MEASUREMENT OF RISK-RELATED AND OTHER DIMENSIONS OF ALCOHOL-INDUCED IMPAIRMENT

Final Report

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16. Abstract

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Analyses of the data, from both individual and group perspectives, indicate that psychomotor tasks have very limited ability to discriminate between an individual impaired by alcohol and the same individual in a sober state. The reason for this is that the impairing qualities of alcohol show up in psychomotor only as second and third-order effects.

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ABSTRACT

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Analyses of the data, from both individual and group perspectives, indicate that psychomotor tasks have very limited ability to discriminate between an individual impaired by alcohol and the same individual in a sober state. The reason for this is that the impairing qualities of alcohol show up in psychomotor performance only as second- and third-order effects.

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1. INTRODUCTION

The specific objective of the research done under this grant was to discover a task or set of tasks which can be used as a reliable prediction of impairment due to alchol. While many investigators have been able to find well-defined functional relationships between impairment on particular psycho-motor tasks and blood alcohol concentration (BAC), no satisfactory taxonomy of alcohol-produced impairment has as yet emerged. Our premise from the beginning of this study has been to use a measurement-oriented approach to the problem.

The measurement-orientation has two components. First, we intended to administer a large number of different tasks to the same subjects at approximately the same time, at each of several BAC levels. This allows us the possibility of using statistical tests, such as factor analysis, to identify the dimensions of impairment common to a number of tasks. Second, we hoped to define, over useful ranges of performance measures, techniques which were practical for the identification of impairment caused by alcohol. The measurement process, if not the particular tasks themselves, would, by extrapolation, provide for the identification of impairment caused by drugs other than alcohol.

Our concern with this problem comes primarily from our interest in the effects of alcohol on automobile driving, and most of our procedures have been selected with the driving task in mind. This fact has a number of implications for our choice of tasks used in the study. We are interested in, first of all, the kinds of impairment most likely to offset driving behavior, and have selected tasks with high face validity in that regard. These tasks therefore have components relating to the perceptual and motor skills thought to be involved in the driving task itself.

A special concern throughout this study has been with the effect of alcohol on risk-taking. The lore of both accident investigators and alcohol researchers is that relatively high BAC's produce large increases in risk-taking behavior, but there is little research evidence to support this position. The obvious relevance of risk-taking phenomena to driving, however, makes them an essential component for study in any attempt to evaluate the impairing affects of alcohol.

Finally, by way of introduction, the number of tasks which could have been studied in this effort number into the thousands. Each of these, however, has been studied infrequently, and information is lacking both as to the variation in performance over a population wider than that of college students and as to the correlations between performance on different tasks. Rather than design new tasks, therefore, we selected a small subset suitable for our purposes, from those already established as workable laboratory procedures.

The doctoral dissertation of Kurt Snapper was supported by this grant and is included as an Appendix to this report.

II. THE TASKS AND PAYOFFS

A list of the tasks used in this study is shown in Table 1.

Responses to Discrete Stimuli

Equipment: For all tasks in this battery, a Digital Equipment Corporation PDP-7 computer was used to present the stimuli and measure the responses. Stimuli were presented using either a Type 30-G cathode ray tube display, a pair of computer-controlled neon lights, or a computer-driven memory drum. Whenever a randomized time interval was called for, such as the random foreperiod in the simple reaction time task, the computer actually sampled randomly from an appropriate distribution each time it presented a trial. Real-time random sampling was also used to select the stimulus (e.g., left or right stimulus for those choice reaction tasks) to be prevented in a trial. This sampling was clock-based to prevent any repeating cycles of sampled values. Because of the time accuracy called for by both this stimulus presentation program and the measurement of response times, a millisecond clock was designed revised into the computer.

Memory drum responses were detected on a ten-button array (two rows of five) mounted on the memory drum. Other task responses were detected on pairs of button-controlled microswitches positioned at the cathode ray screen and at the neon lights. Responses were coded as correct or incorrect. The time elapsed between stimulus and response was measured to the nearest millisecond. Simple runs and averages of times and tallies were also computed and stored by the computer. These summary statistics were available immediately for feedback and computation of payoff to S, while all raw scores were stored on paper tape for a more detailed analysis later.

Table 1

LIST OF TASKS

Number	Name
1	Simple Reaction Time
2	Choice Reaction Time
3	Rare Event CRT
4	Delayed Response CRT
5	Peripheral Vision CRT
6	Visual Discrimination CRT
7	Simple Tracking
8	Critical Tracking
9	Accelerative Tracking
10	Divided Attention
11	Pursuit Rotor
12	Fitts Task
13	Phystester
14	Digit Symbol
15	Intersection
16	Slalom
17	Backwards Slalom

Simple Reaction Task. The S was seated in front of the cathode raye screen with left and right forefingers resting on button-controlled microswitches. To begin the test, S pushed both response buttons. A matrix appeared on the screen which specified costs and payoffs, and therfore designated whether the response whould be made with the right or left hand. The cost was assessed as 1¢ per 10 milliseconds of response time. The pay varied from 4¢ to 10¢ for each appropriate response depending on S's level of training. A penalty of $1.00 was assessed for anticipatory responses.

After a fixed time the matrix disappeared. The S initiated a trial by again pushing down both response buttons. After a 1- to 3-second foreperiod (selected from a rectangular distribution between these limits), the stimulus, a square approximately 2 inches by 2 inches, appeared on the screen. The S responded by releasing the appropriate button as quickly as he could. The payment and cost for response time were displayed immediately following the response, while the reaction time was stored for analysis. The task was self-paced since each trial was initialized by S pushing both response buttons. In every session, S had one block each of both right and left responses. Which response was appropriate was always specified in advance and did not change during a block of trials. The S ran through two sessions each day.

Choice Reaction Task. This task used the same stimulus and response apparatus as the simple reaction task. The costs and payoffs were different and the stimuli were different. The stimulus was a rectangle, approximately 2 inches by 1 inch, slanted 45^{o} to the left or right of vertical with equal probability. The appropriate response was to lift the left or right forefinger respectively from its response button. For an appropriate response, S received a payment ranging from 4¢ to 10¢ depending on extent of training. Costs were in the form of 1¢ per 10 milliseconds of response time, 30¢ for an incorrect response, and $1.00 for an anticipatory response. Due to very low error rates, only correct-response choice reaction times were analyzed. All other aspects of this task, including the display of costs and payoffs, arrangement of sessions, etc., were the same as in the simple reaction task.

Rare Event Choice Reaction Task. This variation was the same as the choice reaction task, except that one of the stimuli occurred with a probability of .1, and the other, .9. Either stimulus, with equal probability, could be the rare one for a given block of trials. Payoffs were as follows:

3¢ for correct response to frequent stimulus,
0¢ for incorrect response to frequency stimulus,
13¢ for correct response to rare stimulus,
-14¢ for incorrect response to rare stimulus,
-$1.00 for anticipatory response,
-X¢/second for response time,

where X¢ varied from 8¢ to 12¢ as a function of extent of training. Due to very low error rates, only correct-response choice reaction times were analyzed. The correct-response reaction times for the frequent stimulus and for the rare stimulus were analyzed as two separate measures.

Visual Discrimination Choice Reaction Task. This task represented another variation of the choice reaction task, with the two stimuli made very difficult to discriminate. The length to width ratio for the rectangle was changed from 2-to-1 for the choice reaction task to 45-to-44 for this task. The actual physical size of the rectangle was about 2 inches by 1.96 inches, about 14 inches from the eyes of S. All other aspects of the task, including payoffs, sessions, etc., were the same as for the choice reaction task.

Peripheral Vision Choice Reaction Task. This task is another version of the choice reaction task that differed in the form of the stimulus. Instead of rectangles on a cathode-ray-tube screen, the stimuli were two neon bulbs, mounted at eye height, each set in the end of a 1/4 inch round by 11 inch long black tube. The tubes and lights were arranged so that the lights could be seen only when they were 45 degrees to either side of S's fixation point. This forced the use of S's near-peripheral visual field in detecting the stimulus onset. The S had to lift his left or right forefinger from its response button as quickly as possible after the corresponding light came on. The lights would light with equal probability, one and only one coming on a .5 second fixed delay plus a random foreperiod after the last response. (Note that this made the task machine-paced, while the other choice reaction tasks were self-paced.) The random foreperiod was sampled from a geometric distribution with a 7 millisecond interval and a termination probability equal to .0078 per interval. This procedure kept S's expectation uniform, and led to a mean intertrial interval of 1.4 seconds (.5 sec fixed + a sample from a distribution with a mean of .19 sec.).

The payoffs for this task were the same as the choice reaction task payoffs faced by S that same night. Anticipatory responses were indicated to S by both lights rapidly flashing. As with the other choice reaction tasks, only correct-response choice reaction times were analyzed, due to low error rates.

Delayed-Response Choice Reaction Task. This task was run on a memory drum controlled by the PDP-7. The task began with S pushed the middle of three buttons, bringing into the viewing window a symbol corresponding to one of the three response buttons. The S then pushed the middle button again, causing the drum to step to the next symbol. He then had to push the button appropriate for the first symbol, stepping the drum once more, and so on. In general, S had to respond to symbol n-1 as he viewed symbol n. His response caused the drum to step to symbol n+1. This meant that S would respond only after he felt he had memorized the response to the symbol presently in front of him. The response time, then, did not represent a typical reaction time, but rather an encoding time. Due to low error frequencies, only correct-response response times were analyzed.

Each _S_ ran 3 blocks of 100 trials each session, and ran 2 sessions each night. The payoffs used were of the same form as in the choice reaction task, a reward for each correct response, a penalty for each incorrect response, and a cost per second for response time.

Digit Series. In this task, also run on a memory drum, _S_ initiated the trial by pressing the top middle button of a 5x2 ten-button array, bringing a 5-digit series into the window. After one second, the drum automatically stepped, removing the digit series from sight. After a delay of 2 seconds, a new word was displayed: "forward" or "reverse," signalling _S_ to begin responding. He then had to punch in the digit series on the ten numbered buttons, as fast as he could, in the left-to-right order as presented if the signal was "forward," or in the right-to-left order if the signal was "reverse,"

The _S_ ran 32 trials per 15 minute session, 2 sessions per day. Payoffs were:

2¢ for each correct response

-8¢ for each incorrect response

-X¢ per second for response time for the entire response (five button presses)

X¢ varied from 2¢ to 4¢ as a function of extent of training. Error rates were on the order of 1 or 2%, so the score for analysis was reaction time for correct responses only.

Digit Symbols. In this task, the third of three tasks run on a memory drum, _S_ initiated a block of 2 trials by pressing the top middle button of a ten-button array. After a short delay, five letter-digit pairs were displayed one at a time, each displayed for 400 milliseconds. The letters were randomly selected from the set: (F,H,K,L,M,N,T,V,X,Y) in order to reduce form heterogeneity. The digits were randomly selected from the set 0 through 9. Immediately after the last letter-digit pair display, the five letters included in the displayed pairs were presented in a row in a random order. The _S_ had to punch in the corresponding digits in the indicated order, as fast as he could. If the fifth button push had not taken place before

10 seconds of response time had elapsed, the trial was automatically terminated and counted as five errors.

The second trial of the block began automatically, one second after the last response to (or 10-second termination of) the first trial. Sixteen two-trial blocks were presented in each session. The S went through two such sessions, each lasting about 15 minutes, each night. Different memory drum tapes, from a total set of five, were used each session. The score used for analysis was percent correct responses. The payoff for each session was:

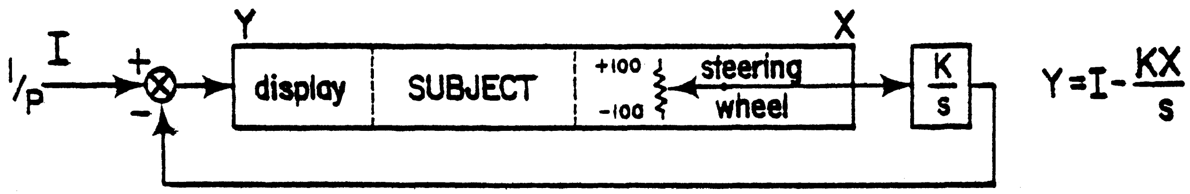
4/session = 8¢ (number of correct responses-
breakeven number)

where the breakeven number progressed from 50 to 80 (out of 160 possible for 32 trials), as a function of extent of training.

Responses to Continuous Stimuli (tracking)

Equipment: All tracking tasks were run on an Applied Dynamics AD-4 analog computer. The stimulus was displayed on a 25-inch rectangular-screen cathode ray tube, placed at "automobile hood level," 40 inches in front of S's eyes. The screen displayed orthogonal cross-chairs, parallel to and filling the frame, intersecting 4 inches above the middle of the bottom of the screen. At a point 2-1/2 inches above the intersection there was a 2-inch horizontal bar centered on the vertical crosshair. The cursor was a 4-inch vertical line, brighter and thicker than the crosshairs, centered on the horizontal crosshair. The cursor moved along the horizontal axis only.

Simple Compensatory Tracking. Upon a warning from E, the system was activated. The cursor displacement was set equal to the difference between a random signal and the integral of the steering wheel displacement (wheel centered = 0 volts). See figure one for a schematic and transfer function of this system. With this system, a given steering wheel position imparted a particular velocity to the cursor. So while the cursor was controlled in position by the random signal, it was controlled in velocity by S, just as the steering wheel of an actual car controls the lateral angular velocity of the car heading. The random signal was the output of a digital random noise source, filtered to 5 radians per second with a low-pass 30 decibel per decade filter $(1/(-s+1)^3)$. The parameters of the noise source were set such that a gaussian signal with a repeating period of 128 seconds was obtained.



Schematic, System Transfer Function
Simple Compensatory Tracking
Figure 1

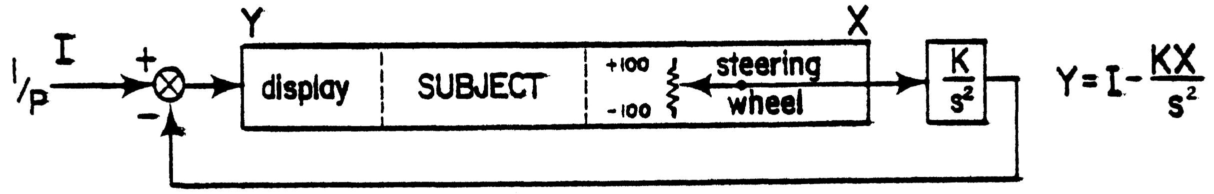
The S attempted to keep the cursor centered for a period of 39 seconds, after which the display disappeared. The S's score was the mean squared deviation of the cursor from the screen center, over the entire 39 seconds, though the first four seconds were ramp-weighted from below. The initial low weighting was used to minimize the effects of initial control transients on the score. At the end of each 39 second trial the score was announced to S, a short (one-minute) break taken, then the next trial begun. Ten trials were run in a 15 minute session, and each S went through two sessions each night.

The S was paid as a linear function of his average score over ten trials. The scaling was worked out such that a run with the cursor steady at 1 inch from the center (at the end of the horizontal reference bar) yielded a score of 100. This was the break-even point for the first night S worked with payoffs. The payoff function was figured on the average score for a ten-trial session:

$$\text{S/session} = \frac{\text{(break-even) - (average score)}}{20}$$

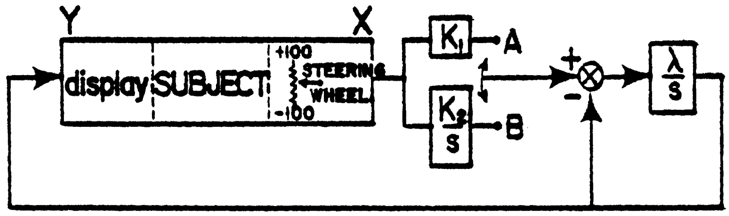
where the breakeven was lowered in steps of five points as a function of extent of training, ending up at 70 for the testing phase, during which it was held constant.

Accelerative Tracking. This task was run in the same manner as simple compensatory tracking, except that one more integrator was placed between S and cursor (see Figure 2). Thus a given steering wheel position imparted a particular acceleration to the cursor. Trials, session, scoring and payoffs were the same as in simple tracking, except that system gains had to be adjusted to prevent computer overload in this inherently less stable task. Payoff breakevens were also much different because of the different gains, the higher level of difficulty, and the lower degree of improvement found in S performance in this task.



Schematic, System Transfer Function
Accelerative Tracking
Figure 2

Critical Tracking. The stimulus display for this task differed from that of the other tracking tasks, in that the horizontal crosshair was only 7 inches long (10^0 arc subtended from the S's eyes). The cursor was controlled in this task by an unstable system, with no input aside from the S's error. The S had to balance the system by displacement (first order) or velocity (second order) inputs from the steering wheel. If the cursor ever touched one of the endpoints of the horizontal crosshair, the trial was ended (see Figure 3).



first order: "A": $Y = \frac{K_1 \lambda}{s - \lambda} X$

second order: "B": $Y = \frac{K_2 \lambda}{s(s - \lambda)} X$

Schematic, System Transfer Function Critical Tracking,
First Order ("A"), Second Order ("B")
Figure 3

The system instability was increased linearly through time from an initial value, at .25 rad/sec for first order, .04 rad/sec for the second order configuration. The initial values ranged from 2 to 4 rad for the first order, and from .4 to 1.8 rad for the second-order version, as a function of extent of training. The second-order configuration was used for the first 3 S's, the first-order configuration for all further S's. The S's score was the value of that had been attained when he first failed to keep the cursor between the ends of the horizontal crosshair. This score corresponds roughly to the inverse of the S's dynamic time delay. Ten or 20 trials were run per session, at two sessions per night. On nonsalaried sessions, the S was paid according to the function:

$$\$/\text{session} = \frac{(\text{average score}) - (\text{break-even score})}{X}$$

where:

$X = 2.$ for first order

$X = .8$ for second order

"average score" = S's average score over ten trials.

The breakeven score for the first-order version started at 3.5 rad and increased as a function of training in .5 rad steps up to 5 rad, where it was held constant throughout the testing sessions. For the second-order version, the breakeven started at 1 rad and progressed up to 2.2 rad for the testing sessions.

Divided Attention Task. In this task, the simple compensatory tracking trask was run exactly as described above, simultaneously with a two-alternative choice reaction time task. The choice reaction stimuli were two neon bulbs mounted at the same height as the tracking stimulus, 19^{0} to each side of the center in the S's field of view. The correct response to the left light was to press the brake pedal; for the right light, the accelerator. The S was made to use his right foot only. Microswitches were mounted such that a 1/2-inch displacement of the brake or a 1/4-inch motion of the accelerator would trigger the switch.

Responses to Stimuli; With Review

Pursuit Rotor. This new version of the classic human performance task was run on self-contained equipment, with no computer links. This equipment consisted of a variable speed platter with a 1.9 cm diameter aluminum target disc, centered 8.1 cm from the platter center and flush with its surface; a limp hand-held stylus; a hand-held single thumb-button; and a two-channel timing-logic system. The timing-logic system displayed two relevant measures:

t_M = time button was depressed while stylus was off target

t_H = time button was depressed while stylus was on target.

Just before a trial began, with the platter stationary, S held the stylus on target and the thumb button down. The trial began when the platter started turning, accelerating smoothly until it reached its operating speed, 30 to 60 rpm (depending on extent of training), in .5 to .75 seconds, depending on the operating speed. After 20 seconds, the power to the platter was cut and the trial ended. After a 20-second rest interval, a new trial started again. Timers were active from when the platter began turning to when the platter power was cut.

The S's task was to keep the stylus tip on the target disc throughout the trial, and to press the thumb button only while he was on target. The stylus was held in S's dominant hand, the thumb switch held in the other. The stylus was "limp," hinged in such a way that S couldn't press the stylus tip down against the target, so that there was very little frictional force to assist S in keeping the stylus on target. Five trials were run each session, with two pairs of sessions run each night. Each pair of sessions bracketed a five-trial session on the Fitts task to be described later in this section.

The S was scored during test sessions on a weighted difference of the two measured times:

$$\text{score} = t_H - 1.5\, t_M.$$

Payoffs to S for each trial on the n^{th} day of practice were:

$$¢/\text{trial} = 2\, t_H - D(.5 \cdot t_M + 4)$$

where:

$$D = \begin{cases} n-1, & n<7 \\ 6, & n \geq 7 \end{cases}.$$

This payoff function (a linear function of the score when D = 6) was designed to motivate S both to keep the stylus on target and to closely match his tracking status with the thumb button.

Slalom Driving Task. This task provided a more direct measure of S's driving ability than did other tasks. It was conducted in an outdoor parking lot, set up with seven traffic cones placed 25 feet apart in a straight line. Start and finish lines were placed perpendicular to the line of cones, and 25 feet from either end. The S centered the experimental car (a 1972 Plymouth Satellite) on the line of cones and behind the "start" line. On a signal from E, S drove a slalom course through the cones and over the "finish" line. After a forward slalom trial, S centered the car on the line of cones and just beyond the "finish" line, with the car pointing away from the cones. On a signal from E, S backed the car through the slalom and over the "start" line. Each evening, S drove forward and backward slaloms in alternation until 5 trials of each were completed.

Driving time was measured from E's signal to the time the car cleared the last cone. Errors counted were: knocking over a cone; displacing a cone more than 12 inches; or failing to drive the proper path around a cone. The forward slalom and backward slalom were considered separate tasks, and for each one, driving times and error scores were analyzed as separate scores. The S's were paid by the following formulae:

forward: ¢/trial = 100- 6(# errors) + 2(# seconds - 10)
backward: ¢/trial = 100- 10(# errors) + 2(# seconds - 10)

These formulae of course reduce to a simpler form, but the "10-second breakeven" on the time dimension proved to be an aid for S's internalizing the payoff structure.

The two tasks described below also involve responses to stimuli with preview, and were run with the same S's used for the tasks described above. However, problems with the stability of the data from these last two tasks prevented the meaningful analysis of their ability to discriminate behavioral impairment. The task descriptions are nevertheless included below for the sake of completeness and interest.

Intersection Task. In this driving task, S sat in a car at a stop sign, waiting to cross a simulated lane of traffic. This simulation was presented by a 185-yard line of light bulbs, one every 5.5 feet. Sequences of 4 adjacent light bulbs, representing cars, propagated down this line with speeds from 25 to 60 mph, and gaps between them from 2.5 to 5.5 seconds in duration. The S's were presented with a series of gaps between cars. As each pair of cars with the target gap between them came down the simulated lane, S had to predict whether or not he could safely make it across the lane. He then had to actually try to make it across the lane through the gap, regardless of his prediction. On some trials, the car would actually be driven across the lane. On other trials, the car was taken out of gear and a timer simulated the car crossing the lane. In either case, S received immediate feedback as to whether he had avoided an accident or not (a large floodlight in his eyes if he got into an accident).

Stimulus sets were adjusted so that each S made about 50% of the gaps presented to him on any given night. Different gap length-speed combinations were used for each gap duration in order to enrich the stimulus set and prevent cueing by S on speed alone or gap width alone. The S had to attend to both attributes in order to estimate gap duration and thus his probability of making it. Each S was presented with from 40 to 80 gaps, all in one session, each night.

Motor performance was quite stable in this task, since S simply had to stamp on the accelerator at the right time, with plenty of preview of the stimulus. The task was designed primarily to measure S discrimination and decision-making ability. The payoffs were designed to motivate careful decision-making in the simulated context. At one payoff level, if S said "yes" before he stamped on the accelerator, he would get $1.25 if he made the gap, or lose $3.75 if he got hit. If he said "no," no decision payoffs would be in effect. In addition, there was a small performance pay of +10¢ if he made the gap, -10¢ to -80¢ (depending on level of training) if he didn't, regardless of whether he had said "yes" or "no." Thus an optimal S would say "yes" to any gap he felt he could make with a probability p_.75, and would say "no" otherwise, but still try to make the gap on every trial.

Two scores were calculated from S's performance on this task. One was a measure of his ability to discriminate between gaps he could and couldn't make. This was essentially a perceptual discrimination score. The other score took into account the subject's rate of success in making gaps and his ability to discriminate between possible and impossible gaps. This second decision score measured how much money the subject made, compared with how much an optimal decision maker (with the same performance and discrimination limitations) would have made, given that stimulus set and payoff scheme. The actual measure used was the subject's earnings in percent off of optimal. This represents a pure decision score, normalized for the motor and perceptual performance of the subject.

Fitts Task. This non-driving task was run on self-contained equipment, with no computer links. The equipment consisted of a hand-held rigid stylus, two one-inch-diameter aluminum target discs separated by 9 inches (between centers), and a logic system which displayed the number of alternating contacts between the stylus and each of the targets and sensed and indicated any errors. The S, on signal from E, began tapping the two targets alternately, as fast as he could. Twenty seconds after the first tap, the trial was terminated. Five such trials were run in a session, with two pairs of sessions each night. Each pair of sessions bracketed a 5-trial session of the Pursuit Rotor Task described previously.

The S score and payoff were figured as a linear combination of the number of correct taps and the number of misses, where a miss was sensed when one target was tapped twice in succession.

III. PROCEDURES

The subjects used in this study were males between 18 and 28 years of age, about half of them college students. They were selected from a paid subject pool and from among respondents to newspaper advertisements.

Since the most important criterion of selection for the tasks is the ability to discriminate impairment in an extremely well-trained driver, most of our running time was spent training subjects until stable performance was reached. Subjects were run, three or four at a time, in four-hour sessions beginning at 8:00 p.m. five nights a week. The late hours were selected because of the necessity of running the intersection task in the dark, and also because this time period covers hours of the day when drunk-driving incidents are common. Time to achieve stable performance from a subject varied depending on the task, but was at least two to three hours per week, sometimes more. Shorter times were found for some tasks where there was positive transfer from previously learned skills. The end result was that subjects were trained from two and one-half to three weeks before testing began.

After the first group of subjects was run a more rigid screening procedure was used than the one originally established of ascertaining that the subjects were self admitted "moderate" drinkers. This was necessitated by the fact that two subjects in the first group became ill after the first drinking test session and never appeared in the laboratory again, a waste of the three-week training period. Thereafter we gathered about twice the number of subjects we needed, and had an informal "party" before the selection was made. Subjects were given alcohol so that their BAC's were about .12 and allowed to reconsider their decision to participate in the study, and the experimenters could observe those who were unable to tolerate the required amount of spirits.

Since it was desired that the Ss be brought to a pre-determined level of alcohol intoxication, and have that level maintained for a prolonged period of time, the drinking protocol is readily divided into two portions: the initial phase, one hour in which the Ss are made to drink a premeasured amount of alcohol, and given time for this alcohol to be absorbed; and a maintenance phase in which the Ss are given additional (generally smaller) drinks to maintain the desired BAC and to adjust for any deviation from that level.

Prior to the start of the training phase of the experiment, the group of volunteers attended a screening session in which they were given sufficient alcohol to produce BACs of 0.12-0.15 gm/100 ml. They were then kept at this level for two to three hours. The purpose of this screening was to eliminate from the pool of potential Ss those who were physiologically unable to tolerate elevated BACs for prolonged periods. Usually at the end of this screening session, there were some Ss who voluntarily withdrew from further activity in the experiment. In addition, a sufficient number of other persons were excused until the desired number of Ss was obtained.

The amount of alcohol given in the initial stage was computed in the following manner:

$$A = (K)(r)(p)(Cd)^*$$

(mls of 100^0 proof of alcoholic beverage in one hour)

where

K = constant (11.55), a combination of conversion factors: Kg/lbs,

wt/volume/(of alcohol), etc., e.g.,

r = "reduced body mass," that "fraction of the body volume in which alcohol would be present if it were distributed at a uniform concentration equal to that observed in the blood"

"r" was determined by visual estimation, given that the mean value for males is 0.72 and the standard deviation is 0.06. It is (generally) an estimate of somatotype, with lean people having higher values of reduced body mass, and stout people lower.

p = body weight, in pounds and

Cd = the desired BAC (gms/100 ml + 0.015, to allow for elimination during the initial phase).

Hence for a person of average build, weighing 170 lbs., the amount of 100 proof alcohol required to obtain a BAC of 0.12 would be

$$A = 11.55(0.72)(170)(0.12 + 0.015)$$

$$A = 191 \text{ ml.}$$

This was divided into four or five equal portions, mixed with ice and sugarless, carbonated mix (Tab, Fresca), and served to the subject. He was expected to finish the entire initial dose within one half to three quarters of one hour. After finishing, he was allowed one half hour for the alcohol to be absorbed fully, then given a breath test to determine BAC. If he was at the desired level, he would be given a small maintenance dose to keep him there during the next half hour, and sent off into the experimental area. If he was either too high or too low (+ 10%) he was given either additional alcohol or additional time to detoxify.

At frequent intervals, usually as soon as the subject had finished one portion of the test battery, he would be brought back to the room in which drinking took place, re-tested, and given enough additional alcohol to maintain him at the desired BAC for another hour. The amount was computed in a manner described above, using a value of 0.015 gm/100 ml as the amount of alcohol eliminated in one hour.

Subject to the constraints given below, the Ss were allowed free choice of alcoholic beverage and mixer. They were allowed to select from Scotch, Bourbon, or Vodka, and any mix that was sugarless and carbonated. They were not permitted to drink the liquor neat, nor were they permitted non-carbonated, sugared mixers (such as orange juice) or other alcoholic beverages (such as beer or wine). These were all prohibited on the grounds that they prolong the period of absorption and (for the same reason) lead to a lower, wider "peak."

The Ss were instructed not to eat anything within four hours of the start of the drinking session. They were picked up at their homes and delivered back to them by experimental personnel on the night when drinking took place. In addition, they signed waivers absolving the University from all responsibility for any injury or sickness resulting from their consumption of alcohol.

After data were collected on the subjects while well-trained and sober, the experimental sessions. Three levels of alcohol impairment were used .02, .07, and .12 g/100 ml. Each drinking night was run directly adjacent to a sober control session, and each subject was scheduled for two sessions at each BAC level. The net effect of this was that the experimental sessions took about ten days per group of subjects, resulting in a very low sample size for the entire study.

Payoffs for the subjects were quite high for all the tasks, and were very sensitive to subject performance. Subjects lost as much as $20 or gained as much as $40 in one four-hour session. Due to pronounced inter-subject differences in performance, along with large learning effects within subjects, payoff schedules were made more difficult as training progressed. Payoffs and task difficulty were manipulated as the study progressed in an attempt to keep subject pay in the $2 to $4 per hour range, while avoiding "gaining" on the part of the subject. Payoffs could have been made less sensitive to performance, simplifying greatly the problems of subject and money management. We considered it important, however, to keep payoffs per trial in the range of appreciable monetary gain or loss, since we were attempting to observe highly motivated behavior, as would be the behavior of a driver who wants to start his car.

The high degree of motivation employed led to some very surprising performance on the part of some subjects. With the tracking tasks in particular, we observed certain subjects complete a trial with mean squared error scores of about one-half of the experimenter's own best scores. This type of performance leads to problems in task development. Task difficulty is a very important determinant of the ability of a task to discriminate within the range of impairment of interest here. If a task is too easy or too diffiuclt, subject scores will be little different for different states of impairment. Often our highly motivated and trained subjects discovered strategies or acquired talents that rendered a task excessively simple to be sensitive to their impairment. Thus we had to continually modify the candidate and validation tasks to cope with unexpected performance.

Table No. 2

Task; Simple Reaction Time

Analysis of Variance

Subject No.	Condition	Sessions	Mean	df	SS_b	SS_w	F	Signif
1	All	9	223	8,671	8524	583	14.63	
	BAC=0	5	221	4,395	1536	425	3.62	No
2	All	10	226	9,790	15665	488	32.12	
	BAC=0	5	217	4,395	1976	390	5.06	
3	All	7	230	6,473	168473	1908	88.28	
	BAC=0	3	217	2,237	8967	701	12.81	
4	All	10	244	9,790	3009	415	7.24	
	BAC=0	5	239	4,395	2336	422	5.54	
5	All	10	237	9,790	42685	408	104.70	
	BAC=0	5	229	4,395	824	384	2.15	No
6	All	10	220	9,790	8591	741	11.59	
	BAC=0	5	212	4,395	3744	454	8.25	
7	All	8	275	7,592	20894	1921	10.88	
	BAC=0	3	279	2,197	17656	2829	6.24	No
8	All	9	227	8,711	14622	1349	10.84	
	BAC=0	4	221	3,316	11487	1779	6.46	
9	All	8	224	7,632	12916	2363	5.46	
	BAC=0	4	217	3,316	17745	1379	12.87	

Table No. 3

Task: Choice Reaction Time

Analysis of Variance

Subject No.	Condition	Sessions	Mean	df	SS_b	SS_w	F	Signif
1	All	7	303	6,643	9.58×10^5	2.48×10^5	3.87	
	BAC=0	4	300	3,396	6.17×10^5	2.48×10^5	2.48	No
2	All	8	337	7,792	11.30×10^5	3.89×10^5	2.90	No
	BAC=0	4	330	3,396	4.57×10^5	3.93×10^5	1.16	No
3	All	5	326	4,395	20.75×10^5	3.66×10^5	5.67	
	BAC=0	2	316	1,198	36.45×10^5	4.78×10^5	7.63	
4	All	8	320	7,792	1.53×10^5	3.58×10^5	.42	No
	BAC=0	4	319	3,396	1.69×10^5	4.30×10^5	.39	No
5	All	8	340	7,792	36.27×10^5	2.15×10^5	170.37	
	BAC=0	4	325	3,396	1.60×10^5	2.12×10^5	.75	No
6	All	8	340	7,792	2.14×10^6	$.55 \times 10^6$	3.92	No
	BAC=0	4	333	3,396	3.24×10^6	$.49 \times 10^6$	6.56	
7	All	5	398	4,495	3.73×10^6	$.45 \times 10^6$	8.28	
	BAC=0	3	389	2,297	1.09×10^6	$.48 \times 10^6$	2.26	No
8	All	7	362	6,693	4.11×10^6	$.38 \times 10^6$	10.80	
	BAC=0	3	347	2,297	3.63×10^6	$.34 \times 10^6$	10.53	
9	All	8	305	7,792	4.81×10^6	$.15 \times 10^6$	31.08	
	BAC=0	4	289	3,396	$.46 \times 10^6$	$.13 \times 10^6$	3.61	No

Table No. 4

Task: Rare Event Choice Reaction Time - Frequent Event

Analysis of Variance

Subject No.	Condition	Sessions	Mean	df	SS_b	SS_w	F	Signif
1	All	7	265	6,1293	2.44×10^6	4.47×10^5	5.44	
	BAC=0	4	261	3,796	$.85 \times 10^6$	4.94×10^5	1.72	No
2	All	8	299	7,1592	1.63×10^6	6.11×10^5	2.67	No
	BAC=0	4	301	3,796	2.44×10^6	4.55×10^5	5.36	No
3	All	4	274	3,696	5.09×10^6	5.08×10^5	10.01	
	BAC=0	2	264	1,398	2.12×10^6	6.57×10^5	3.22	No
4	All	8	288	7,1592	1.35×10^6	3.83×10^5	3.51	
	BAC=0	4	287	3,796	1.98×10^6	4.50×10^5	4.39	No
5	All	8	312	7,1592	4.08×10^6	1.94×10^5	21.05	
	BAC=0	4	304	3,796	$.88 \times 10^6$	1.67×10^5	5.28	No

Table No. 5

Task; Rare Event Choice Reaction Time - Rare Event

Analysis of Variance

Subject No.	Condition	Sessions	Mean	df	SS_b	SS_w	F	Signif
1	All	7	339	6,1193	27.80×10^6	5.47×10^5	50,79	
	BAC=0	4	322	3,796	3.50×10^6	4.57×10^5	7.64	
2	All	8	381	7,1592	30.08×10^6	8.14×10^5	36.94	
	BAC=0	4	359	3,796	9.59×10^6	5.32×10^5	18.03	
3	All	4	385	3,696	92.72×10^6	1.60×10^5	58.06	
	BAC=0	2	353	1,398	219.39×10^6	1.01×10^5	205.43	
4	All	8	385	7,1592	29.56×10^6	1.41×10^5	20.76	
	BAC=0	4	364	3,796	22.76×10^6	1.16×10^5	19.65	
5	All	8	380	7,1592	26.59×10^6	5.08×10^5	52.35	
	BAC=0	4	360	3,796	5.79×10^6	5.78×10^5	10.01	

Table No. 6

Task: Delayed Response Choice Reaction Time

Analysis of Variance

Subject No.	Condition	Sessions	Mean	df	SS_b	SS_w	F	Signif
1	All	6	470	5,3294	7.66×10^8	9.48×10^5	808	
	BAC=0	4	450	3,2396	3.80×10^8	7.18×10^5	530	
2	All	7	582	6,4193	4.43×10^8	1.99×10^5	2225	
	BAC=0	3	570	2,1797	10.43×10^8	1.58×10^5	6610	
3	All	3	589	2,1697	4.72×10^8	7.07×10^5	667	
	BAC=0	2	575	1,1098	7.14×10^8	9.04×10^5	790	
4	All	8	558	7,4792	3.59×10^8	6.36×10^5	565	
	BAC=0	4	534	3,2396	1.90×10^8	5.51×10^5	344	
5	All	8	602	7,4792	22.77×10^8	7.32×10^5	3113	
	BAC=0	4	553	3,2396	31.21×10^8	1.90×10^5	16450	
6	All	7	708	6,3793	12.00×10^8	16.00×10^5	751	
	BAC=0	3	699	2,1797	16.00×10^8	20.40×10^5	784	
7	All	6	620.8	5,3274	10.20×10^8	10.30×10^5	993	
	BAC=0	4	621.2	3,2396	16.10×10^8	9.80×10^5	1645	
8	All	7	883	6,3893	12.60×10^8	22.80×10^5	5.25	
	BAC=0	3	899	2,1797	13.50×10^8	29.9×10^5	452	
9	All	7	531	6,4193	6.16×10^8	6.98×10^5	882	
	BAC=0	3	499	2,1797	9.72×10^8	3.95×10^5	2461	

Table No. 7

Task: Peripheral Vision Choice Reaction Time

Analysis of Variance

Subject No.	Condition	Sessions	Mean	df	SS_b	SS_w	F	Signif
1	All	13	378	12,6087	135145	2256	59.9	
	BAC=0	10	373	9,4740	42906	2198	19.5	
2	All	15	393	14,6985	264245	2583	102.3	
	BAC=0	10	384	9,4740	93295	2519	37.0	
3	All	12	367	11,5738	235045	2195	107.1	
	BAC=0	8	357	7,3092	46679	2684	17.4	
4	All	15	346	14,6985	76232	2174	35.1	
	BAC=0	10	340	9,4490	76569	2299	33.3	
5	All	15	391	14,7460	333262	2006	166.2	
	BAC=0	10	377	9,4990	67422	1998	33.8	
10	All	6	369	5,2344	250994	1044	240.5	
	BAC=0	3	356	2,1222	178653	988	180.9	
11	All	5	278	4,2495	870650	1188	732.6	
	BAC=0	2	298	1,998	196000	1266	154.8	
12	All	5	319	4,2195	108744	1153	94.3	
	BAC=0	3	337	2,1197	32320	1060	30.5	

Table No. 8

Task; Visual Discrimination Choice Reaction Time

Analysis of Variance

Subject No.	Condition	Sessions	Mean	df	SS_b	SS_w	F	Signif
6	All	8	714	7,803	99.66×10^6	2.79×10^6	33.93	
	BAC=0	4	710	3,412	827.71×10^6	2.39×10^6	353.74	
7	All	6	655	5,818	35.36×10^6	3.05×10^6	11.59	
	BAC=0	4	653	3,548	38.76×10^6	3.80×10^6	10.20	
8	All	7	568	6,954	9.06×10^6	2.00×10^6	4.53	
	BAC=0	3	557	2,405	13.68×10^6	1.84×10^6	7.42	
9	All	8	476	7,1054	62.41×10^6	4.51×10^6	13.84	
	BAC=0	4	411	3,541	223.44×10^6	5.56×10^6	40.20	

Table No. 9

Task; Simple Tracking
Analysis of Variance

Subject No.	Condition	Sessions	Mean	df	SS_b	SS_w	F	Signif
6	All	8	79.21	3,36	26665	831	32.09	
	BAC=0	4	66,46	7,72	1718	575	2.98	No
7	All	5	86.43	4,45	5621	2090	2.68	No
	BAC=0	3	81.32	2,27	1432	950	1.50	No
8	All	7	70.73	6,63	6814	1063	6.47	
	BAC=0	3	63.29	2,27	1319	495	2.66	No
9	All	8	40.73	7,72	4971	180	27.57	
	BAC=0	4	35.21	3,36	601	105	5.74	No
10	All	5	53.1	4,75	5510	586	7.52	
	BAC=0	3	50.2	2,47	383	330	1.16	No
11	All	6	61.8	5,84	9254	1065	8.68	
	BAC=0	3	60.8	2,37	11159	1026	10.87	
12	All	5	61.0	4,69	59385	1396	43.37	
	BAC=0	3	51.8	2,47	1274	811	1.57	No

Table No. 10

Task; Critical Tracking

Analysis of Variance

Subject No.	Condition	Sessions	Mean	df	SS_b	SS_w	F	Signif
6	All	8	58.2	7,152	20160	496	40.63	
	BAC=0	4	53.8	3,76	14315	462	30.95	
7	All	5	49.1	4,95	1271	612	2.07	No
	BAC=0	3	48.8	2,27	1795	1273	1.41	No
8	All	7	50.6	6,137	1649	324	5.08	
	BAC=0	3	50.7	2,57	3378	295	11.44	
9	All	8	68.0	7,152	7561	835	9.05	
	BAC=0	4	71.0	3,76	1327	398	3.33	No
10	All	5	55.4	4,155	31040	1935	16.04	
	BAC=0	3	59.0	2,97	8465	2531	3.34	No
11	All	6	33.76	5,194	2907	370	7.85	
	BAC=0	3	33.78	2,77	2836	266	10.66	
12	All	5	52.78	4,175	12575	1748	7.19	
	BAC=0	3	55.0	2,97	1921	1169	1.64	No

Table No. 11

Task; Accelerative Tracking

Analysis of Variance

Subject No.	Condition	Sessions	Mean	df	SS_b	SS_w	F	Signif
1	All	4	20.3	3,66	5579	386	14.45	
	BAC=0	3	18.6	2,57	1159	349	3.32	No
2	All	6	33.9	5,114	7849	2397	3.27	No
	BAC=0	4	31.4	3,66	3485	1534	2.27	No
3	All	3	46.9	2,47	87509	1871	46.77	
	BAC=0	2	39.0	1,38	25992	1699	15.29	
4	All	5	20.9	4,95	3930	263	14.94	
	BAC=0	3	18.7	2,57	372	225	1.65	No
5	All	5	24.2	4,95	29889	665	44.94	
	BAC=0	3	18.6	2,57	737	240	3.07	No

Table No. 12

Task; Divided Attention - Tracking Portion

Analysis of Variance

Subject No.	Condition	Sessions	Mean	df	SS_b	SS_w	F	Signif
6	All	8	89.9	7,72	58480	1128	51.83	
	BAC=0	4	70.7	3,63	2967	363	8.16	
7	All	5	89.4	4,45	1193	787	1.51	
	BAC=0	3	87.3	2,27	582	679	.85	No
8	All	6	92.2	5,54	15610	1107	14.10	
	BAC=0	3	93.5	2,27	30762	1247	24.67	
9	All	8	43.9	7,72	9648	212	45.42	
	BAC=0	4	36.4	3,36	329	114	2.88	No

Table No. 13

Task: Divided Attention - Reaction Time Portion

Analysis of Variance

Subject No.	Condition	Sessions	Mean	df	SS_b	SS_W	F	Signif
6	All	6	649	5,54	698640	9134	76.48	
	BAC=0	3	590	2,27	19921	9700	2.05	No
7	All	5	715	4,44	1399×10^3	66×10^3	21.30	
	BAC=0	3	758	2,27	2200×10^3	83×10^3	2.64	No
8	All	5	601	4,45	99167	11402	8.69	
	BAC=0	3	607	2,27	185033	12979	14.25	
9	All	6	531	5,51	155680	13591	11.45	
	BAC=0	4	510	3,36	45415	13844	3.28	No

Table No. 14

Task; Persuit Rotor

Analysis of Variance

Subject No.	Condition	Sessions	Mean	df	SS_b	SS_w	F	Signif
6	All	8	834	7,152	7.15×10^8	5.66×10^6	126.28	
	BAC=0	4	1654	3,76	4.33×10^8	1.36×10^6	318.38	
7	All	6	-72	5,114	4.11×10^8	16.22×10^6	25.36	
	BAC=0	4	554	3,76	$.44 \times 10^8$	9.32×10^6	4.76	No
8	All	7	336	6,133	$.59 \times 10^8$	8.06×10^6	7.35	
	BAC=0	3	338	2,57	$.34 \times 10^8$	6.14×10^6	5.48	No
9	All	8	1212	7,152	1.06×10^8	4.29×10^6	24.81	
	BAC=0	4	1626	3,76	$.07 \times 10^8$	2.23×10^6	3.00	No
10	All	6	-276	5,84	1.36×10^8	27.75×10^6	4.93	
	BAC=0	3	159	2,47	$.05 \times 10^8$	8.21×10^6	.63	No
11	All	7	1099	6,143	$.81 \times 10^8$	28.93×10^6	2.79	No
	BAC=0	4	1002	3,76	$.95 \times 10^8$	27.76×10^6	3.42	No
12	All	5	599	4,85	$.99 \times 10^8$	10.00×10^6	9.87	
	BAC=0	3	969	2,47	$.05 \times 10^8$	3.38×10^6	1.53	No

Table No. 15

Task; Phystester
Analysis of Variance

Subject No.	Condition	Sessions	Mean	df	SS_b	SS_w	F	Signif
1	All	7	3402	6,322	$.96 \times 10^8$	2.16×10^7	4.45	
	BAC=0	4	3327	3,211	1.12×10^8	2.15×10^7	5.99	No
2	All	8	3430	7,493	1.70×10^8	1.94×10^7	8.73	
	BAC=0	4	3416	3,249	2.14×10^8	1.64×10^7	13.00	
3	All	5	3524	4,250	1.04×10^8	3.24×10^7	3.20	No
	BAC=0	2	3360	1,118	$.94 \times 10^8$	3.04×10^7	3.18	No
4	All	8	3475	7,452	2.35×10^8	34.60×10^7	.68	No
	BAC=0	4	3553	3,225	3.04×10^8	3.38×10^7	9.00	
5	All	8	3301	7,475	$.97 \times 10^8$	$.80 \times 10^7$	12.10	
	BAC=0	4	3242	3,259	1.09×10^8	$.96 \times 10^7$	11.41	

Table No. 16

Task: Digit Symbol

Analysis of Variance

Subject No.	Condition	Sessions	Mean	df	SS_b	SS_W	F	Signif
6	All	8	4915	7,423	30.74×10^7	7.19×10^7	4.27	
	BAC=0	4	4767	3,234	14.38×10^7	6.09×10^7	2.35	No
7	All	6	4175	5,335	12.33×10^7	7.63×10^7	1.61	
	BAC=0	4	4097	3,245	6.08×10^7	7.21×10^7	.84	No
8	All	7	7039	6,367	41.13×10^7	15.22×10^7	2.70	No
	BAC=0	3	7144	2,182	43.70×10^7	18.76×10^7	2.32	No
9	All	8	4900	7,423	9.91×10^7	9.08×10^7	1.09	No
	BAC=0	4	4853	3,234	13.60×10^7	12.96×10^7	1.04	No
13	All	5	6577	4,282	18.22×10^7	7.28×10^7	2.50	
	BAC=0	2	6759	1,126	6.64×10^7	8.45×10^7	.78	No
14	All	5	7188	4,296	27.9×10^7	13.9×10^7	2.01	No
	BAC=0	2	6921	1,112	19.9×10^7	11.1×10^7	1.80	No
15	All	5	6866	4,285	22.0×10^7	13.2×10^7	1.66	No
	BAC=0	2	6729		11.6×10^7	15.5×10^7	.75	No

Table No. 17

Task: Slalom

Analysis of Variance

Subject No.	Condition	Sessions	Mean	df	SS_b	SS_w	F	Signif
1	All	7	5.00	6,48	260	66	3.95	No
	BAC=0	4	4.07	3,28	251	43	5.85	No
2	All	8	3.44	7,55	154	43	3.59	No
	BAC=0	4	2.25	3,28	16	12	1.40	No
3	All	5	3.08	4,35	121	54	2.26	No
	BAC=0	2	2.15	1,14	8	30	.26	No
4	All	8	2.67	7,56	117	60	1.95	No
	BAC=0	4	2.12	3,28	89	35	2.52	No
5	All	8	3.88	7,56	119	10	12.19	
	BAC=0	4	2.92	3,28	80	13	5.90	No
6	All	7	2.11	6,28	67	16	4.33	No
	BAC=0	3	1.06	2,12	4	7	.61	No
7	All	5	2.80	4,25	21	9	2.21	No
	BAC=0	2	2.00	1,8	18	3	5.62	No
8	All	6	4.66	5,29	77	59	1.29	No
	BAC=0	2	4.30	1,8	144	71	2.04	No
9	All	7	3.97	6,28	119	66	1.80	No
	BAC=0	3	3.86	2,12	10	20	.50	No

Table No. 18

Task: Backwards Slalom

Analysis of Variance

Subject No.	Condition	Sessions	Mean	df	SS_b	SS_w	F	Signif
1	All	7	15.54	6,49	1985	399	4.96	
	BAC=0	4	13.60	3,28	2819	507	5.55	No
2	All	8	8.28	7,55	637	126	52.64	
	BAC=0	4	9.62	3,28	6737	169	39.87	
3	All	5	9.38	4,35	155	96	1.61	No
	BAC=0	2	8.50	1,14	46	99	.46	No
4	All	8	13.91	7,56	562	257	2.18	No
	BAC=0	4	14.27	3,28	491	353	1.39	No
5	All	8	12.27	7,56	257	169	1.52	No
	BAC=0	4	10.85	3,28	142	169	.83	No
6	All	7	15.71	6,28	121	138	.87	No
	BAC=0	3	14.66	2,12	36	83	.43	No
7	All	5	17.68	5,24	93	85	1.08	No
	BAC=0	2	17.50	1,8	24	75	.32	No
8	All	6	16.56	5,24	260	39	6.62	
	BAC=0	2	13.80	1,8	18	65	.27	No
9	All	7	14.34	6,28	423	155	2.71	No
	BAC=0	3	10.26	2,12	104	112	.92	No

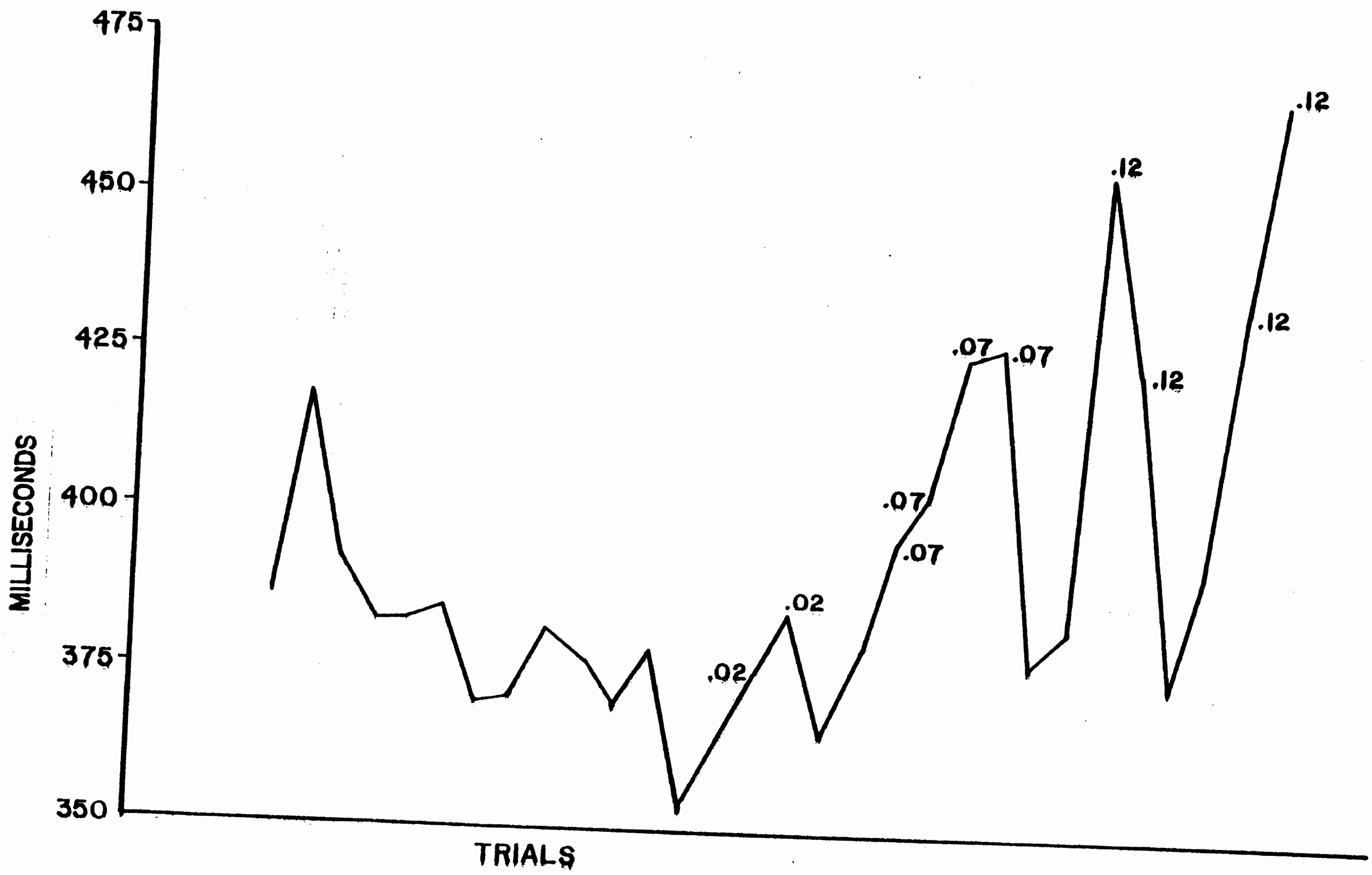


Figure 4. Peripheral Vision Choice Reaction Time Task

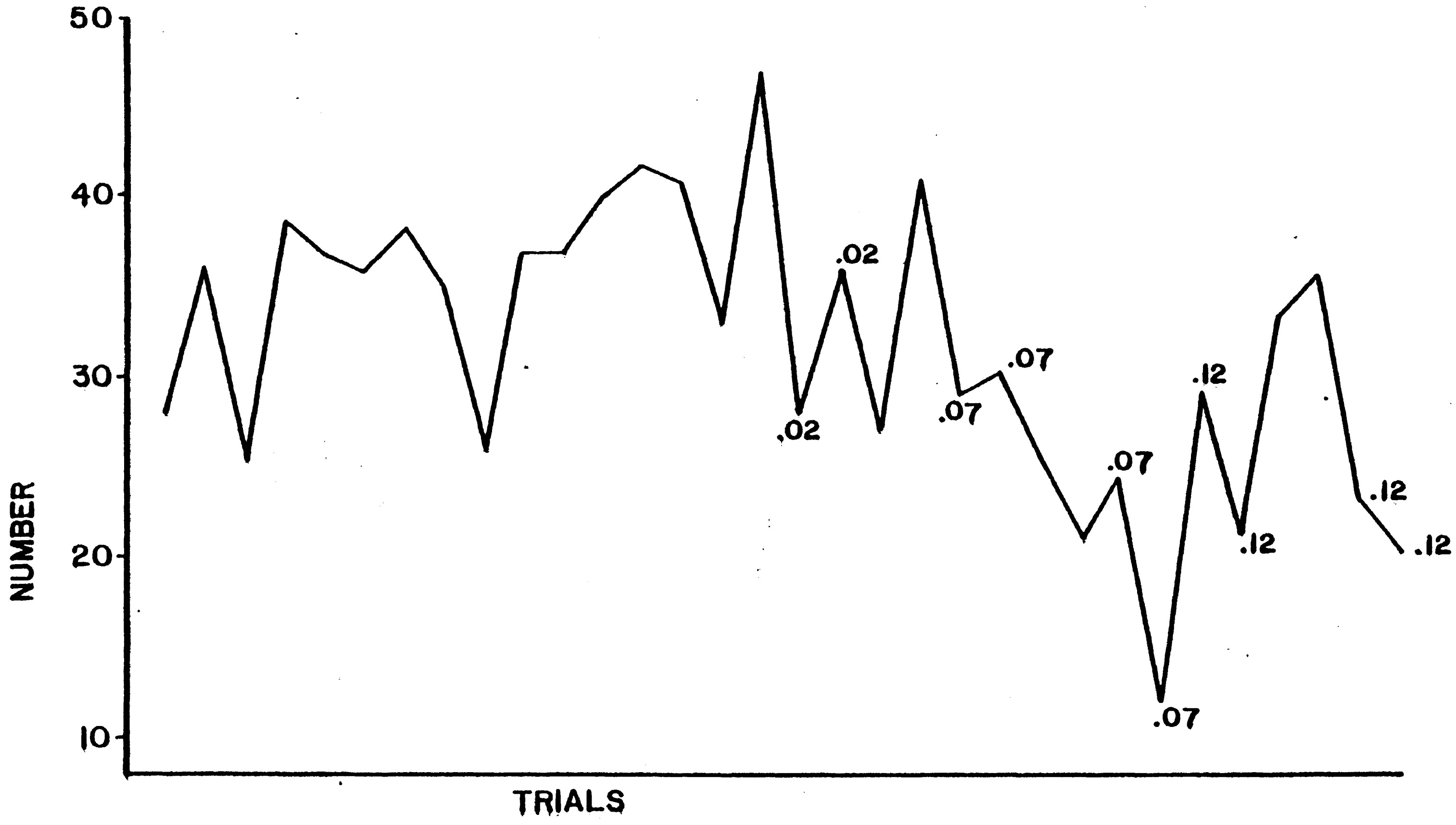


Figure 5. Fitts Task

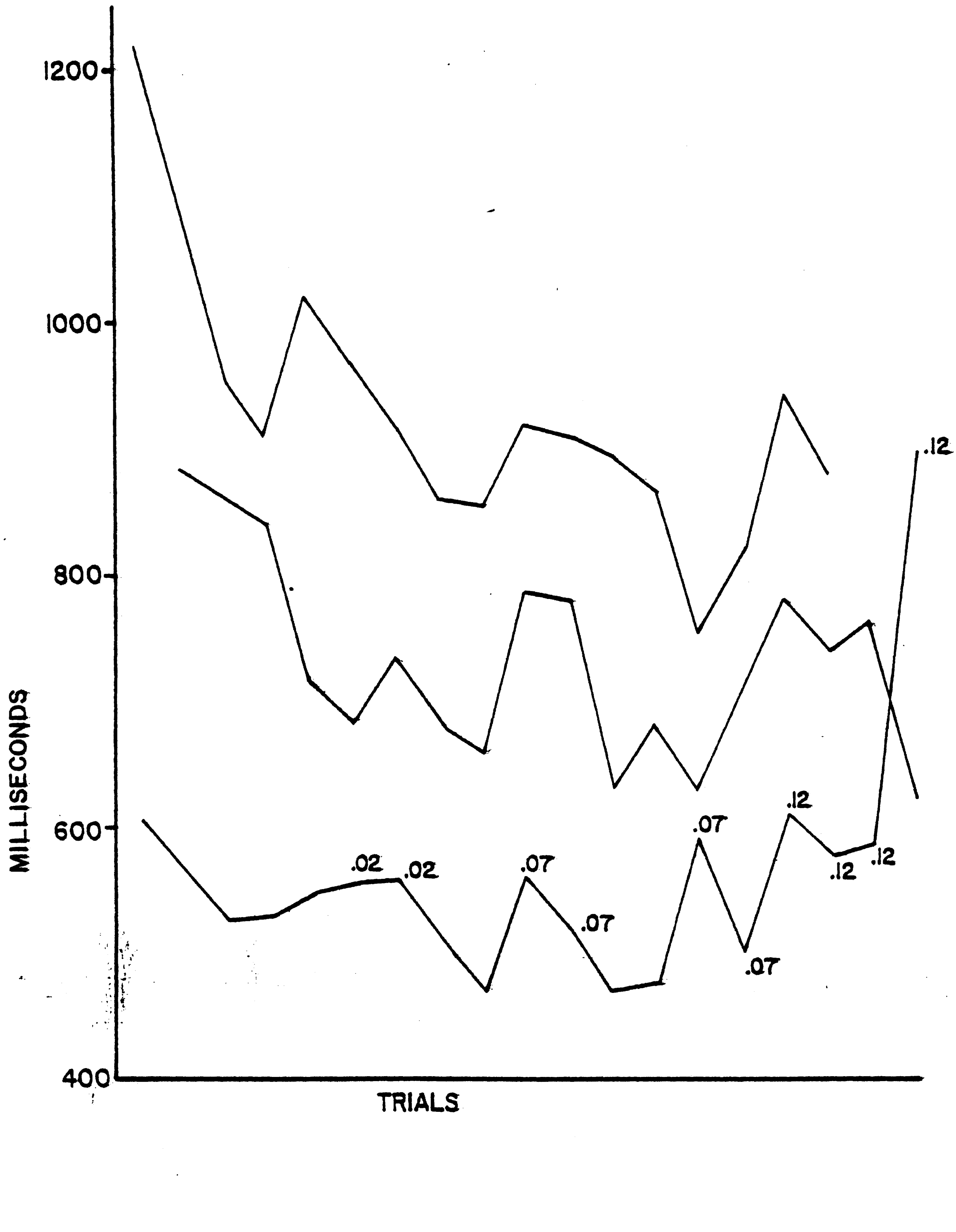


Figure 6. Delayed Choice Reaction Time

example, that only three of the nine subjects behave ideally in their performance on the simple-reaction-time task.

The reason for analyzing these data in this way is that each subject is considered to be a population within which samples of responses are taken over a period of time and for a large number of tasks.

To get an indication of individual subject performance, three characteristic subject performance curves are presented. Figure 4 shows one subject's performance on the peripheral vision choice reaction time task. The numbers on the performance curve indicate the subject's BAC level and where no numbers appear BAC was equal to zero. Since this is a reaction time task, low on the curve is good performance. Had we selected a threshold of about 390 milliseconds for this subject on the task, he would have passed the test whenever his BAC was below .07 g/100 ml, but would never have passed it when his BAC was .07 or higher. The task, then, is perfectly discriminating at the .07 BAC level for this particular subject.

Figure 5 describes an individual's performance on the Fitts task, and we see that the behavior is substantially less consistent than in the first case. Had the threshold been set so that a passing score was greater than 27, this subject would have passed two out of four times with a BAC of .07 and one out of four times with a BAC of 12 g/100 ml. What is of equal concern to our objective of finding a task which discriminates between the individual's drunk and sober states is that he failed this test twice with a BAC of zero.

Figure 6 is included to show the greater variability among subjects, three of whom are shown on the same scale. The task is not a particularly good one at discriminating, as evidenced by the fact that the middle subject turned in his best performance with a BAC of .12 g/100 ml. What we want to emphasize here is the necessity, even if a perfectly discriminating task were found, to establish thresholds for adequate performance, taking into account each individual's own baseline of performance. Here, for example, there is a factor of two between the fastest and the slowest responding subjects.

To arrive at some measure of goodness for each of the tasks we have studied so that they may be compared, we have established three progressively more stringent criteria. They are as follows:

1) Performance must be in the proper direction. Proper means that the impairment must be evidenced in a deterioration of performance as the BAC level increases.

2) The BAC = 0 condition must show non-significance. That is to say that the training procedure must have yielded asymptotic performance in the subjects so that no significant variability in behavior remains at the end of the period.

3) Both 1) and 2) above must hold and the "All" condition must be significant at the .001 level. In addition to being adequately trained and having impairment degrade performance, we must in this case be able to discriminate statistically between sober and drunk performance.

Table 19 shows a summary of this analysis by task, reporting the numbers and percentages of the subjects meeting the three criteria. The ranking for each of the three criteria was done using the percentage scores. To get a single figure of merit for each of the tasks, the percentage scores were combined to form a single score and the tests were then ranked on this score. Two different arbitrary weightings were applied in the combining of the scores as shown in the last two pairs of columns of the table. The best four tasks are the same under both schemes, and they are Rare Event Choice Reaction Time (measurement of the frequent event), Simple Tracking, Accelerative Tracking, and Persuit Rotor.

It is to be noted that in only four of the 17 tasks did over 50% of the subjects meet the highest criterion.

Table 19

SUMMARY OF ANOVA ANALYSIS FOR INDIVIDUAL SUBJECTS

Task	No. of Ss	No. of Ss Meeting Criterion Number			% of Ss Meeting for Criterion			Rank Order on Criterion			Combined Scores (Weighted 2,1,4)		Combined Scores (Weighted 4,1,2)	
		1	2	3	1	2	3	1	2	3	Score	Rank	Score	Rank
SRT	9	8	3	2	89	33	22	7	13	10.5	51.6	12	69.1	11
CRT	9	9	5	4	100	56	44	3.5	10	8	74.5	6	86.8	5
RE(F)	5	4	5	4	80	100	80	11.5	2	1	100.0	1	92.5	3
RE(R)	5	5	0	0	100	0	0	3.5	15.5	15.5	34.5	14.5	63.8	13
DR	9	7	0	0	78	0	0	13.5	15.5	15.5	26.9	17	48.8	17
PV	8	7	0	0	87	0	0	8	15.5	15.5	30.0	16	55.5	16
VD	4	4	0	0	100	0	0	3.5	15.5	15.5	34.5	14.5	63.8	13
ST	7	7	6	5	100	85	71	3.5	5.5	2.5	98.1	2	100.0	1
CT	12	10	8	6	83	67	50	10	9	6	74.7	5	79.6	7
AT	5	5	4	3	100	80	60	3.5	7	4	89.7	4	95.7	2
DA(T)	4	3	2	2	75	50	50	15	11	6	69.0	8	71.8	9
DA(RT)	4	2	3	2	50	75	50	17	8	6	64.7	9	59.8	15
PR	7	6	6	5	85	85	71	9	5.5	2.5	92.9	3	90.4	4
PH	5	4	2	1	80	40	20	11.5	12	12	48.3	13	63.8	13
DS	7	5	7	3	71	100	42	16	2	9	70.7	7	74.6	8
S	9	9	9	1	100	1CC	11	3.5	2	13	59.3	10	83.2	6
Z	9	7	8	2	78	89	22	13.5	4	10.5	57.4	11	71.0	10

V. COMBINED SUBJECT ANALYSIS

To combine the scores of all subjects, the mean of each subject's score for each task was calculated for the last ten experimental sessions. Deviations from this mean were then computed for each of the three BAC levels and for the sober control sessions which occurred after the first drinking session. The resulting z-scores are presented in Table 20 for each separate group of subjects run.

Ideally the z scores for a perfectly discriminating task would progress downward monotonically from slightly positive for the zero BAC condition to highly negative for the .12 g/100 ml BAC sessions. In two cases, one group in the Delayed Response Choice Reaction Time and one in the Tracking portion of the Divided Attention Task, the difference between the extremes is greater than five standard deviations. Dispite the apparent discriminating power of these tasks, we note that they were both quite low ranking in the previous individual analysis. Some of the tasks, such as the Digit Symbol Task, showed almost no differences in performance across the BAC levels studied, and in one of the Intersection groups, the .12 g/100 ml BAC condition exhibited the best performance.

Another way to get some insight into the combined subject data and attempt to perceive the underlying mechanisms of the process by which impairment may be revealed by these tasks would be to isolate elements common to the tasks. We could then see how they differ between performance in the sober and drunk states. Only eight of the tasks were performed by all of the subjects, and the intercorrelations of these were subjected to a factor analysis. The reduction in the number of tasks studied is unfortunate from the standpoint of data loss, but this limitation more nearly meets the requirement of the factor analytic

Table 20

SUMMARY OF GROUP = Z-SCORES BY TASK

		BAC			
Task	N	0	.02	.07	.12
1 SRT	5	.02	-.23	-.43	-1.09
2 SRT	4	.15	.06	-.42	-.39
1 CRT	5	.04	-.24	-.14	-.42
2 CRT	4	.06	-.26	-.33	-.71
(F) RE	5	-.01	.01	-.11	-.30
(R) RE	5	.05	-.27	-.61	-1.01
1 DR	5	1.11	-2.30	-1.68	-4.20
2 DR	4	.81	-.68	-.22	-.92
1 PV	5	.06	-.15	-.44	-1.19
2 PV	3	-.06	-.31	-.70	-----
VD	4	.06	.00	-.03	-.20
1 ST	4	-.10	-----	-1.79	-3.37
2 ST	3	.21	-.93	-1.43	-2.36
1 CT	5	.07	-.15	-.60	-1.01
2 CT	4	.23	-.46	-.52	-1.26
3 CT	3	.01	-.18	-.62	-.98
AT	5	.16	-.28	-1.56	-3.06
(T) DA	4	.20	-----	-1.97	-4.92
(RT) DA	4	.27	-----	.29	-2.10
1 PR	4	.04	-.36	-1.60	-2.44
2 PR	3	.01	-.73	-.71	-1.21
FT	4	-.01	-.13	-2.08	-1.58
PH	5	.04	-.16	.00	-.44
1 DS	4	-.04	-.08	-.05	-.23
2 DS	3	.00	-----	-.01	-.09
1 S	5	-.08	-.58	-1.10	-1.32
2 S	4	-.38	-.74	-.41	-1.01
1 Z	5	.08	.11	-.05	-.19
2 Z	4	-.16	-.16	-.54	-.93
1 I	4	.31	-.48	-----	.71
2I	3	.33	-----	.92	-.56

procedure that the number of variables be about one-third the number of subjects.

Two factor analyses were done, one on the sober-only data and another on the drunk data, using the results from the .07 and the .12 g/100 ml BAC conditions. Table 21 shows the high factor loadings for the four factors emerging in each case. By looking at the tasks associated with the various loadings, the factors have been named as follows:

1) Basic psychomotor skill
2) Performance on new and difficult tasks
3) Speed/error tradeoff preference
4) Perceptual ability

The first thing we note in the comparison between the drunk and sober conditions is that there is no change in the factor loadings for factors 1 and 4. Any decrement in performance due to alcohol is, therefore, not attributable to a lowering of basic psychomotor skill or interference with perceptual ability. These two factors account for about 70% of the variance in the correlation matrix.

It is, then, the second and third-order effects which explain the difference between performance in the drunk and sober states of the subjects. The evidence we have here points to the subjects being less able to perform unfamiliar and difficult tasks while in the elevated BAC conditions and shifting in their preference from performing quickly to performing accurately. These two factors account for about 30% of the variance in performance as determined by the intercorrelations among the eight tasks used in the analysis.

FACTOR ANALYSIS

	Task	Factor I	II	III	IV
	ST	.96			
	CT	.96			
	AT		.72		
SOBER	DA	.95			
	SRT			.95	
	CRT	.62		.77	
	VD				.97
	DS		.90		
	ST	.92			
	CR	.97			
	AT		.99		
	DA	.96			
DRUNK	SRT		-.85		
	CRT	.92			
	VD				.99
	DS			1.03	

VI. CONCLUSIONS

The seventeen tasks used in this study represented a wide variety of performance variables, incorporating aspects of perceptual ability, psychomotor skill, and risk-taking behavior. Task difficulty was manipulated by adjustments in the payoffs received by the subjects, resulting in highly motivated and skilled performance at the end of the training period.

Neither the analysis of individual subject performance or of the group performance for separate tasks showed any substantial ability of the task as a predictor of degraded performance due to alcohol impairment. In less than half of the tasks did 50% of the subjects reach the most stringent criterion, and 50% was the highest number. Using combined measures, in only five of 31 groups of subjects is the performance monotonically decreasing through increasing BAC levels and is the highest BAC more than two standard deviations worse than the zero BAC condition.

The most plausible explanation for the lack of positive findings is seen from the results of the factor analysis of a portion of the data. The most important factor, that of pure psychomotor skill, does not change its loadings from the sober to the drunk conditions. It is only in the second- and third-order factors, those labelled new/difficult tasks and speed/accuracy tradeoff, that a difference between the sober and drunk states of the individual becomes apparent. These two factors account for too small a proportion of the total variance in the correlation matrix to show up in any reliable fashion in the subject's performance.

Any future search for tasks which attempt to discriminate between a drunk subject and his sober self should concentrate on tasks which are difficult and unfamiliar in the course of normal everyday behavior. The task should also be one in which the subject, when sober, naturally prefers speedy rather than accurate performance. We are pessimistic about discovering such a task which will predict performance impairment due to alcohol intoxication over a wide range of the population.