Technical Memorandum
HuF-TM-2

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EFFECTS OF PRACTICE AND ALCOHOL ON SELECTED SKILLS: IMPLICATIONS FOR AN AUTOMOBILE ALCOHOL IGNITION INTERLOCK

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Summary.--Drivers practiced two psychomotor tasks before being tested during absorption, peak and elimination phases of the blood alcohol cycle at BAC's of 0.05%, 0.10%, and 0.05%. A significant performance decrement was found at the 0.10% BAC level compared to the performance at 0% BAC, after improvements due to practice had ceased on both tasks used. The task involving stylus tracking showed reasonable test discrimination between subjects when sober and after drinking.

Several studies concerned with the role of alcohol in motor vehicle fatalities have found that legally drunk or impaired drivers are involved in 48 to 75% of all fatal single vehicle crashes, and 39 to 57% of all fatal motor vehicle crashes (Freimuth, Watts & Fisher, 1958; Haddon & Bradess, 1959; New Jersey Department of Law and Public Safety, 1964; Davis & Fisk, 1967; Filkins et al., 1970).

The Department of Transportation has acknowledged the problem and, as one response, has begun a program to evaluate a number of alcohol ignition interlock systems (AIIS) for feasibility

(Susman, Davis & Warner, 1972). An AIIS would automatically detect impairment of a driver's performance capabilities and prevent an intoxicated driver from operating his vehicle.

One approach to developing an AIIS involves making the operation of a vehicle's ignition contingent on the completion of a simple psychomotor task which is known to be debilitated by alcohol. Such a task would not only have to be greatly susceptible to deterioration under alcohol, but should be easily instrumented and easily understood by the general public.

The General Motors Corporation (1970) has reported a device merging several psychomotor tasks which may have some merit as an AIIS. The device presents a driver with a five-digit random number which must be remembered for several seconds before being entered into a numbered keyboard within a given length of time. If any entry errors are made or if the test is not completed within a time limit the vehicle's engine cannot be started.

A review of the literature concerning the effects of alcohol on the three main components of the General Motors task--immediate memory, reaction time, and simple motor performance--indicates that the device may have some success in discriminating between sober and intoxicated drivers. Carpenter (1962) summarized the results of the bulk of studies performed between 1940 and 1961 dealing with the effects of alcohol on psychological processes. He concluded that, while the sophistication of many studies was low, increases in reaction time and decrements in motor skills were often found at quite low blood-alcohol concentrations. In representative studies (Dettling, 1956; Forbes, 1947; Grüner, 1955; Grüner & Ptasink, 1953; Howells, 1956) reaction time was increased by 4 to 200% depending on BAC and the task employed. In two studies in which alcohol doses were specified and actual BAC's noted (Carpenter, 1959; Katkin, Hayes, Teger & Pruitt, 1970) simple visual reaction time was found to be significantly increased under alcohol (BAC=.08%), although the magnitude of the difference was "not very important and for most purposes can be ignored" (Carpenter, 1959).

Performance of tasks such as typing, target shooting, and hand writing has also been found to deteriorate at moderate BAC's (Newman, 1957; Eggleston, 1941; Prag, 1953; Rabin & Blair, 1953). Proficiency in typing, which provides the closest motor performance analogy to the General Motors task, was found to be adversely affected at BAC's of 0.05%. An increase in typing errors from a sober baseline of 0-4% to 35-61% was found at BAC's of 0.14-0.17% (Prag, 1953).

The effects of alcohol on memory are not as clear cut. Ryback's (1971) review makes a functional distinction between immediate memory (lasting a few seconds to one minute) and short-term memory (lasting several minutes). Ryback cites seven studies involving tasks classified as measuring immediate memory in which no change in performance was found following varied alcohol doses (Davis, Gibbs, Davis, Jetter & Trowbridge, 1941; Ekman, Mindlin, Minear & Short, 1955; Hutchinson, Tuchtie, Gray & Steinberg, 1964; McFarland & Barach, 1936; Muller, Tarpez, Giorgi, Mirone & Rouke, 1964; Rudin, 1902; Talland, Mendelson & Ryback, 1964) and contrasts them with three examples of short-term memory tasks which showed significant impairment at equal BAC's (Hutchinson, Tuchtie, Gray & Steinberg, 1964; Muller, Tarpez, Giorgi, Mirone & Rouke, 1964; Rudin, 1902). Ryback feels that the distinction is due to a differential effect of alcohol on the specific brain areas held to be responsible for temporary and permanent memory storage. Thus, the General Motors AIIS may not require the type of memory which is most sensitive to debilitation under alcohol, as the interval between stimulus termination and response in the GM task is only several seconds.

While evidence exists that performance on the General Motors AIIS should be in some way degraded by alcohol, the complexity of the task would also indicate a need for considerable practice for an asymptote in sober performance to be reached before testing for the effects of alcohol. This would also be appropriate because drivers would be highly practiced on the task if it preceded driving. Pilot studies by the authors have shown improvement in performance on the task over approximately 150 trials. Thus, any investigation of the effects of alcohol on the GM task should be preceded by an investigation of the effects of practice alone.

A second task, stylus tracking, has been previously found by the authors to also show a large practice effect and considerable decrement under alcohol. Other forms of tracking ability, such as compensatory tracking with an oscilloscope display (Pearson, 1968), and lane tracking on a driving simulator (Mortimer, 1963) have shown great sensitivity to moderate amounts of alcohol. While instrumentation of a tracking-based AIIS may present unique problems, it may be worthwhile to undertake if a tracking task is found exceptionally sensitive to alcohol.

The object of this study was to examine the effects of practice and alcohol on a task similar to that required by the General Motors AIIS and on a stylus tracking task. The feasibility of either task functioning as an AIIS was determined both by the performance decrement found under alcohol as well as the degree to which the tasks were sensitive to individual differences between subjects.

Method

Subjects

Six females and ten males were paid to participate in the study. The females were 21 to 28 ($\overline{X}$=25) years of age, and the males 22 to 25 ($\overline{X}$=24) years of age. All regarded themselves "experienced drinkers."

Apparatus

To replicate the General Motor's AIIS task (hereafter referred to as task 1), an apparatus was constructed (Figures 1 & 2) which enabled presentation of 5-digit numerical stimuli on 1 in. National readout tubes spaced on 1 1/2 in. centers. Potter and Brumfield time delay relays (accuracy = ±5% nominal, ±1% repeatability) determined both duration of stimulus presentation (2 sec) and duration of waiting interval (5 sec). Responses were made by pressing numbered pushbuttons mounted on 1 1/2 in. centers, 2 in. beneath the readout tubes. A lamp, fitted with a green lens 1 in. in diameter, was centrally mounted 2 in. above the readout tubes and was lighted to signal S to start responding. Response logic was automatically set when the stimulus number was selected on five rotary switches. Response time from the onset of the green lamp to the last correct button press was measured in hundredths of seconds on a digital clock. The number of button presses was accumulated on a digital counter.

In the stylus tracking task (hereafter referred to as task 2), a curving 1/2 in. wide slot in a metal plate was tracked with a 1/8 in. diameter stylus 12 in. in length terminating in a wooden handle. A lamp, fitted with a green lens

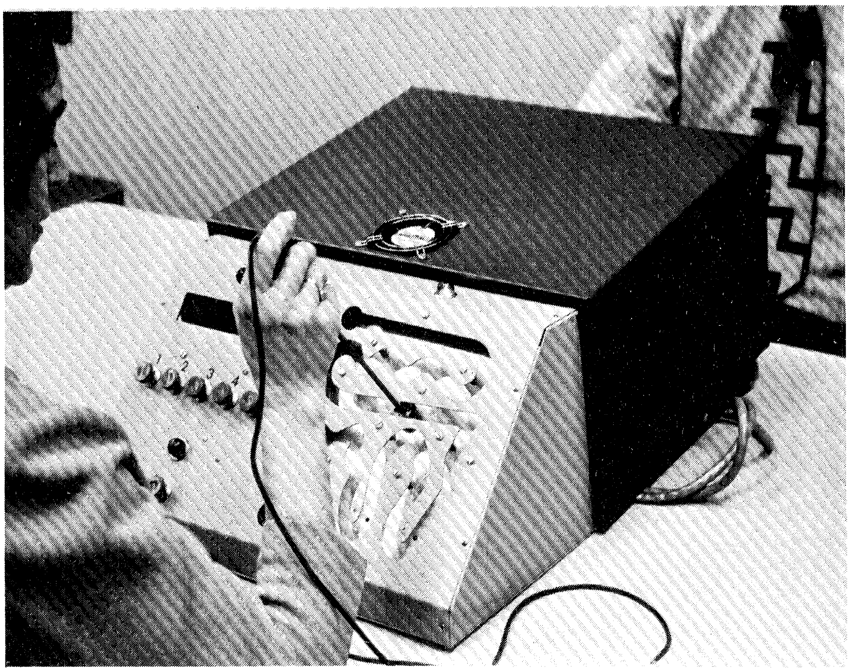

Figure 1. The test equipment.

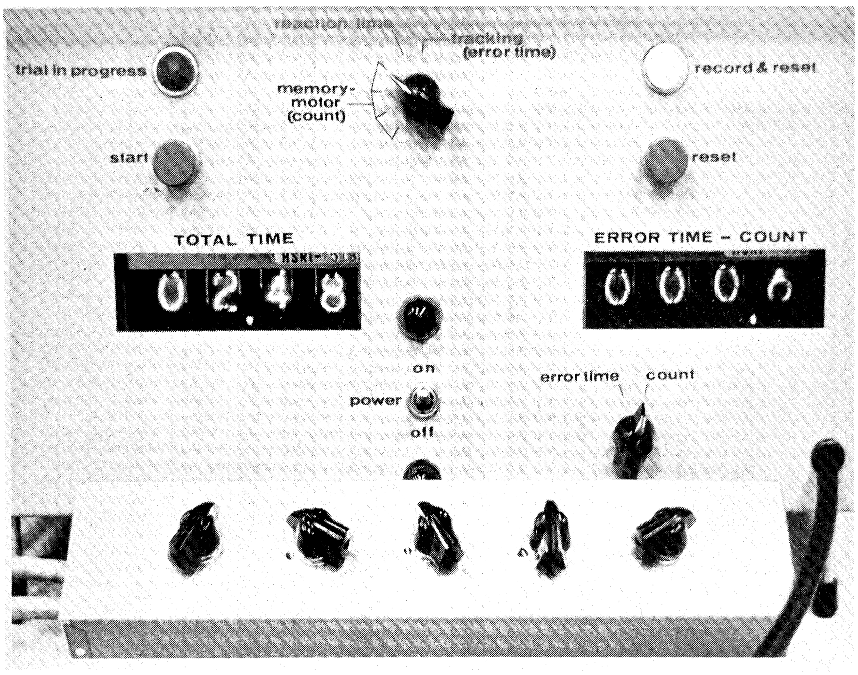

Figure 2. The experimenter's control panel.

1 in. in diameter, was lighted to signal S to begin tracking while a microswitch mounted across the end of the tracking slot terminated the trial when contacted. One digital clock measured total tracking time and another clock cumulated the time during which the stylus touched the edge of the slot.

Procedure

Each S was given 45 trials of task 1 followed by 8 trials of task 2 at approximately the same time of day (3 p.m.-6 p.m.) on four consecutive days. Six Ss were tested during each of the first two weeks of the study, four Ss were tested during the third week. During each week, two Ss began the testing procedure on Monday, two began on Tuesday, and, with the exception of the third week, two began on Wednesday. A list of 45 randomly organized 5-digit numbers (utilizing digits 1-5, without repeating digits) was presented in a systematically varied order across days to overcome position effects. The inter-trial interval on both tests was 20 seconds, and one minute breaks were given after each 15 trials of task 1 and the first four trials of task 2. Ss were frequently reminded during the testing that low response times were desired in task 1, while accuracy was desired in task 2.

On the fifth day each S was asked to eat a normal breakfast, but to refrain from eating or drinking anything (other than water) later than 11 a.m. Two Ss were transported to the place of testing by E, arriving at 12 noon.

The Ss were tested on both tasks 1 and 2 as before, with the following modifications. After the first test session, S was given 15 minutes to drink a solution of .28 ml of 100% ethyl alcohol/lb of body weight mixed 1:6 with orange juice or lemonade. Forty-five minutes later, S was retested on tasks 1 and 2 and given 15 minutes to consume an identical alcohol dose. Forty-five minutes after finishing the second alcohol dose, S was again retested on tasks 1 and 2. A Stephenson Model 900 Breathalyzer was used to measure BAC immediately before and after each test when alcohol was given. At the completion of the third test session, S was allowed to each lunch. Breathalyzer tests were then given every thirty minutes until S reached a BAC of 0.05% when he was again retested on tasks 1 and 2. Between testing sessions, Ss relaxed in a secluded room with magazines and a television available.

After the final test of the day, both Ss were transported home where they were cautioned against driving or performing any hazardous duties.

Design

Ss were tested over a number of days to assure familiarization with the procedures, to dispel anxiety that may have been induced by the test situation, and to enable the Ss to reach an asymtotic level of response. The alcohol doses were formulated to produce BAC's of 0.05% and 0.10%, respectively (Carpenter, 1965). Since little is known about psychomotor performance during alcohol elimination, testing also took place when the BAC of Ss had dropped to 0.05% during the elimination phase of the blood alcohol cycle.

Two dependent variables were measured for each task: number of errors per session and response times were examined in task 1, while total tracking time and tracking error time were obtained in task 2.

Results

Blood Alcohol Concentrations

Table 1 shows the medians and ranges of the BAC's reached in the three experimental conditions. No range is given for condition three, as each S was tested in that condition when his BAC declined to the testing criterion of 0.05%.

The large variation in BAC's in sessions 6 and 7 was apparently due to the body weight/alcohol formula used for determining alcohol doses, although Ss had been uniformly instructed concerning food and drink intake prior to the tests. The BAC appeared to be correlated with body build, with slimmer Ss reaching considerably lower BAC's than those apparently overweight.

Task 1

Response Time. In each session there were 45 trials in which the response times needed to input the five digits were measured. These trials were put in five blocks on nine consecutive trials, and the median response time of each block

TABLE 1

Median and Range of Blood Alcohol Concentrations Obtained in the Alcohol Sessions

BAC	Session		
	6	7	8
Median	.05	.095	.05
Range	.03-.06	.075-.13	-

was computed. A natural log transformation (Winer, 1962) was performed on the median response time scores to reduce skewness.

The analysis of variance performed on the transformed data showed that the main effects of blocks and sessions were significant, as were the Blocks X Sessions and Sessions X Subjects interactions.

Results of a Tukey (b) test on block means within sessions showed that the means of several blocks differed significantly in the first three sessions, but no significant differences between blocks of trials existed in sessions four through eight, implying that trial position becomes relatively unimportant after this amount of practice.

The significant Sessions X Subjects interaction indicates that Ss performed differentially across sessions. The non-significant Blocks X Subjects interactions, however, indicates that Ss performed in a similar manner across blocks.

Comparisons among session means (Figure 3) made by the Tukey (b) test, indicated that significant decreases in response time between sessions ended by session four. Mean response time in sessions six and eight (the ascending and descending BAC sessions) did not differ from sessions four or five, but in session seven (the peak BAC session) the mean response time was significantly greater than in session five.

Response Errors. An arc sine transformation (Winer, 1962) was performed on the response error data to reduce skewness. The analysis of variance of the transformed number of errors showed that the sessions main effect was significant. A Tukey (b) test on the session means, shown in Figure 4, showed that the number of response errors made in session seven (peak BAC) was greater than in all other sessions. No other significant differences were found.

Task 2

Tracking Error Time. Each S carried out the tracking task eight times in each session. Median tracking error times were found for each block of four trials and transformed to square roots to reduce the correlation between the means and variances of the session distributions (Winer, 1962).

The analysis of variance of the transformed median tracking error times showed significant main effects of trial blocks and sessions. Thus, less tracking error time was accumulated during the second block of four trials than the first in each session. The session means (Figure 5) were compared by Tukey (b) test which indicated that mean tracking error time in session seven (peak BAC) was significantly greater than in all other sessions, and the mean error time accumulated in session one was significantly greater than in session five, implying that performance improved across 32 trials. No other significant differences between session means were found.

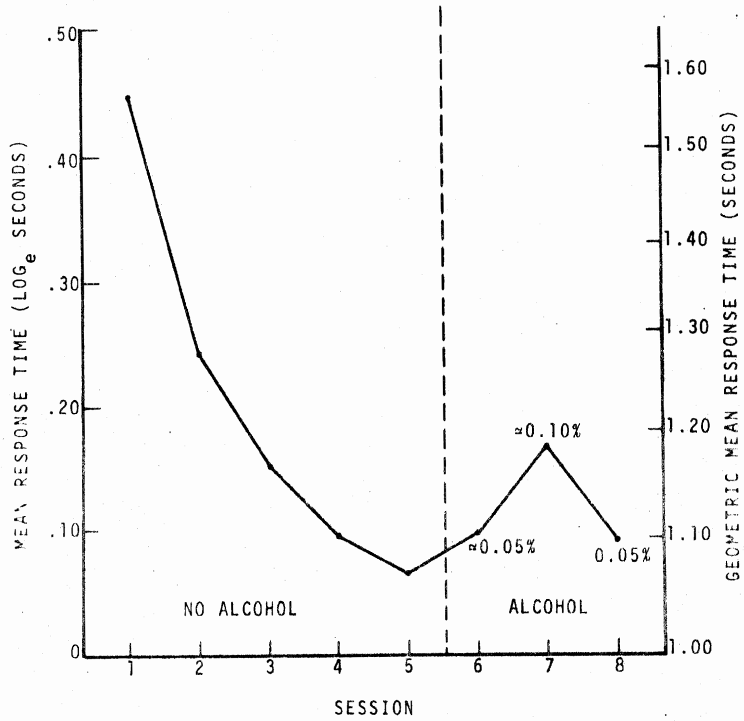

Figure 3. Mean response time in no alcohol and alcohol sessions on task 1.

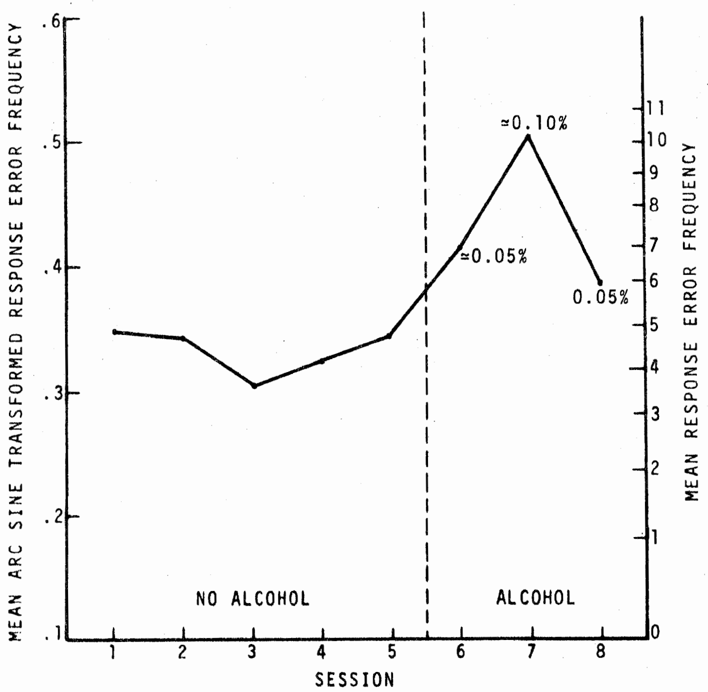

Figure 4. Mean number of errors in no alcohol and alcohol sessions on task 1.

Total Tracking Time. Median trial block scores were also calculated for total tracking time and transformed to square roots, and an analysis of variance performed on these data. A greater degree of inter-subject variability was found as both the Trial Blocks X Subjects and Sessions X Subjects interactions were significant. The significant Trial Blocks X Sessions interaction was examined by performing Tukey (b) tests on trial blocks means within sessions. The only significant difference between trial blocks was found in session seven with more total tracking time accumulated during the second block of four trials. Tukey (b) tests performed on the significant sessions main effect showed that mean total tracking time accumulated in session one was greater than in the other sessions (Figure 6).

Discussion

In both tasks performance improved significantly with practice. Significant decreases in mean response time in task 1 ceased after three sessions, or 135 individual trials, while mean tracking error time in task 2 decreased significantly across the first four test sessions, or 32 trials. The performance then asymptoted in both tasks so that practice effects can be assumed to have been removed before alcohol was administered.

Although subjects showed significant impairments in the peak BAC condition for response time in task 1 and tracking error time in task 2, the magnitudes of these changes in performance were

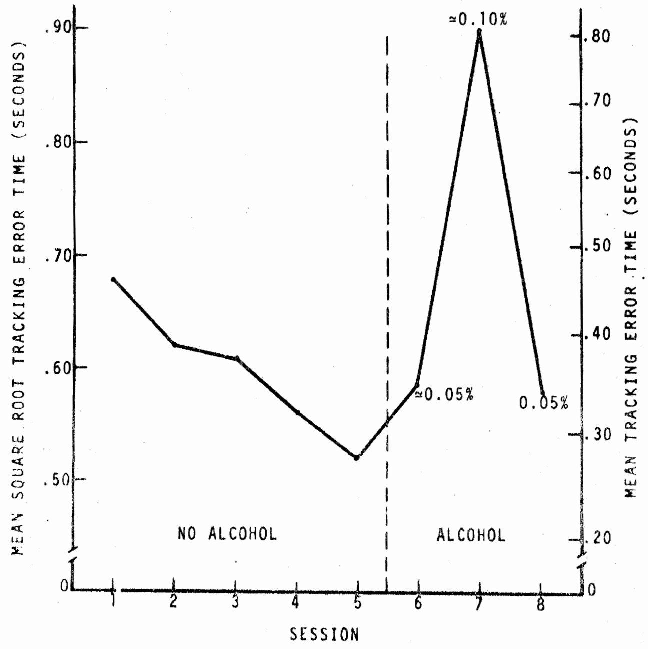

Figure 5. Mean tracking error time in no alcohol and alcohol sessions in task 2.

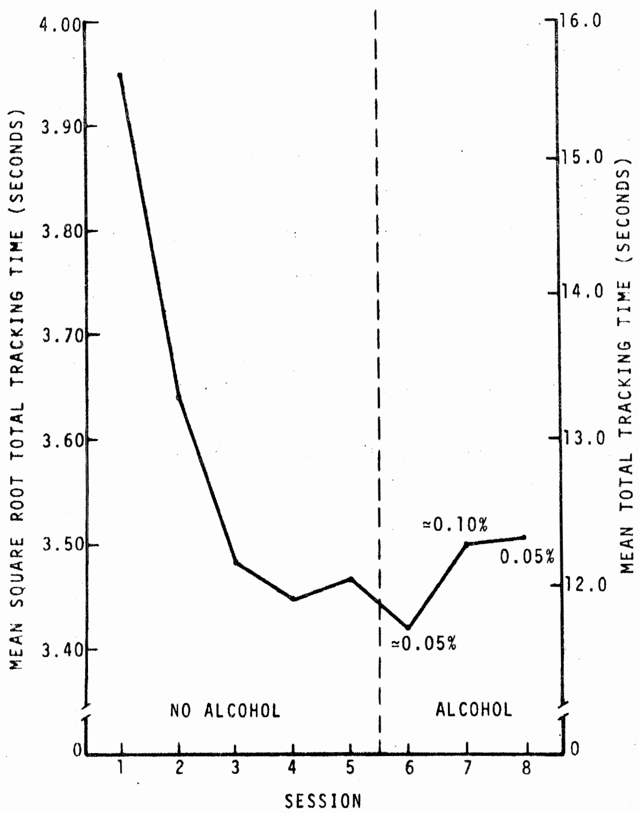

Figure 6. Mean total tracking time in no alcohol and alcohol sessions in task 2.

relatively small. In task 1, the decrease in geometric mean response time due to practice was nearly four times as great (1.56 to 1.07 sec) as the increase under alcohol (1.07 to 1.19 sec). The decrease in mean tracking error time with practice in task 2 was also quite large (.42 to .27 sec), but the increase under alcohol was relatively much larger than in task 1 (.27 to .81 sec). No performance decrement was found at BAC's of 0.05% in either the blood-alcohol absorption or elimination stages.

Subjects did not try to compensate for the debilitating effects of alcohol by becoming more cautious in task 1, as there was a significant increase in the number of trials in which errors were made in the peak BAC condition; nor did they take more time in task 2 in an effort to reduce tracking error time. (A tracking-based AIIS would necessarily have a total time cutoff point.)

Individual differences between subjects made the selection of a cutoff point separating sober from 0.10% BAC performance difficult for both tasks. Several subjects in both tasks performed better at the peak BAC than other subjects in the last practice session.

The effectiveness of response time (task 1) and tracking error time (task 2) in discriminating between subjects at 0% and 0.10% BAC is shown in Figure 7. These data were produced from the cumulative distributions of the mean performance of each subject at 0% and 0.10% BAC, in the two tasks, based on response

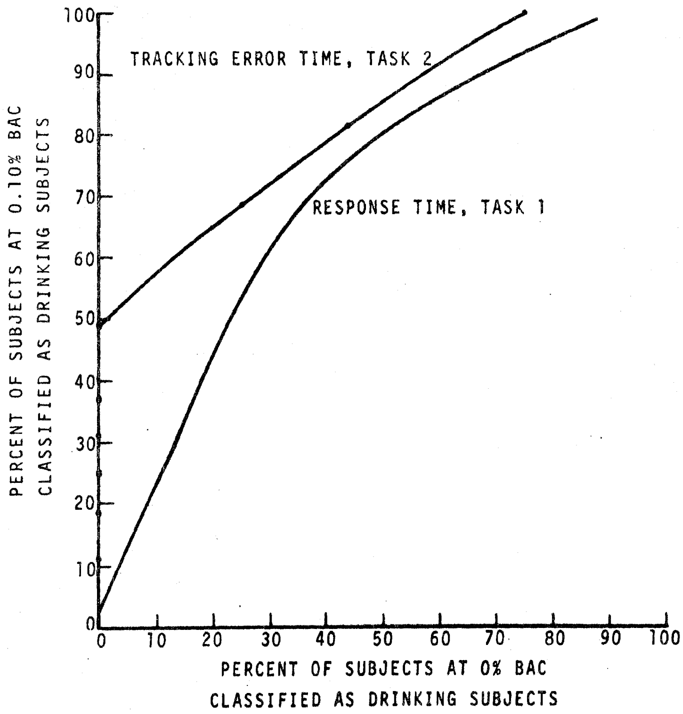

Figure 7. Effectiveness of the tasks in discriminating between subjects at 0% and 0.10% BAC.

time and tracking error time. It is shown that a false positive rate of zero, i.e. classifying none of the sober subjects as 0.10% BAC subjects, allows correct classification of 4% of the drinking subjects by means of task 1 and 48% with task 2. The Figure also shows how greater percentages of the drinking subjects could be correctly classified, by both tasks, at the expense of increased percentages of false positives. In practice it is doubtful that a false positive rate of as much as 5% would be tolerable, particularly when added to the inconvenience of taking such a test every time a driver wishes to start a trip.

Thus, neither task enables a clear-cut discrimination to be made between sober and drinking subjects for the BAC's that were used, although task 2 was reasonably effective.

If subjects had been used who better represented the age distribution of drivers, discrimination would be expected to decline, because older persons show poorer performance in motor skills (Welford, 1958). This means that, unless performance on the tasks could be shown to be highly correlated with driving ability and accident involvement, there would be little rationale for rejecting even a moderate proportion of responses made by sober drivers with naturally slow reactions or poor coordination.

Further studies may find, however, that a performance cutoff allowing even the slowest, most poorly coordinated sober driver to pass repeatedly would reject a majority of the responses of drivers, including problem drinkers, who had been drinking to high (e.g., 0.15%+) BAC's. Such BAC levels are more frequent than might be supposed. They were found to be exceeded by 66% of the drivers who had been drinking and were killed in crashes in Detroit and Wayne County, Michigan (Filkins et al. 1970). Thus, it is evident that by not allowing such drivers to operate their vehicles on AIIS could make a significant contribution in reducing severe crashes.

References

Carpenter, J. A. The effect of caffiene and alcohol on simple reaction time. Journal of Comparative and Physiological Psychology, 1959, 52, 491-496.

Carpenter, J. A. Effects of alcohol on some psychological processes: A critical review with special reference to automobile driving skill. Quarterly Journal of Studies on Alcohol, 1962, 23, 274-314.

Carpenter, J. A., & Ross, B. M. Effect of alcohol on short-term memory. Quarterly Journal of Studies on Alcohol, 1965, 26, 561-579.

Davis, J. H., & Fisk, A. J. The Dade County, Florida study on carbon monoxide, alcohol and drugs in fatal single vehicle automobile accidents. Dade County, Florida, Coroners Office, Proceedings of National Association of Coroners, 1964-66.

Davis, P. A., Gibbs, F. A., Davis, H., Jetter, W. W., & Trowbridge, L. S. The effects of alcohol upon the electroencephalogram. Quarterly Journal of Studies on Alcohol, 1941, 1, 626-637.

Dettling. L'influence de l'alcool sur Le temps de réaction d'un automobiliste. Review Alcool, 1956, 4, 40-45. Cited by J. A. Carpenter, Effects of alcohol on some psychological processes: A critical review with special reference to automobile driving skill. Quarterly Journal of Studies on Alcohol, 1967, 23, 274-314.

Eggleton, M. The effect of alcohol on the central nervous system. British Journal of Psychology, 1941, 32, 52-61.

Ekman, G., Frankenhaeuser, M., Goldberg, L., Bjerver, K., Järpe, G., & Myrsten, A. Effects of alcohol intake on subjective and objective variables over a five hour period. Psychopharmacologia (Berlin), 1963, 4, 28-38.

Filkins, L. D., Clark, C. D., Rosenblatt, C. A., Carlson, W. L., Kerlan, M. W., & Manson, H. Alcohol abuse and traffic safety: A study of fatalities, DWI offenders, alcoholics and court-related treatment approaches. Ann Arbor, Highway Safety Research Institute, The University of Michigan, 1970.

Forbes, G. The effect of alcohol on the psycho-motor reactions as a possible index of the degree of alcoholic intoxication. Medical-Legal Journal, London, 1947, 15, 23-38.

Freimuth, H. C., Watts, S. R., & Fisher, R. S. Alcohol and highway fatalities. Journal of Forensic Science, 1958, 3, 65-71.

General Motors Corporation, Delco Electronics Division Press Release. Marquette med school evaluates GM's drunk driver tester. August 25, 1970.

Grüner, O., & Ptasnik, H. Zur Frage der Beeinflussung Alkoholbedingten Leistungsabfalles durch Laevulosegaben. Munchener Medizinische Wochenschrift, 1953, 95, 931-933. Cited by J. A. Carpenter, Effects of alcohol on some psychological processes: A critical review with special reference to automobile driving skill. Quarterly Journal of Studies on Alcohol, 1967, 23, 274-314.

Grüner, O. Alkohol und Aufmerksomkeit. Ihre Bedeutung im motorisierten Verkehr. Deutsch Zeitschrift fur die Gesamte Gerichtliche Medizin, 1955, 44, 187-195. Cited by J. A. Carpenter, Effects of alcohol on some psychological processes: A critical review with special reference to automobile driving skill. Quarterly Journal of Studies on Alcohol, 1967, 23, 274-314.

Haddon, W., Jr., & Bradess, V. A. Alcohol in the single vehicle fatal accident; experience of Westchester County, New York. Journal of the American Medical Association, 1959, 169, 1587-1593.

Howells, D. E. Nystagmus as a physical sign in alcoholic intoxication. British Medical Journal, 1956, i, 1405-1406.

Hutchinson, H. C., Tuchtie, M., Gray, K. G., & Steinberg, D. A study of the effects of alcohol on mental functions. Canadian Psychiatric Association Journal, 1964, 9, 33-42.

Katkin, E. S., Hayes, W. N., Teger, A. J., & Pruitt, D. G. Effects of alcoholic beverages differing in congener content on psychomotor tasks and risk taking. Quarterly Journal of Studies on Alcohol, Supplement No. 5, 1970, 101-114.

McFarland, R. A., & Barach, A. L. Relationship between alcoholic intoxication and anoxemia. American Journal of the Medical Sciences, 1936, 192, 186-198.

Mortimer, R. G. Effect of low blood alcohol concentrations in simulated day and night driving. Perceptual and Motor Skills, 1963, 17, 399-408.

Muller, B. P., Tarpey, R. D., Giorgi, A. P., Mirone, L., & Rouke, F. L. Effects of alcohol and mephenoxalone on psychophysiological test performance. _Diseases of the Nervous System_, 1964, 25, 373-375.

Neilson, R. A. _Alcohol involvement in fatal motor vehicle accidents_. California Traffic Safety Foundation of San Francisco. April 1967.

New Jersey alcohol determination problem in fatal traffic accident cases--Report of findings of a three year study, 1961 through 1963. New Jersey Department of Law and Public Safety, Division of Motor Vehicles, Traffic Safety Service, Trenton, New Jersey, 1964.

Newman, H. Variability in tolerance to depressant drugs. _Stanford Medical Bulletin_, 1947, 5, 12-14.

Pearson, R. G. Alcohol-hypoxia effects upon operator tracking, monitoring and reaction time. _Aerospace Medicine_, 1968, 39, 303-307.

Prag, J. J. The chemical diagnosis of alcoholic intoxication. _South African Journal of Medical Science_, 1953, 18, 141-154. Cited by J. A. Carpenter, Effects of alcohol on some psychological processes: A critical review with special reference to automobile driving skill. _Quarterly Journal of Studies on Alcohol_, 1967, 23, 274-314.

Rakin, A., & Blair, H. The effects of alcohol on hand writing. _Journal of Clinical Psychology_, 1953, 9, 284-287.

Rudin, E. Auffassing und Merkfähigkeit unter alkoholwirkung. Psychologische Arbeiten. 1902, 4, 495-522.

Ryback, R. S. The continuum and specificity of the effects of alcohol on memory: A review. Quarterly Journal of Studies on Alcohol, 1971, 32, 995-1016.

Sussman, E. D., Davis, P. W., & Warner, A. Automatic detection of intoxicated drivers. Society of Automotive Engineers; Report No. 720138, 1972.

Talland, G. A., Mendelson, J. A., & Ryack, P. Experimentally induced chronic intoxication and withdrawal in alcoholics. Pt. 5. Tests of attention. Quarterly Journal of Studies on Alcohol, Supplement No. 2, 1964, 74-86.

Winer, B. J. Statistical principles in experimental design. New York: McGraw-Hill, 1962.