ALCOHOL, TASK DIFFICULTY, AND INCENTIVES IN DRILL PRESS
OPERATION

by

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INTRODUCTION

Though the estimations vary, the dollars lost from absenteeism due to alcohol are probably in the billions annually. One estimation was 19.64 billion (U.S. Department of Health, Education, and Welfare, 1978). Despite its apparent importance, there is little research on the effects of alcohol on specific industrial tasks performed in a laboratory setting.

Price and Hicks (1979) found a 19% increase in assembly time for subjects at 0.09% BAC during a manual assembly task. In an arc welding task, Price and Liddle (1982) found significantly more variability in electrode to workpiece gap (measured by changes in current) at the 0.09% BAC compared to a placebo for an arc welding task.

This study was the third in a series of ongoing alcohol research at Virginia Polytechnic Institute and State University studying the effects of low levels of alcohol (less than 0.1% BAC) on quality and productivity of specific industrial tasks. This study examined the effects of various low levels of alcohol, task difficulty, and incentives on a drill press simulation task. A version of

Fitts' Law was used to define an appropriate experimental task whose difficulty could be systematically varied.

Fitts (1954) developed an equation which relates amplitude of movement, target width, and movement time of a manual task. The type of task described by Fitts involved moving an object such as a probe or a disk a designated distance (amplitude) to a certain size target which could be a hole or peg, and then back to the starting point (which could be a hole or peg of the same size). The equation $MT = a + (b)\log_2(2A/W)$ states that the movement time for a response (MT) is a linear function of the index of difficulty. This equation is often referred to as Fitts' Law. The index of difficulty is $\log_2(2A/W)$ and is the ratio of the amplitude or distance moved (A) to the tolerance or target width (W) in bits of information. The (a) and (b) are constants. The (a) is the y-intercept and corresponds to an index of difficulty of zero. When the index of difficulty is plotted against the MT, the slope (b) of the line formed is the rate of gain of information, and the inverse of the slope is the information processing rate in bits per second.

Welford (1968) showed that a better fit to the data could be achieved through the following modification of Fitts' Law: $MT = a + (b)\log_2(A/W + .5)$. This equation takes into

consideration that the subject identifies the borders of the target (by adding .5 to A/W). $\log_2(A/W + .5)$ is the index of difficulty and was used in this study to set task difficulty levels.

The experimental task required the subject to place a 0.635 cm diameter blunt metal probe alternately between two holes of the same diameter in a metal plate. This task was accomplished by sliding the workpiece back and forth under the probe. Task difficulty was varied by exchanging the metal plate with other identically sized plates having different sized holes and/or different distances between holes. This task was performed under various low levels of blood alcohol concentration, and incentive conditions.

REVIEW OF LITERATURE

Alcohol

Alcohol has a depressant effect on psychological functions. It also causes a depressant effect of the central nervous system functions which regulate sensory and motor performance, motivations, and emotions (Levine, Greenbaum, and Notkin, 1973).

Levine, et al., (1973) note difficulty in applying the findings of many previous studies of alcohol research due to lack of uniformity of procedure and approach, different types of control conditions, different determinations of dosage, administration sequence, time of day, to name a few. Also, experimental results can be influenced by experimental conditions and procedures, not to mention presentation and analysis of the data (Levine, et al., 1973).

Sensorimotor Effects

Levine, et al., (1973) divide the alcohol ingestion literature into four categories: sensory effects, sensorimotor effects, motor effects, and effects on intellectual functions. Sensorimotor tasks involve

coordination of sensory input and motor output. Of these categories, a drill press task would seem to be best defined as a sensorimotor task. Review of the following alcohol research is therefore confined to research examining the effects of alcohol on sensorimotor tasks.

Reaction Time

There are no consistent effects of alcohol on reaction time at a blood alcohol level (BAL) of 0.1% or less (Heacock and Wickle, 1974; Huntley, 1974; King, 1975; Shillito, King, and Cameron, 1974; Tharp, Rundell, Lester, and Williams, 1974). Rundell and Williams, (1979), and Jennings, Wood, and Lawrence, (1976) indicate that a tradeoff function for speed versus accuracy provides a more sensitive and informative index of the impairment of choice reaction time (RT) by alcohol than either average speed or accuracy alone. This may explain why some researchers found no effects of alcohol on choice RT (they used measures of speed and accuracy alone instead of the more sensitive speed-accuracy tradeoff function). The results of the speed-accuracy tradeoff studies of Jennings, Wood, and Lawrence, (1976), and Rundell and Williams, (1979) found that alcohol had no effect on fast but inaccurate responses, while it did affect slow but accurate responses. Extending these results to task

difficulty, the more difficult the task, the slower the responses; thus alcohol should affect the processing of a difficult task more than an easy task. It was also found that alcohol level had an effect on accuracy. The higher the blood alcohol concentration (BAC), the more difficult a task will seem, and the slower it will be performed, and probably with a decrease in accuracy.

Tracking and Controlling Objects in Motion

In studies requiring adjustive-responses of the arm or entire body, very low doses of alcohol are sufficient to impair the ability to track objects in motion, and errors are progressively increased by higher doses (Drew, Colquhoun, and Long, 1958; Forney, Hughes, and Greatbatch, 1964; Mortimer, 1963).

Task Difficulty

Fitts' Law provides a convenient operational definition of task difficulty and holds for a wide variety of experimental situations (Carlton, 1980). It has been supported by many studies (Annett, Golby, and Kay, 1958; Crossman, 1960; Fitts and Peterson, 1964; Keele and Posner, 1968; Kerr, 1973; Kerr and Langolf, 1977; Knight and Dagnall, 1967; Langolf, 1973; Langolf, Chaffin, and Foulke, 1976; Welford, 1968).

Fitts' Law is highly analogous to Shannon's (1949) theorem: $C = W \log_2(P + N)/N$, which describes the capacity of a continuous information channel in the presence of noise. (W) is channel bandwidth, (P) is signal power, and (N) is the power of noise. The power of noise is equivalent to the variance of its amplitude distribution around its mean value. The "signal" in Fitts' Law would be the exact movement amplitude necessary to hit the target. The noise would be the allowable tolerance. Crossman and Goodeve (1963) showed that the velocity of movement was inversely proportional to the remaining distance away from the target, and so arrived at Fitts' Law. Langolf (1973) related acceleration and velocity of the movement to the distance away from the target. As Crossman and Goodeve (1963), Keele (1968) describes that a subject makes an initial adjustment, then makes as many fine adjustments as necessary to converge on the target. He assumes that each correction takes the same amount of time, and uses estimates of the time to process visual feedback for the time between corrections. Keele and Posner (1968) estimated the time between corrections to be 190 to 260 ms. Their model assumes that the average accuracy per correction is a constant proportion of the distance moved (between 0.04 and 0.07). With the time between corrections equal to 260 ms and the accuracy

constant equal to 0.07, Keele (1968) reports that he was able to fit the slope of the Fitts' Law relationship reported by Fitts and Peterson (1964) "quite nicely."

Langolf (1973) performed a Fitts' Law experiment in which subjects manipulated a probe-mounted peg under a 10-power microscope, simulating the performance of microscopic assembly operations. He obtained time histories of the motion profile of the probe used to move the 1.1 mm diameter peg distances of 1.27 or 0.254 cm. into holes of varying tolerances. He found the Fitts' Law prediction quite satisfactory for this performance under a microscope. Moreover, by performing ensemble averaging of the motion trajectories of several of these movements he found clear evidence for discontinuities in the path to the target and, amazingly, the times (200 ms per correction) and the movement accuracies were not inconsistent with Keele's estimates. (Kantowitz, 1974, p. 24).

Various motor control models have been hypothesized to account for Fitts' Law. Annett, et al. (1958) suggested that aiming movements have two parts. The first part is an initiation of movement. The second part, lasting longer than the first, is a prolonged deceleration during which a subject actively monitors the movement, homing in on the target.

There are two feedback models developed by Crossman and Goodeve (1963) and by Keele (1968). In these models, after an initial movement toward the target, the subject makes discrete corrective movements until making contact with the target.

Schmidt (1976), and Schmidt, Zelaznik, and Frank (1978) disagreed with the feedback models, reasoning that information gained by feedback could not be processed quickly enough to be utilized for the control of rapid responses. Schmidt, et al. (1978) argued that the speed accuracy relationship of Fitts' Law could be explained by a movement output variability model. In the model, output of the motor system contains noise in the form of within subject variability related to the amplitude and speed of the movement in a way consistent with Fitts' Law.

An approach to determining which control model accounts for Fitts' Law is the examination of movement patterns near the target. Carlton (1980) used rapid sampling techniques to measure displacement patterns. There were three response types, no corrections, discreet corrections, and responses having characteristics of both. The frequency of each type of response was altered by the index of difficulty of the task. The more difficult task caused subjects to make discreet corrections. In another part of the study, even higher indexes of difficulty caused subjects to make even more discreet corrections.

Sheridan (1979) was more specific in predicting performance of a Fitts' Law task. He indicated that the tolerance component of the index of difficulty was mostly

responsible for determining performance, and for equivalently difficult tasks, the task with a smaller tolerance would take longer to perform.

Perhaps because there is still much unknown about Fitts' Law and the human motor system, most research using Fitts' Law is directed toward studying the human motor system in general, or the motor system of special populations such as children (Hay, 1981; Sugden, 1980), or the aged (Kochhar and Ali, 1979). Except for Langolf (1973), there are no studies concerned with the effects of task difficulty on productivity using Fitts' Law.

Incentives

Wage incentive programs are designed to motivate employees to improve their productivity (by promising them higher pay for increased output) while reducing production costs (Ireson and Grant, 1971, p. 845; Lokiec, 1977, p. 115). Without careful design and administration of incentive programs, they often fail (Collins, 1981). Collins (1981) writes that another reason for the failure of an incentive program is the employee's decision that the program does not fit his personal needs or priorities. For example, the employee may perceive the probability for success of the program to be too low to even try the

program. An explanation for the employee's view that the program will probably not work is that he lacks significant control over the attainment of the incentive program's goals (Goettinger, 1981). Or after a number of years, the program may have deteriorated due to changes in the work requirements by management not reflected in the time standards, effectively giving workers less time to do the "same task" (Maynard, 1971, p. 6-22). Foster (1981), Goettinger (1981), and Hubler and O'Neill (1981) also feel that mismanagement is to blame for failures in incentive programs. In some cases, incentive plans exist only to pay competitive levels of compensation rather than rewarding superior performance (Goettinger, 1981).

Another contributing factor to failure of incentive programs is that unions view them negatively. A purpose of unions is to secure high guaranteed wages for all workers. Incentive programs weaken that function (Ireson and Grant, 1971, p. 846). Unions consider incentive programs as threatening worker unity because in an incentive program each worker tries to earn more than the other (Lokiec, 1977, p. 116).

Employees often resist implementation of incentive programs. They believe that management will raise the productivity standards. They feel that increased

productivity will result in layoffs (because a company can sell only so much of a product). Older workers usually work slower than younger workers, and so they feel that incentive programs would make them look bad (Collins, 1981).

Many of the problems related to union and employee acceptance, along with other causes of incentive program failure, could be remedied by designing and administering the program with certain criteria in mind. Superior performance should be rewarded (Collins, 1981; Goettinger, 1981). The measurement of employee performance and the incentive plan in general should be fair, objective, and easily understood by the employee (Collins, 1981; Foster, 1981; Goettinger, 1981; Hubler and O'Neill, 1981; Maynard, 1971). The incentive plan (which includes productivity standards) should be updated each time corporate objectives change, or the manufacturing operation itself changes (Goettinger, 1981).

Monetary incentives are used in the present study to emphasize and ensure that the subject will maintain the directed incentive condition, productivity or accuracy. This is a much simpler application of incentives compared to their normal use in industry.

Though most findings of the literature on the effects of alcohol, task difficulty, and incentives on productivity are

difficult to apply to the current research, there are three results in the literature which form the basis of the hypotheses of this study.

1) Alcohol has a depressant effect on psychomotor functioning (Levine, et al., 1973).

2) Low levels of alcohol affect the tracking of objects in motion (Drew, Colquhoun, and Long, 1958; Forney, Hughes, and Greatbatch, 1964; Mortimer, 1963).

3) Alcohol has a greater effect on slow, accurate responses, than on fast, inaccurate responses (Jennings, Wood, and Lawrence, 1976; Rundell and Williams, 1979).

Hypotheses

1) As blood alcohol concentration increases, productivity of acceptable units (hits) will decrease.

2) As blood alcohol concentration increases, accuracy of performance will decrease (misses will increase).

3) As task difficulty increases, performance will be more adversely affected by increased levels of alcohol.

4) As blood alcohol concentration increases, there will be a greater adverse effect on hits and misses in the accuracy incentive condition than in the productivity incentive condition.

The following experiment was designed to test these hypotheses in a laboratory setting.

METHOD

Subjects

The subjects were eight paid, volunteer, male university students 21 to 29 years of age with an average age of 23. The subject questionnaire on personal drinking habits indicated that as a group, the subjects ingested an average of 7.5 ounces of alcohol per week, with a standard deviation of 1.069 ounces. The target subject group was a homogeneous group of moderate drinkers. The low standard deviation indicates that they were homogeneous in their drinking habits, and that the average reported amount of alcohol which the subjects ingested each week (about one ounce per day) was moderate.

Experimental Design

Because individual tolerance to alcohol is quite variable, it was decided that each subject should act as his own control. To further decrease between subject variability, each subject received each level of the three independent variables, blood alcohol concentration, task difficulty, and incentive. All combinations of the

independent variables were presented to each subject to obtain maximum information. To prevent order effects, the order of presentation of the independent variables were counterbalanced using balanced latin squares. Therefore, a factorial, within subjects, three-way analysis of variance design was used.

Presentation of Independent Variables

Two, four-by-four balanced latin squares were used to counterbalance the order of presentation of the four levels of alcohol. Four eight by eight latin squares were used to counterbalance the order of presentation of the eight levels of task difficulty. The two levels of incentive were randomized by using a random number table. Each level of incentive appeared first exactly half of the time. Table 1 shows the order of presentation of each level of the independent variables. To more easily understand the order of presentation of the independent variables, the following explanation of the table is presented.

There are three sections to the table. The top section displays the order of presentation of each level of task difficulty and incentive for each subject, for each of their four experimental sessions (day one through day four). The bottom left section shows the order of presentation of

alcohol dosage for each subject for each experimental session. The bottom right section defines task difficulty levels one through eight in their corresponding bits of information, and defines the bits of information by their corresponding amplitude (center-to-center distance between holes), and hole tolerance. For a specific example of how to read the table, the order of presentation of the independent variables for subject number one on day one follows.

The presentation of alcohol (in the lower left section of the table) shows that subject number one received alcohol level A on day one. Alcohol level A corresponds to the placebo level, or 0.00% BAC. The uppermost and leftmost subsection of the top section of the table shows that subject one received task difficulty level seven first. It also shows that task difficulty level seven was performed under the productivity incentive condition first, and performed under the accuracy incentive condition second. The P denotes the productivity incentive condition, and the Q denotes the accuracy incentive condition. This subsection also shows that after performing task difficulty level seven under both incentive conditions, the second task difficulty level presented was task difficulty level 5. Again subject one (denoted as S1) performed this task under the

productivity incentive condition first, and then performed the task under the accuracy incentive condition second. The lower right section of the table indicates that task difficulty levels seven and five are the eight bits and 6 bits of information levels respectively.

Each subject participated in four experimental sessions separated by at least one day. In each experimental session the subject received one level of alcohol, both levels of incentive, and all eight levels of task difficulty twice, (once for each level of incentive) for a total of 16 trials per session.

Independent Variables

Blood alcohol concentration. The target BAC's were 0.00%, 0.03%, 0.06%, and 0.09%. In actuality, the average obtained BAC's were 0.00%, 0.0281%, 0.0617%, and 0.0922%. These BAC's were based on the alcohol- per-bodyweight formula by Moskowitz and Sharma (1974). The placebo level of BAC was obtained by floating a trace of 80 proof vodka on top of orange juice. The drinks contained 80 proof vodka, and orange juice. Orange juice was used as the mixer for the vodka as the two in combination form the common and popular drink, a Screwdriver. Previous researchers, Price and Hicks, (1979), and Price and Liddle, (1982) also used

TABLE 1

Order of Presentation of Alcohol, Task Difficulty,
and Incentive Conditions

(see text for explanation)

		Day 1								Day 2								Day 3								Day 4							
Order		1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
S1	1st	P	P	P	P	Q	Q	Q	Q	P	P	Q	P	P	Q	Q	Q	P	P	Q	Q	P	Q	Q	P	Q	Q	P	P	Q	P	Q	P
	7*5	4	2	6	8	3	1			8	3	2	1	6	7	4	5	1	2	8	3	7	4	6	5	1	7	6	3	2	8	5	4
S2	2nd	Q	Q	Q	Q	P	P	P	P	Q	Q	P	Q	Q	P	P	P	Q	Q	P	P	Q	P	P	Q	P	P	Q	Q	P	Q	P	Q
	1st	Q	Q	Q	P	Q	P	P	P	Q	Q	Q	P	P	P	Q	P	Q	P	P	Q	Q	P	P	P	Q	P	Q	P	Q	Q	P	P
S3	2nd	P	P	P	Q	P	Q	Q	Q	P	P	P	Q	Q	Q	P	P	Q	P	Q	P	Q	Q	P	P	Q	Q	P	Q	P	P	P	Q
	1st	P	Q	Q	Q	P	P	P	Q	P	Q	Q	P	P	Q	Q	P	Q	P	P	P	Q	Q	Q	P	P	P	Q	Q	P	Q	P	Q
S4	2nd	Q	P	P	P	Q	Q	Q	P	Q	P	P	Q	Q	P	P	Q	P	Q	Q	Q	P	P	P	Q	Q	Q	P	P	Q	P	Q	P
	1st	P	P	Q	Q	P	P	Q	Q	P	Q	Q	P	P	Q	Q	P	Q	Q	P	P	Q	Q	P	P	Q	P	P	P	P	P	Q	Q
S5	2nd	Q	Q	P	P	Q	Q	Q	P	Q	P	P	Q	Q	P	P	Q	P	Q	P	Q	P	Q	P	P	P	Q	P	P	P	Q	Q	P
	1st	Q	Q	Q	P	P	Q	P	P	Q	P	Q	Q	P	Q	P	P	Q	Q	P	Q	P	Q	P	P	Q	Q	Q	P	P	P	Q	P
S6	2nd	P	P	P	Q	Q	P	Q	Q	P	Q	P	P	Q	P	Q	Q	P	P	Q	P	Q	P	Q	Q	P	P	P	Q	Q	Q	P	Q
	1st	Q	P	P	Q	P	P	Q	Q	P	P	Q	P	Q	Q	P	Q	P	P	P	P	Q	Q	Q	Q	P	Q	P	Q	P	Q	Q	P
S7	2nd	P	Q	Q	P	Q	Q	P	P	Q	Q	P	P	Q	P	P	Q	Q	Q	Q	P	P	P	P	P	Q	P	Q	P	P	P	P	Q
	1st	Q	P	P	Q	Q	P	Q	P	Q	Q	P	P	P	P	P	P	Q	Q	Q	P	Q	P	P	P	P	P	Q	P	Q	Q	Q	P
S8	2nd	P	Q	Q	P	P	Q	P	Q	P	P	P	Q	Q	Q	Q	P	P	P	P	Q	P	Q	Q	Q	Q	Q	P	Q	P	P	P	Q
	1st	Q	Q	Q	P	P	Q	P	P	Q	Q	P	P	P	P	P	P	Q	Q	Q	P	Q	P	P	P	P	P	P	Q	Q	Q	Q	P

†Incentive Criteria: P = productivity, Q = accuracy

Presentation of Alcohol Level									
Subjects								Alcohol Level	
	1	2	3	4	5	6	7	8	
Day	1	A	B	C	D	D	C	B	A
	2	B	C	D	A	B	D	A	C
	3	D	A	B	C	C	A	D	B
	4	C	D	A	B	A	B	C	D

*Task	Bits	Ampli.	Toler.
Diff.		(cm.)	(cm.)
1	2	2.54	.716
2	3	2.54	.345
3	4	10.16	.635
4	5	20.32	.635
5	6	20.32	.317
6	7	20.32	.159
7	8	20.32	.079
8	9	40.64	.079

vodka and orange juice in their research. The use of vodka and orange juice in the current study is in keeping with that convention.

Task difficulty. Welford's (1968) version of Fitts' (1954) index of difficulty was used to determine the eight levels of task difficulty.

Incentive. There were two incentive conditions, productivity and accuracy. In the productivity condition, the subject was instructed to try for both productivity and accuracy, favoring productivity over accuracy. For this condition, the subject was given a penny for every full insertion of the probe in a hole (whether it was a hit or not) plus an extra quarter cent for every hit. In the accuracy condition, the subject was instructed to try for both accuracy and productivity, favoring accuracy over productivity. For this condition, the subject was given a penny for every hit plus a quarter cent for every full insertion of the probe in a hole. In general, the subject could expect to earn approximately one to three extra dollars per session for maintaining the desired incentive condition.

Dependent Variables

Hits. Each time the probe was placed in one of the two holes in the top metal plate without touching the plate, and the probe continued down striking a second metal plate below the first plate, it was a hit.

Misses. If the subject touched the top plate with the probe, it was a miss.

Apparatus

Breathalyzer. A Smith and Wesson breathalyzer was used to measure blood alcohol concentration of the subject.

Drill press. A typical table-top drill press with the following alterations was used: the belt drive was disengaged, the power was off, and a blunt 0.635 cm metal probe was used instead of a drill bit.

Workpiece. The workpiece was a one-piece teflon frame which supported the interchangeable top plate (which had two holes), and the fixed bottom plate used to register full insertion. See Figure 1.

Hit or miss counter. The counter electronically recorded hits and misses, digitally displayed the number of each, and contained a built-in 30 second timer initiated by the subject's starting of the trial. This timer would allow the

(not drawn to scale)

Figure 1. Diagram of Workpiece

* Hole diameter, and distance between holes as shown define a task difficulty of six bits of information.

counter to record only during the 30 second trial. Figure 2 shows the drill press, workpiece, and hit or miss counter.

Procedure

1) The subject was given a physical examination by a medical doctor.

2) The subject was informed of his rights as a participant in an experiment, and told about the requirement to abstain from alcohol for 24 hours, and from food for four hours prior to each experimental session. The subject was allowed to drink water during the four hours prior to each experimental session.

3) The subject answered a questionnaire on his drinking and drug habits.

4) The subject practiced the experimental task on all 16 trials (without first ingesting alcohol) until the performance scores on the dependent variables were within ten percent of each other on three consecutive groups of 16 trials.

5) After one to three days, the subject returned for the first experimental session. At the beginning of the session the subject was weighed. Next the subject was given the drink and 30 minutes to ingest it. He was asked to sip the drink slowly and evenly throughout the entire 30 minutes.

Figure 2. Drill Press, Workpiece, and Hit or Miss Counter

* The hit or miss counter was turned away from the subject during the experiment.

Starting ten to 15 minutes after the ingestion of the drink, the subject was given breathalyzer tests until he reached the near target BAC. The subject was then given two 30 second warm-up trials. Next he was informed of the incentive condition for the first experimental trial and shown a reminder card with the name of the incentive condition on it placed just outside of the subject's primary visual field. The subject performed the first experimental trial. The difficulty level of the first trial was maintained while the incentive condition was changed. Again the subject was both verbally and visually reminded of the incentive condition. The subject performed the second trial. The sequence of the subject performing two trials at the same difficulty level with a different incentive condition for each was repeated until all eight difficulty levels had been covered, for a total of 16 trials. The subject was given a breathalyzer test. (The before trials and after trials breathalyzer test were averaged together). This ended the experimental session. Not including the breathalyzer test, the experimental session lasted approximately 12 minutes. The subject received a short break of under a minute after each trial while the top plate of the workpiece was being changed.

RESULTS

Table 2 lists the mean number of hits and misses for each level of the independent variables. A summary of cell means is found in Appendix G.

Analysis of Variance

Table 3 and 4 show the analysis of variance summaries for hits and misses respectively.

Main effects. Except for the effect of alcohol on misses, there were significant main effects of alcohol, task difficulty, and incentive for both hits and misses.

Interactions. There were significant interactions between alcohol and task difficulty for hits, and for incentive and task difficulty for both hits and misses.

Alcohol

Main effects. The Tukey's Honestly Significant Differences multiple comparison test showed the significant effect of alcohol for hits to be at the 0.06% and 0.09% BAC ($p < .01$). There was a 12% and 19% reduction in hits at the 0.06% and 0.09% BAC respectively as compared to the placebo.

TABLE 2

Mean Number of Hits and Misses

Independent Variable	Mean Number of Hits	Mean Number of Misses
<u>Alcohol</u>		
0.00% BAC	15.19	11.14
0.03% BAC	15.00	11.00
0.06% BAC	13.37	9.77
0.09% BAC	12.28	10.22
<u>Task Difficulty (Bits)</u>		
2	27.17	9.70
3	17.13	12.89
4	22.03	8.92
5	19.94	6.03
6	12.13	9.91
7	5.94	12.53
8	3.91	13.56
9	3.42	10.70
<u>Incentive</u>		
Productivity	11.73	16.66
Accuracy	16.18	4.40

TABLE 3

Analysis of Variance Summary Table for Hits

Source	df	Sum of Squares	F	PR>F
<u>Between Subjects</u>				
Subjects (S)	7	2087.05		
<u>Within Subjects</u>				
Alcohol (A)	3	734.95	17.48	0.0001
A x S	21	294.30		
Task Difficulty (T)	7	36,179.46	207.79	0.0001
T x S	49	1218.79		
Incentive (I)	1	2529.38	54.02	0.0002
I x S	7	327.74		
A x T	21	382.15	2.91	0.0001
A x T x S	147	920.35		
A x I	3	26.01	2.16	0.1225
A x I x S	21	84.12		
T x I	7	342.65	6.89	0.0001
T x I x S	49	347.98		
A x T x I	21	157.46	1.48	0.0924
A x T x I x S	147	744.66		
Total	511	46,377.05		

TABLE 4

Analysis of Variance Summary Table for Misses

Source	df	Sum of Squares	F	PR>F
<u>Between Subjects</u>				
Subjects (S)	7	2671.47		
<u>Within Subjects</u>				
Alcohol (A)	3	160.73	1.66	0.2059
A x S	21	677.67		
Task Difficulty (T)	7	2732.88	18.40	0.0001
T x S	49	1039.66		
Incentive (I)	1	19,257.03	174.20	0.0001
I x S	7	773.81		
A x T	21	239.64	1.14	0.3168
A x T x S	147	1475.45		
A x I	3	66.11	2.39	0.0976
A x I x S	21	193.67		
T x I	7	844.97	14.47	0.0001
T x I x S	49	408.69		
A x T x I	21	172.89	1.14	0.3109
A x T x I x S	147	1058.83		
Total	511	31,773.50		

The 11% reduction in hits from the 0.03% to the 0.06% BAC was significant, as was the 18% reduction in hits from the 0.03% to 0.09% BAC ($p < .01$).

Interactions. The plot of the significant alcohol interaction, alcohol by task difficulty for hits did not support the hypothesis that as task difficulty increases, performance will be more adversely affected by increased levels of alcohol. The plot indicated that as task difficulty increased, the number of hits at all alcohol levels were affected similarly. See Figure 3.

The shape of the plot seemed to be determined almost entirely by hole tolerance (target width), rather than by the index of difficulty. The index of difficulty takes into consideration both target width and amplitude. If amplitude played a more important role in determining performance, it is likely that the plot would have been more linear, as predicted by Fitts' Law.

Task Difficulty

Main effects. There was a 90% decrease in mean hits from the easiest task difficulty level to the most difficult task difficulty level (averaged across incentive). The largest decrease in misses between two levels of difficulty was 57% and occurred between the eight and five bit task difficulty

Figure 3. Alcohol by Task Difficulty Interaction (Hits)

level (averaged across incentive). The Tukey's Honestly Significant Differences test showed 82% of the task difficulty differences between means to be significant for hits. 79% of the task difficulty differences between means were significant for misses. Table 5 shows which differences between mean number of hits and misses were significant for task difficulty.

The hole tolerance component of index of difficulty had a much higher correlation than the amplitude component, with both hits and misses. A very strong positive linear relationship was indicated between hits and tolerance ($r = .97$). A corresponding strong negative linear relationship was indicated between hits and index of difficulty ($r = -.94$).

Incentive

Main effects. There were 27.5% less hits in the productivity condition than in the accuracy condition. There were 74% less misses in the accuracy condition compared with the productivity condition.

Interactions. The hypothesis that as blood alcohol concentration increases, there will be a greater adverse effect on hits and misses in the accuracy incentive condition than in the productivity incentive condition was

TABLE 5

Task Difficulty Multiple Comparison

Hits								
Id	1	2	3	4	5	6	7	8
1	-	**	**	**	**	**	**	**
2		-	**	n.s.	**	**	**	**
3			-	n.s.	**	**	**	**
4				-	**	**	**	**
5					-	**	**	**
6						-	n.s.	n.s.
7							-	n.s.
8								-
Misses								
Id	1	2	3	4	5	6	7	8
1	-	**	n.s.	**	n.s.	*	**	n.s.
2		-	**	**	*	n.s.	n.s.	*
3			-	*	n.s.	**	**	n.s.
4				-	**	**	**	**
5					-	*	**	n.s.
6						-	n.s.	n.s.
7							-	n.s.
8								-

* = alpha 0.05 ** = alpha 0.01 n.s. = not significant

not evident from the plots of the significant incentive interactions, incentive by task difficulty for both hits and misses. The plots indicated that the directed incentive conditions were maintained by the subject. (see Figures 4 and 5).

To maintain the accuracy incentive condition as BAC increased, the subject knowingly or unknowingly slowed down, as indicated by the subject having fewer total responses, while maintaining similar ratios of hits to misses.

The shape of the plot of the incentive by task difficulty interaction for hits was similar to the shape of the plot of the alcohol by task difficulty interaction for hits.

Figure 4. Plot of Incentive by Task Difficulty Interaction (Hits)

Figure 5. Plot of Incentive by Task Difficulty Interaction (Misses)

DISCUSSION

Alcohol

Misses were expected to increase uniformly as BAC and task difficulty increased. Misses did not increase uniformly. There was no reason to expect that there would not be a significant effect of BAC on misses. There was no significant effect of BAC on misses. Both results may be explained by misses being an insensitive measure.

Due to the small amounts of alcohol at the placebo and 0.03% BAC, it was expected that there would be no significant effect of alcohol on the dependent variables at these levels. There was no significant effect. The somewhat higher amounts of alcohol at the 0.06% and 0.09% BACs caused there to be a significant effect of alcohol on hits at the 0.06% and 0.09% levels. This result was expected.

No explanation is offered for why the alcohol by task difficulty interaction was significant, but the plot of the interaction revealed no meaningful relationship.

Task Difficulty

As expected, the largest decrease in the mean number of hits occurred between the easiest and most difficult task difficulty levels. These two levels were clearly opposite extremes as indicated by the easiest task eliciting the greatest number of hits, and the most difficult task causing the fewest number of hits.

It was unexpected that the largest decrease in misses would occur between the eight and five bit tasks. This result may be explained by misses being insensitive.

The strong positive linear relationship between hits and tolerance indicates that tolerance is a better predictor of task difficulty than amplitude. This result supports Sheridan's (1979) findings which indicated that tolerance was more important to the index of difficulty than amplitude.

Incentives

It was no surprise that there were fewer hits in the productivity incentive condition than in the accuracy incentive condition. It was also expected that there would be fewer misses in the accuracy incentive condition than in the productivity incentive condition. These results indicate that the directed incentive conditions were

maintained by the subject. And as BAC increased, the subject maintained the accuracy incentive condition by slowing down. It is unclear whether or not the subject knowingly slow down to maintain accuracy.

It was not surprising that the shape of the plot of the incentive by task difficulty interaction for hits was similar to the shape of the plot of the alcohol by task difficulty interaction for hits. In both cases, hole tolerance probably played an equally important role in determining performance.

CONCLUSION

Hypothesis 1. The hypothesis that as blood alcohol concentrations increase, productivity of acceptable units (as measured by hits) will decrease was supported at the 0.06% and 0.09% level compared with the placebo. The loss in productivity at the 0.06% and 0.09% was very large (12% and 19% respectively) and can represent considerable costs to industry for workers performing this type of task who are on the job with such BAC levels.

Hypothesis 2. The hypothesis that as blood alcohol concentrations increase, accuracy of performance will decrease was not supported. The levels of alcohol used did not affect accuracy of performance as measured by misses.

Hypothesis 3. The hypothesis that as task difficulty increases, performance will be more adversely affected by increased levels of alcohol was not obvious from this study. A significant interaction between these two variables existed, but visual inspection of plots of this interaction did not support acceptance of this hypothesis.

Hypothesis 4. The hypothesis that increasing levels of blood alcohol concentration will have a greater adverse

effect on hits and misses under the accuracy incentive condition than under the productivity incentive condition was not demonstrated in this study.

Low levels of blood alcohol concentration (0.06% and 0.09%) significantly affected subjects' performance on this study's drill press simulation task. Therefore, low levels of blood alcohol concentration (less than 0.1% BAC) probably decrease workers' productivity and thus cost industry large amounts of money. Both workers and management should be concerned about this potential loss.

The percentage of productivity lost in this study could be translated into dollars that an industry with similarly intoxicated workers performing similar tasks could expect to lose. Those figures could be used to determine if it would be cost effective to start a program that would encourage workers not to be under the influence of alcohol on the job.

Welford's version of Fitts' Law does not wholly apply to productivity as measured by hits. A modification of Fitts's Law more strongly emphasizing hole tolerance might produce a more linear fit to the data.

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Appendix A

INSTRUCTIONS

Introduction. This study will examine the effects of alcohol on a drill press task. You will be given a certain amount of alcohol (vodka) and orange juice. Most likely this level will not make you exceed legally acceptable levels of intoxication. You will then perform the drill press task. You will have 30 minutes to ingest the alcohol, (make sure that you make your drink last for the entire 30 minutes, by sipping it slowly) then about 30 more minutes for the alcohol to take effect. The drill press task will take about 20 minutes to complete. This session and other sessions will end at either nine or 11 P. M. at which time I will drive you home.

I would like to remind you that you have the right to withdraw from this study at any time, and you will be paid for the time which you have attended, it is important for you to understand that for your data to do us any good, you must attend every session. Questions.

Participation. In this part of the study you are going to perform the drill press task. There will be emphasis on

either speed or accuracy. In each condition you will perform the eight trials once for a total of 16. Each trial will last 30 seconds. You will begin with two practice trials to help you get warmed up.

In the productivity condition, it is most important for you to make the largest number of hole completions as possible within the 30 seconds. It is also important for you to be accurate by not hitting the sides of the hole with the probe. To give you a better idea of how important it is for you to be productive, (to go as fast as you can) and to be accurate, we will pay you a bonus of one cent for every hole completion regardless of whether it is a hit or miss. We will also pay you a quarter of a cent on top of the one cent for every one you get correct.

If a penny or a quarter of a cent does not sound like much to you, remember that you will be doing many hole completions today and those pennies will really add up.

In the accuracy condition, it is most important for you to be as accurate as possible, for we will pay you one cent for every hole completion which you get correct (which is getting the probe in the hole without hitting the sides). It is also important for you to be productive, for we will pay you a quarter of a cent for every hole completion regardless of whether it is correct or not.

To sum up, in the productivity condition you will get one cent for every hole completion, plus a quarter of a cent for every one you get right. In the quality condition, you will get one cent for every hole completion which you get right, plus a quarter of a cent for every hole completion.

I will tell you which condition you are in before each trial. You will have 30 seconds after I say go. Ready? Five seconds, 3, 2, 1, go.

Appendix B
IRB PROPOSAL

Research Project Involving Human Subjects
Using Alcohol Ingestion

The basic purpose of this research will be to investigate the effects of alcohol on the performance of an industrial task. The task will be to use a drill press.

General Procedure for Experimentations

The following is the general procedure which will be used for the experiment described above. Each subject will be given:

- (1) alcohol for ingestion over a 30 minute period,
(alcohol will be given in accordance with body weight formula to attain levels of blood alcohol content which will be generally less than .1%. In many states, .1% is used as a criterion for legal drunkenness while driving. In no case will an attempt be to produce blood alcohol content in excess of .1%. Therefore, our interest is in relatively light doses of alcohol.);
- (2) an additional period of about 30 minutes to allow

- absorbtion of alcohol into the system;
- (3) breath tests at close intervals during the absorbtion period until the measurement indicates the criterion level of blood alcohol content called for in the experimental design has been reached;
 - (4) a practice run of the experimental task;
 - (5) the experimental task;
 - (6) another breath test following the experimental task;
 - (7) direct observation and intermittent breathalyzer tests on the premises until the breathalyzer tests indicate a blood alcohol level less than .03%;
 - (8) payment for session participation including bonuses;
 - (9) delivery home by a driver who has not recently ingested alcohol.

Use of Human Subjects

Description of the Characteristics of the Proposed Subject Population

The subject population for the experiment will consist of male university students. Subjects will not be used whose ability to give voluntary informed consent may be in question. No minors will serve as subjects.

Safety Procedure

Provisions for performing the task safely under levels of alcohol ingestion which will be provided will be included in the experiment. These provisions will be designed not only to minimize the potential of physical risk but where possible to eliminate such potential. Since the levels of alcohol ingestion are not severe, no lasting effects are anticipated. However, subjects participating in these experiments will be required to receive a physical examination by R. F. Desjardins, M. D., from whom they must receive permission to participate in the experiment. Physical risk will be minimized by using a flat-nosed smooth metal cylinder instead of a standard drill bit. The subjects will use a predrilled metal plate, and the drill press chuck will not be revolving, thus they will not do any drilling. Also, the "drill bit" and the workpiece has been designed for and used by handicapped people which implies that it is very safe. The subjects will be transported home after the experimental session by the experimenter in his car.

The design of the equipment for safety will be approved by Dr. Keith Furr before the experiment.

Consent Procedures

The experimenter, either a staff member or a graduate student, will provide the subject with a set of

instructions. This set of instructions will include a participants informed consent form. This form is shown in the following appendix.

Subject Privacy

The procedures for each experiment will include the use of assigned numbers for subjects' names. As soon as a subject indicates that he does not require his data, the name associated with each number will be discarded. This will protect the subject by providing anonymity for his data.

Potential Benefits

The potential benefits to the subject involved with the experiment is fairly limited. He will gain specific information about the effects of various levels of ingestion of alcohol on his performance capabilities. The potential benefit to Virginia is considerable. Little is known at the present time about the effects of alcohol ingestion on productivity in industrial tasks. A great deal of research on the effects of alcohol on performance of psychomotor tasks has been accomplished; however this essentially has been on elemental tasks such as reaction time, tracking, etc. The principal composite task which has been addressed fairly extensively in the literature is vehicular driving.

Other than this, there is very little information which can be used eventually to estimate effects on industrial productivity and quality control, and perhaps safety. The effects could be highly significant economically. It is also of some significance to the legal rights, safety, and well being of employers and employees.

Risk-Benefit Comparisons

The evaluation of the risk-benefit ratio for this series of research is qualitative. As described above, the potential benefits are considerable; the risks are relatively small. The intent of the investigators is to minimize risk to the extent that it is reasonable to do so. The levels of alcohol ingestion are relatively mild. Essentially the risks involved are much less than those inherent to the tasks which are performed every day in industry. These risks are minimized by special design of equipment to provide for the protection of the subject.

Appendix C

PARTICIPANT CONSENT FORM

As a participant in this experiment, you have certain rights and obligations. The purpose of this form is to make you aware of these rights and obligations, and to obtain your consent to participate.

1. You are obligated not to drink alcohol for 24 hours prior to the experiment, and you are also obligated to limit your intake for the four hours prior to the experiment to water only.
2. During this study, your blood alcohol level will most likely not exceed legally acceptable levels.
3. You have the right to stop the experiment in which you are participating at any time if you feel that it is not agreeable to you. Should you terminate the experiment, you will receive pay only for the proportion of time you participated, including all time your presence is required. If you should terminate your participation in the experiment, you will be required to remain on the premises until your blood alcohol content reaches a level of 0.03% or less.
4. The session should take approximately five hours. Dur-

ing the first hour you will ingest the alcohol. During the second hour you will perform the experimental tasks. Detoxification will occur during the last three hours. It may take less than the full three hours to do so.

5. At the end of the experimental session you will be paid for your participation including the time you spend detoxifying at the rate of \$3.00/hr. You will also receive any bonuses which you have earned.
6. You have the right to see your data and to withdraw it from the experiment if you feel that you should. In general, data are processed after all runs are completed. In this experiment, we can provide you with some qualitative information immediately after the entire experiment. Subsequently, all data will be treated with anonymity. Therefore, if you wish to withdraw your data you must do so immediately after your participation is completed.
7. You have the right to be informed on the results of the overall experiment. If you wish to receive information on the results, please include your address (3 months hence) with your signature below. A summary will be sent to you. If you would like further information, please contact the Human Factors Laboratory, and a full report will be made available to you.

8. You will be required to remain under observation until your blood alcohol content, indicated by a breathalyzer test, is reduced to no more than 0.03% or less.
9. After each experimental session, you will be transported home by the experimenter. Under no circumstances will you be allowed to walk or drive home alone.
10. You might or might not be in an inebriated condition. You might experience blurred vision, dizziness, nausea, loss of balance, and difficulty with speech.
11. Should you suffer injury, we will not offer care or compensation except for first aid.
12. Should you have any questions or problems, feel free to contact Dr. Dennis L. Price, Associate Professor, IEOR Department at 961-5635, or Dr. Milton P. Stomblor, Chairman, Institutional Review Board for Research Involving Human Subjects at 961-5283.

We hope that you will find the experiment an interesting experience. The faculty and graduate students involved greatly appreciate your help as a participant. If you have any questions about the experiment or your rights as a participant, please do not hesitate to ask. We will do our best to answer them, subject only to the constraints that we do not want to pre bias the experimental results.

YOUR SIGNATURE BELOW INDICATES THAT YOU HAVE READ YOUR ABOVE STATED RIGHTS AND OBLIGATIONS AS A PARTICIPANT, AND THAT YOU CONSENT TO PARTICIPATION. If you include your printed name and address below, a summary of the experimental results will be sent to you.

Signature _____

Printed Name _____

Address _____

(city) (state) (zip)

Appendix D
QUESTIONNAIRE

Subject Number _____
Age: _____ Sex: _____ Height: _____ ft. _____ in.
Weight: _____ P _____ BP _____
R _____ Ears _____
Eyes: Visual _____ Fundi _____
Nose-Throat: _____
Thyroid: _____ Lungs: _____ Heart: _____
Abdomen: _____ Reflexes: _____

TO BE COMPLETED BY CAMPUS
MEDICAL

Alcohol

How much hard (distilled) liquor do you drink per week?

a) What type of wine do you drink? i.e., red, white, port, etc. _____

b) What is the % volume of alcohol of the wine? _____

How much beer do you drink per week? _____

Do you drink during the work week? (i.e., Monday morning to Friday afternoon) _____

What time of day do you generally drink alcoholic beverages?

Drugs

How much coffee do you drink? _____

Do you drink coffee and alcohol together? _____

Are you presently using any drugs, either prescription or illegal? _____

Are you presently using any legal, nonprescription drugs?

Appendix E

ALCOHOL DOSAGE CALCULATIONS

1. Convert body weight in pounds to kilograms
by dividing weight in pounds by the conversion factor
2.205. Example: for a 165 lb. person, $165/2.205 =$
74.82 kg.
2. Calculate the required amount of ethyl alcohol in grams
by multiplying body weight in kg. by:
.207 for 0.03% B.A.C.,
.414 for 0.06% B.A.C., or
.828 for 0.09% B.A.C.
Example: for 0.09% B.A.C., $74.82 \times .828 = 61.95$ g.
3. Calculate the liquid measure of ethyl alcohol in
milliliters by dividing the alcohol in grams by the
specific gravity of ethyl alcohol (.7907).
Example: $61.95 \text{ g.} / .7907 = 78.3483$ ml.
4. Convert alcohol in milliliters to alcohol in ounces by
multiplying the alcohol in milliliters by the conversion
factor .03381. Example: $78.3483 \text{ ml.} \times .03381 = 2.649$ oz.
of ethyl alcohol.

5. Calculate the required amount of vodka in ounces by dividing the ethyl alcohol in ounces by the percentage of alcohol in the vodka. Example: using 80 proof vodka which is 40% alcohol, $2.649/0.4 = 6.6224$ oz. of 80 proof vodka.
6. Calculate the total volume of the drink in ounces by dividing the person's weight in pounds by 50. Then multiply that quotient by 4 (which serves the purpose of giving 4 ounces of liquid per 50 pounds of body weight). Example: $(165/50)(4) = 13.2$ oz.
7. Calculate the required amount of orange juice in ounces by subtracting the amount of vodka in ounces from the total drink volume. Example: 13.2 total oz. - 6.6 oz. of vodka = 6.6 oz. of orange juice.

Appendix F
SUBJECT'S SUMMARY OF RESULTS

June 16, 1981

Thank you for participating in our study on the effects of alcohol on productivity. As requested, here is a summary of results.

We were specifically studying the effects of alcohol, task difficulty, and speed and accuracy criterion on a drill press task. Alcohol accounts for billions of dollars lost to industry each year, but until recently, there were no studies done on the effects of alcohol on specific industrial tasks. The study you participated in was the third in a series of alcohol research going on here at Virginia Tech.

We found alcohol to have a significant effect on the number of hits. You may recall that a hit occurred when you placed the drill probe in a hole without hitting the sides of that hole. On the average, there was a 12% decrease in hits at the second highest alcohol level: .06% blood alcohol concentration (BAC), and a 19% decrease in hits at the highest alcohol level which was .09% BAC (.1% BAC is

legally intoxicated). These decreased hit percentages were obtained by comparing the number of hits at a given alcohol level with the number of hits at the lowest or placebo alcohol level. To obtain the lowest level of alcohol, we floated a very small amount of vodka on top of the orange juice in your drink which resulted in a BAC of 0%. The other alcohol level was .03% BAC and resulted in a one percent decrease in hits. That decrease was not significant.

As you would expect, the smaller and farther away the two holes were, the more difficult was the task of putting the drill probe in the holes. The harder the task, the fewer were the number of hits. There were also more hits in the accuracy condition than in the speed condition.

We hope to at least partially estimate the effects of alcohol on productivity in a real life situation from the results of this study. You have greatly helped us by your participation. Thank you. If you have any questions, you may phone me at either 961-5635, or 552-7031.

Sincerely,

Robert A. Flax

Appendix G

CELL MEANS

<u>Alcohol</u>	<u>Task</u>	<u>Difficulty</u>	<u>Incentive</u>	<u>Hits</u>	<u>Misses</u>
1		1	P	29.13	15.63
1		1	A	30.13	6.75
1		2	P	17.63	21.50
1		2	A	22.75	3.88
1		3	P	19.38	16.75
1		3	A	24.25	4.13
1		4	P	19.63	10.63
1		4	A	22.63	2.38
1		5	P	9.38	18.75
1		5	A	17.63	3.00
1		6	P	3.25	20.00
1		6	A	10.50	4.13
1		7	P	2.13	19.63
1		7	A	6.13	8.00
1		8	P	2.13	17.25
1		8	A	6.38	5.88
2		1	P	27.38	15.75
2		1	A	32.25	3.88
2		2	P	13.50	24.38
2		2	A	22.63	5.38
2		3	P	23.13	13.50
2		3	A	25.13	3.13
2		4	P	18.88	10.50
2		4	A	21.88	1.88
2		5	P	9.88	16.75
2		5	A	15.63	3.88
2		6	P	3.63	20.63
2		6	A	9.25	6.25
2		7	P	2.38	21.00
2		7	A	7.38	6.25
2		8	P	1.25	16.75
2		8	A	5.75	6.00
3		1	P	25.00	13.38
3		1	A	26.75	3.75
3		2	P	12.38	18.25
3		2	A	19.88	4.00
3		3	P	21.25	11.50
3		3	A	22.38	2.50
3		4	P	18.38	9.88

3	4	A	20.88	1.75
3	5	P	8.88	15.13
3	5	A	13.50	3.38
3	6	P	3.38	19.25
3	6	A	8.00	5.38
3	7	P	1.25	20.63
3	7	A	5.88	7.25
3	8	P	1.25	14.38
3	8	A	4.88	6.00
4	1	P	22.50	14.13
4	1	A	24.25	4.38
4	2	P	10.88	21.38
4	2	A	17.38	4.38
4	3	P	17.63	17.25
4	3	A	23.13	2.63
4	4	P	17.88	10.13
4	4	A	19.38	1.13
4	5	P	7.75	16.13
4	5	A	14.38	2.25
4	6	P	2.13	19.13
4	6	A	7.38	5.50
4	7	P	1.50	18.63
4	7	A	4.63	7.13
4	8	P	0.88	14.75
4	8	A	4.88	4.63

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ALCOHOL, TASK DIFFICULTY, AND INCENTIVES IN DRILL PRESS
OPERATION

by

Robert A. Flax

(ABSTRACT)

The effects of alcohol, task difficulty, and incentives on a drill press simulation were examined. On four nonconsecutive days the subject received four alcohol levels, one level per day. The levels were: 0.00%, 0.03%, 0.06%, and 0.09% blood alcohol concentration (BAC). The drill press simulation task consisted of placing a drill probe alternately between two holes in a metal plate. For every level of alcohol, each subject received eight levels of task difficulty which were varied by changing the hole size and distance between holes. Task difficulty was in units of bits of information ranging from two to nine and was derived from a portion of Welford's (1968) version of Fitts' Law. For every level of task difficulty each subject received two levels of incentive: productivity and accuracy which were enforced by monetary rewards.

The subject's response was measured by hits and misses. A Hit was defined as placing the metal drill probe in either of two holes in the top metal plate of the workpiece without touching the plate. A miss was defined as a contact of the probe with the top plate.

Except for the effect of alcohol on misses, there were significant main effects of alcohol, task difficulty, and incentive for both hits and misses. There were significant interactions between alcohol and task difficulty for hits, and for incentive and task difficulty for both hits and misses.