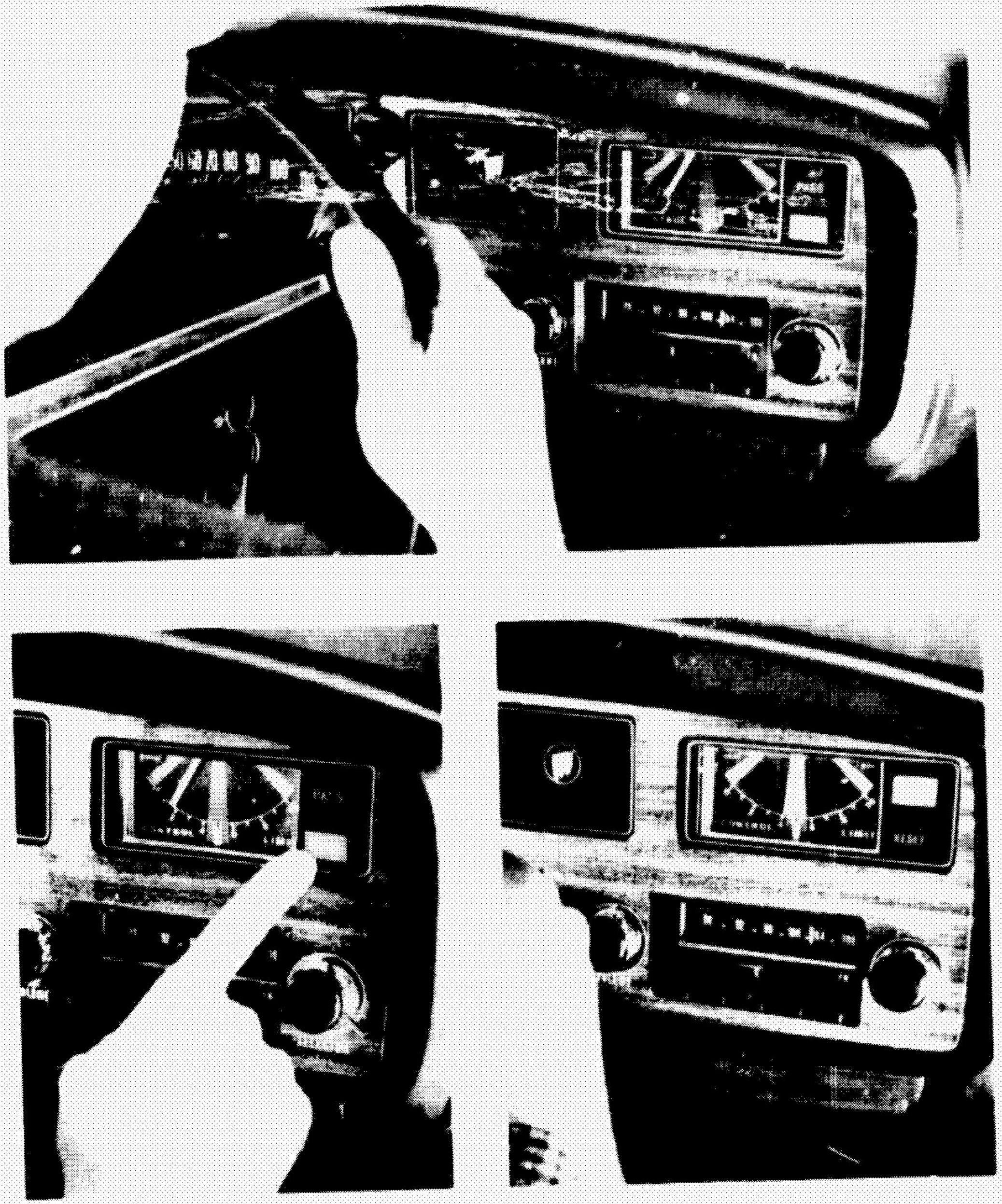

Figure 1 CTT - Current experimental installation in a car. The meter could be time-shared with some other function such as fuel measurement.

IV EXPERIMENTAL DESIGN

A. Subjects

Seventy-six subjects (47 males and 29 females) ranging in age from 17 to 65 participated in the study. The subjects were part of a larger study on the effects of alcohol conducted at Beaumont Hospital under General Motors sponsorship.

In order to avoid any potential complications from the ingestion of alcohol, the volunteers were selected by medical personnel at Beaumont following a study of their medical history.

Those under medication, which if combined with alcohol could prove harmful, and those with diabetes or past liver problems, etc., were eliminated from the studies.

B. Test Protocols

All training and testing were conducted at the hospital on a first order Critical Tracking Task mechanized with an oscilloscope display. The room provided by the hospital was located in a nonmedical building of the hospital complex. During the training and test sessions the room was furnished and arranged to provide an informal, nonclinical setting.

The score, or value of λ at which control was lost, was indicated to the subject at the end of each trial by the location of the line on the face of the oscilloscope. The score was read directly off the markings on the oscilloscope and reset to the center position for the next trial.

During the training and test period the subjects could rest briefly between each trial at their discretion, and they controlled the start of each trial.

Two sessions were used for training on the Critical Tracking Task. In Session 1 the subject was first familiarized with the equipment and the nature of the task. Following this the subject was given 30 trials on the task, and the scores were recorded. Two weeks later the subject returned for the second session. Session 2 consisted of 20 additional training trials, followed by alcohol consumption and 10 test trials. Table I illustrates the overall Testing Plan.

During Session 1, subjects were given training on the CTT on an individual basis. In order to provide a more social, informal setting, four subjects participated together in the training and test phase during Session 2.

The schedule for Session 2 was as follows: Upon arrival each subject was given a Breathalyzer test, followed by 20 trials on the CTT. Next, the subject received four drinks, evenly spaced, in an 80-minute period. Following a 40-minute interval after the last drink, the subject was given 10 test trials on the CTT. A breathalyzer test to determine BAC level was then given, and a blood sample was taken.

C. Administration of Alcohol

One-hundred-proof vodka mixed with either orange juice or tomato juice was used in the study. The total volume of vodka administered to each subject was based on the subject's body weight and his reported drinking habits. Based on his report, each subject was identified as to one of the following four categories and received the corresponding volume of vodka indicated.

Very Light Drinker	- 1.00ml/lb body weight
Occasional Drinker	- 1.25ml/lb body weight
Average Drinker	- 1.50ml/lb body weight
Above Average Drinker	- 1.75ml/lb body weight

TESTING PROGRAM

SESSION 1	2 WEEK INTERVAL	SESSION 2	
30 TRIALS (at BAC = 0)		20 TRIALS (at BAC = 0)	10 TRIALS (at Peak BAC)

Table 1

During the drinking period changes were occasionally made in the amount of vodka given per subject, based upon visual evidence of intoxication, or lack of it, and on verbal reports of nausea.

All drinks were administered by an attending physician, and the Breatholyzer measurements were taken by a trained operator. Calibration of the Breatholyzer was checked after each session.

V SOBER VS INTOXICATED PERFORMANCE

A. Sober Performance

The overall performance of the subjects during the two training sessions is presented in Figure 2. For summary purposes the mean score on the CTT of successive five trial blocks for all subjects and the standard deviation of the scores for each trial block are presented.

Trial blocks 9 and 10 reveal that performance has reached or approached an asymptote by the end of session 2. A stable baseline such as this is a requirement for quantifying the deterioration in performance following the consumption of alcohol.

B. Intoxicated Performance

Of the 76 original subjects, seven were unable to complete the test phase of the study as a result of illness which developed during or following the drinking session.

Figure 3 shows the terminal performance at the end of training and the performance of the remaining subjects on the 10 test trials. Here the mean score has been plotted for each trial. BAC levels obtained by Breathalyzer readings ranged from 0.056 to 0.19%, with a mean level of 0.11%.

As indicated in the figure, the mean performance of the group on the test trials is considerably below that of the predrink performance.

A t-ratio for the difference between the means of the last five training trials and the first five test trials was highly significant. $(t=11.03, P < 0.0005)$

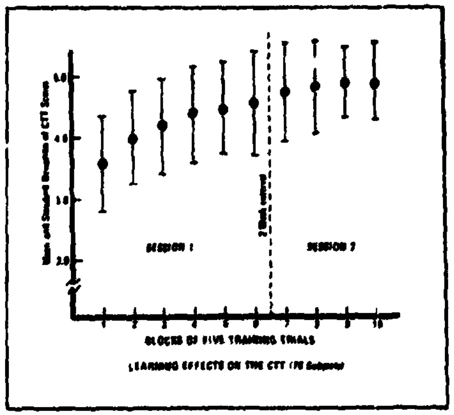

Figure 2

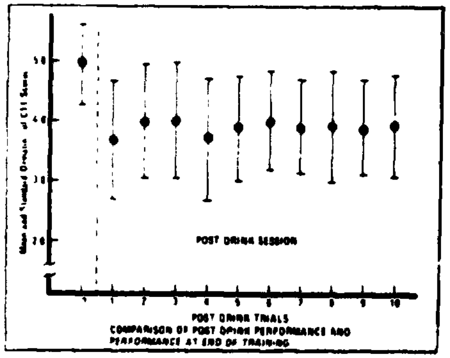

Figure 3

C. Group Comparisons

The range of BAC levels obtained in the test session provided an opportunity to examine the degree of deterioration on the task as a function of various BAC levels. For this analysis the subjects were assigned to one of the five groups indicated below according to the BAC level they reached.

Group 1	BAC 0.05 to 0.08%	N=9
Group 2	BAC 0.081 to 0.099%	N=16
Group 3	BAC 0.10 to 0.119%	N=19
Group 4	BAC 0.120 to 0.149%	N=21
Group 5	BAC 0.150 to 0.20%	N=4

The mean decrement in CTT scores for the five groups between the last block of training trials and the first block of five test trials for each subject is presented in Figure 4.

As indicated in Figure 4, all groups showed a deterioration in performance in the postdrink test session. The mean difference in performance between the last block of five training trials and the first five postdrink trials ranged from 15.4% for the low BAC Group 1 to 48.9% for the high BAC Group 5.

A t-ratio for the difference between the means of the last five training trials and the first five test trials was computed for each of the five groups and is presented in Table II. As indicated, the difference in performance for each group was significant at the 5.0% level.

D. Test Results Summary

This section presents the experimental data in a form that illustrates the effectiveness of the Critical Tracking Task as a potential alcohol ignition interlock device when the universal threshold approach is used. In particular, the data are analyzed by answering the two following questions:

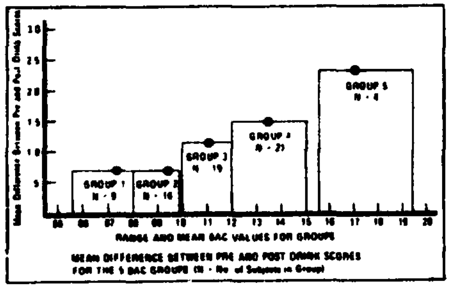

Figure 4

T-RATIOS FOR THE DIFFERENCE
BETWEEN PRE AND POST DRINK CTT SCORES
FOR THE FIVE GROUPS

GROUP	BAC RANGE	MEAN DIFFERENCE	SD	T RATIO	df	P
1	.056 - .081	.71	.219	3.24	8	< .05
2	.088 - .099	.76	.220	3.16	16	< .05
3	.100 - .119	1.15	.176	6.53	18	< .05
4	.120 - .149	1.48	.132	11.22	20	< .05
5	.166 - .192	2.30	.577	3.98	-	< .05

Table II

(a) If the CTT were mechanized as an ignition interlock, and a maximum limit on the percentage of sober failures (false rejection rates) that would be tolerated were stated, what would be the corresponding intoxicated failure rate at various BACs?

The answer to this question is given by Table III for ascending values of sober failure rates ranging from 0% to 3.0%. In addition, Table III stipulates the answers for:

(i) several test criteria (ratio of number of number of required successes to number of trials allowed) given in decreasing order of difficulty and involving the following: 1/1, 2/3, 1/2, and 1/3.

(ii) corresponding threshold values, λ_r, required.

As indicated, all trial criteria and λ_r conditions resulted in 100% failures for BACs equal to or greater than 0.15%, with decreasing intoxicated failure for lower BAC levels and lower λ_r threshold levels.

(b) If the CTT were mechanized as an ignition interlock, what would be the sober and intoxicated failure rates for various threshold values, λ_r, for:

(i) the following test criteria: 1/1, 2/3, 1/2, 1/3, in decreasing order of difficulty?

(ii) various blood alcohol concentrations?

The answer to this question is given by Table IV, where the data are presented as a function of increasing threshold levels (λ_rs) As expected, both the sober and intoxicated failure rates decrease with decreasing criterion difficulty.

As indicated in the tables the data presented are for experiments involving 67 sober subjects and 40 subjects at BACs at or above 0.10%.

Table III

SOBER VS INTOXICATED FAILURE RATE SUMMARY
FOR UNIVERSAL THRESHOLDS

SOBER FAILURE RATE (%)	THRESHOLD (λ_r)	CRITERION		INTOXICATED FAILURE RATE (%)				
		No. of Passes Required	No. of Trials Allowed	BAC ≥ 0.1%	BAC ≥ 0.12%	BAC ≥ 0.13%	BAC ≥ 0.14%	BAC ≥ 0.15%
0	3.7	1	1	57.5	62.5	68.8	81.8	100
0	3.7, 3.8, 3.9	2	3	55.0	62.5	75.0	81.8	100
0	4.0	1	2	50.0	54.2	62.5	72.7	100
0	4.0	1	3	42.5	50.0	56.3	63.6	100
1.5	3.8	1	1	57.5	62.5	68.8	81.8	100
1.5	4.1 & 4.2	1	3	47.5	58.3	68.8	72.7	100
3.0	4.0	1	1	62.5	66.7	75.0	81.8	100
3.0	4.1 & 4.2	1	2	60.0	66.7	75.0	81.8	100
3.0	4.4	1	3	62.5	70.8	87.5	90.9	100
N = 67				N = 40	N = 24	N = 16	N = 11	N = 4

N = No. of Subjects

Table IV

SUBJECT FAILURE RATES FOR THE CTT
USING UNIVERSAL THRESHOLDS

UNIVERSAL THRESHOLD (λr)	CRITERION		BLOOD ALCOHOL CONCENTRATION (%)					
	No of Passes Required	No. of Trials Allowed	0	0.10	0.12	0.13	0.14	0.15
3.8	1	1	1.5	57.5	62.5	68.8	81.8	100
	2	3	0	56.0	62.5	75.0	81.8	100
	1	2	0	45.0	50.0	66.3	63.6	100
	1	3	0	32.5	37.5	50.0	54.5	100
3.9	1	1	3.0	60.0	66.7	75.0	81.8	100
	2	3	0	56.0	62.5	75.0	81.8	100
	1	2	0	47.5	50.0	56.3	63.6	100
	1	3	0	37.5	41.7	50.0	54.5	100
4.0	1	1	3.0	62.5	66.7	75.0	81.8	100
	2	3	1.5	56.0	62.5	75.0	81.8	100
	1	2	0	50.0	54.2	62.5	72.7	100
	1	3	0	32.5	58.0	56.3	63.6	100
4.2	1	1	13.4	72.5	75.0	81.3	81.8	100
	2	3	4.5	65.0	70.8	81.3	90.9	100
	1	2	3.0	60.0	66.7	75.0	81.8	100
	1	3	0	47.5	58.3	68.8	72.7	100
4.4	1	1	10.4	75.0	79.2	87.5	90.9	100
	2	3	11.9	67.5	75.0	87.5	90.9	100
	1	2	7.5	65.6	75.0	87.5	90.9	100
	1	3	3.0	62.5	70.8	87.5	90.9	100
NO OF SUBJECTS			67	40	24	16	11	3

VI DISCUSSION

The data from the present study indicate that the CTT is a sensitive measure for detecting behavioral impairment resulting from alcohol (Tables III and IV). In fact, the data indicate that intoxicated failure rates of 50% for BACs at or above 0.1% and failure rates of 75% for BACs at or above 0.14% can be achieved with no sober failures. Perhaps one of the greatest assets of the task is that only a few parameters are involved in the test configuration, thus simplifying the optimization of the task and tending to minimize variability in performances. As mechanized in the study the task was readily learned, and most subjects approached an asymptotic level of performance in the unimpaired state within a relatively short time (Figure 2). Fast learning of the task is expected, since the operator is always pushed to his limit when the task is pursued until control is lost.

In addition to the use of existing vehicle hardware, the mechanization of the CTT in the automobile environment appears to correlate readily with the driving task, since it resembles the road-tracking portion required of driving. This is an important issue in the development of a performance test to be implemented as an ignition interlock system. Any such task should exercise those faculties that are considered dominant in driving and therefore have a significant correlation with the driving task.

Perhaps the most significant change between the laboratory unit used in the experiments reported herein and a vehicle integrated unit is the dynamic response of the Driver/CTT System. While the laboratory unit involved a small hand-control stick requiring only slight movements of the fingers and wrist, the steering wheel requires larger motions of the hand and arms, thus including large neuromuscular lags in the system. An additional hardware lag would undoubtedly be included when replacing the oscilloscope display with a meter. The net expected effect of these time delays is a decrease in the critical limits (λ_{cr}) reached, but not necessarily a reduction or increase in the effectiveness of the task. Equivalent degradation in performance for the sober and intoxicated states would not affect the expected effectiveness of the device; however, the relative decrement in proficiency would have to be reevaluated. It will be important also to assess the relative performance decrement on a broader based sample of subjects statistically representing the driving population.

The dilemma faced in the development of any alcohol ignition interlock system is that under present laws the legal criterion for impairment resulting from the consumption of alcohol is based upon a BAC measure rather than a measure of behavioral impairment. While there exists a relationship between the two, there is obviously wide variability in proficiency among individuals both in a nonimpaired state and in the degree of impairment which develops under the same BAC. It is the area of overlap of these two distributions of behavior at the legally defined BAC level which complicates the development of a behavioral ignition interlock test. As a result, correlations of performance on the Critical Tracking Task with both BACs and driving proficiency will be included in a following program.

REFERENCES

(1) R. E. Allsop, Alcohol and Road Accidents. A Discussion of the Grand Rapids Study, Road Research Laboratory, Ministry of Transport, RRL Report No. 6, Harmondsworth Road Research Laboratory, 1966.

(2) Alcohol Safety Countermeasures Program, Nat. High. Safety Bureau, June 8, 1970.

(3) T. O. Jones, J. A. Tennant, A Critical Evaluation of the Phystester: A Test for Driver Impairment, American Association for Automotive Medicine, Chapel Hill, North Carolina, October 20, 1972.

(4) C. B. Gibbs, The Effect of Minor Alcohol Stress on Decision Processes in a Step-Tracking Task, IEEE Transactions on Human Factors in Electronics, Vol. HFE-7, No. 4, December, 1966.

(5) Alcohol and the Impaired Driver. A Manual on the Medicolegal Aspects of Chemical Tests for Intoxication. American Medical Association, 1968.

(6) P. W. Davis, E. D. Sussman, A. Warner, W. Z. Leavitt, Alcohol Safety Interlock Systems - A Status Report. Presented at the OECD International Symposium on Countermeasures to Driver Behavior, September, 1971, London, England.

(7) J. A. Tennant, and R. R. Thompson, A Critical Tracking Task as an Alcohol Interlock System, SAE 730095, January, 1973.

(8) H. R. Jex, J. D. McDonneil, and A. V. Phatak, A Critical Tracking Task for Man/Machine Research Related to the Operator's Effective Delay Time, 7th IEEE Symposium on Human Factors in Electronics, May 5, 6, 1966.

(9) R. W. Allen, and H. R. Jex, Visual-Motor Response of Crewmen During a Simulated 90-Day Space Mission as Measured by the Critical Task Battery, Seventh Annual NASA-Univ. Conference on Manual Control, USC, Los Angeles, California, June, 1971.

(10) L. R. Young and J. L. Meiry, Manual Control of an Unstable System with Visual and Motion Cues, IEEE Intern. Conven. Record, Vol. 13, Part 6, 1965, pp. 123-127.