

EFFECTS OF ALCOHOL INGESTION AND WORKLOAD  
ON QUALITY AND PRODUCTIVITY OF FEMALES  
FOR A PACED AND UNPACED ASSEMBLY TASK

by

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## INTRODUCTION

### Statement of Problem

In 1974, the National Institute on Alcohol Abuse and Alcoholism (NIAAA) estimated that there were nine million alcoholics in the United States (Follman, 1976). It is estimated that five percent of the U.S. work force are alcoholic individuals, and almost another five percent are serious alcohol abusers (Schramm, Mandel, and Archer, 1978). Alcohol abuse is clearly disruptive to job efficiency. The legitimacy of examining the importance of alcoholism as a disability affecting productivity cannot be questioned. A 1976 estimate places the annual cost of alcoholism to the economy at 9.35 billion. Within two years, this estimated loss in productivity increased to 19.64 billion (U.S. Department of Health, Education and Welfare, 1978).

Although a portion of these losses can be attributed to absenteeism, on-the-job losses in productivity (for example declining work performance, efficiency and interruption of the activities of fellow workers) are at least equally important. Given these high costs of lost productivity attributable to workers under the influence of alcohol, specific effects on the worker and work performance occupy only a small space within the growing research on the effects of alcohol in industry. The large area of published

research examines the effects of alcohol on psychomotor task variables such as reaction time, dexterity steadiness and tracking (Carpenter and Ross, 1965; Chiles and Jennings, 1970; Young, 1970; and Zwhalen, 1976). A few studies on alcohol effects (Price and Hicks, 1979; Price and Liddle, 1980; and Price and Flax, 1982) used fascimile industrial tasks designed to simulate manual assembly, welding and drill press tasks respectively.

This study, the fourth in this series of industrial studies, investigated the effects of various levels of alcohol on women performing a manual assembly task under paced and unpaced conditions. The study examined the assembly of a simulated circuit component grid board, requiring exact placement of three similarly coded resistors, which must be chosen from a set of five resistors. Two of these were included as distractors. This was followed by adjusting a voltmeter to a specified value, approximately at the center of the meter. The unassembled parts were carried on a conveyor belt to the workstation. The conveyor belt is a moving belt, flat-bed construction, designed to handle unit loads horizontally or on an incline up or down. The parts are discharged off the end of the belt near the operator. This conveyor is widely used in many industries for transporting materials, carrying

packages or handling products for an assembly purpose.

### Objective of Research

This study examined alcohol ingestion effects and the resulting impairments which are considered to be a burden on the industry as far as productivity and quality are concerned. Trice (1972) indicates that "it is logical to expect a deviant drinker to be less steady; his/her coordination, timing, motor responses, and sense of danger would be impaired under the effect of alcohol ingestion."

Therefore, in addition to alcohol, this study examined the effects of workload on quality (i.e. accuracy) and productivity (i.e. speed) of females under paced (maximum speed for paced work, 75% and 50% of that maximum speed) and unpaced work conditions (speed and accuracy).

The work quality measure depends on the ability of the operator to differentiate between each resistor, to determine the correct position, the correct orientation, and adjust the meter to the correct reading. The productivity measure is the time required to assemble the total number of circuit boards.

In paced work (e.g., conveyor belt) activity tends to consist of a period of action followed by a period of waiting and so on (Conrad and Hille, 1955). Unpaced work is that freely chosen work pace where the operator dictates the pace.

## LITERATURE SEARCH

### Alcohol

Alcohol, a controversial and mysterious liquid, has been part of man's culture since the beginning of time (Brisolara, 1979). Regardless of when and where it was discovered, excessive drinking can destroy role performances and permanently impair physical and psychological functioning.

Trice (1972), offered three categories of drinking behavior: the first category is normal drinking. Such drinking does not undesirably alter behavior, does not interfere with the effective and efficient performance of role assignments and obligations, and does not significantly affect day-to-day functioning.

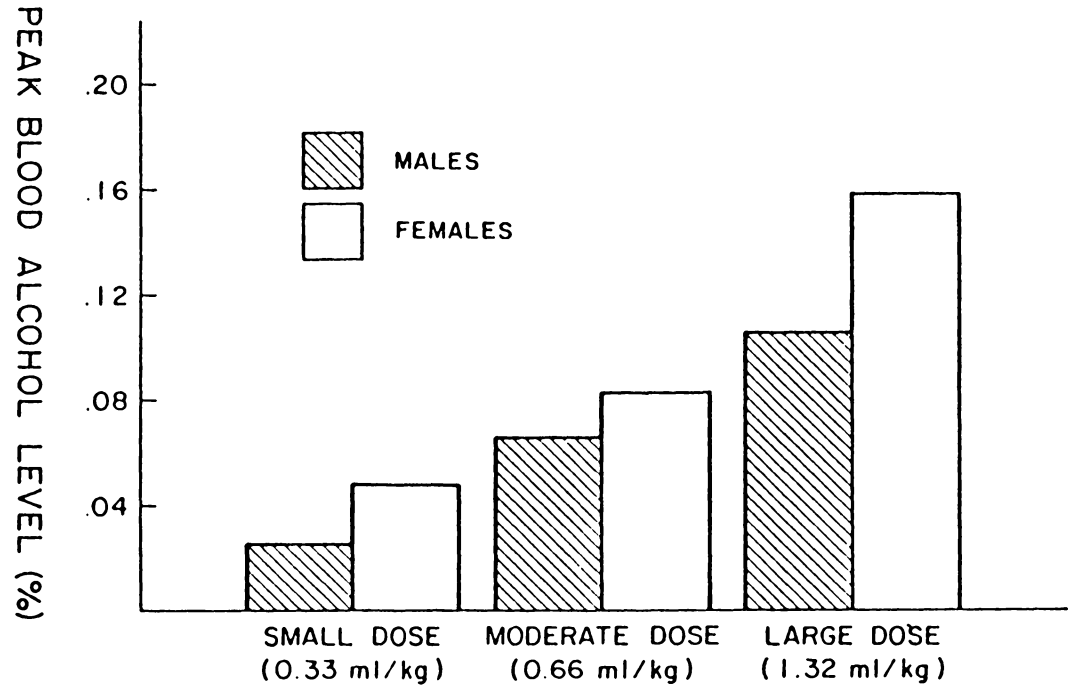
Deviant drinking, the second category, is drinking behavior which exceeds the bounds of community definitions and impairs role performance. Alcohol addiction is the third category, if such an individual is deprived of alcohol, he manifests sharp physiological withdrawal symptoms, such as delirium tremens, severe shakes, and psychological syndromes such as Korsakov's psychosis (considerable loss of memory).

Alcohol's Effect on Women. It is conservatively estimated that there are about 900,000 to one million women

alcoholics in the United States (Burtle, 1979). Although the exact number of women working under the influence of alcohol is unknown, they continue to constitute an increasing percentage of industrial alcoholism caseloads. A finding (Greenblatt and Shuckit, 1976) indicated that women show higher Blood Alcohol Concentrations than men at equivalent alcohol doses (see Figure 1 ). Although a small sample size was used in this finding, one explanation for the difference between women and men in peak BACs is related to the difference in body water content. The total body weight of men is composed of 55% to 65% water, while the total body weight of women is composed of 45% to 55% water. Since alcohol is distributed throughout the body in proportion to the water content of the body tissues, the alcohol tends to be more diluted in the body of males than females. The difference between females and males is that females have more adipose (fatty) tissue and males have more muscle tissue. More water is contained in muscle tissue than adipose tissue. Therefore, the peak BACs should be lower in men than women.

It also appears that sex hormone levels are related to blood alcohol concentration and to behavioral effects; not only do women tested at different stages of the menstrual cycle show variation in BACs (in response to the same amount of alcohol), it also appears that women taking oral contraceptives show differences in ethanol metabolism when

Figure 1. Peak Alcohol Dosage for Women and Men



MEAN PEAK BLOOD ALCOHOL LEVELS FOR TWO MEN AND TWO WOMEN WHO WERE GIVEN THREE ALCOHOL DOSES

(From Greenblatt and Shuckit, 1976).

compared with women not taking oral contraceptives (Burtle, 1979). Women apparently become more intoxicated than men on the same amount of alcohol per unit of body weight, and they demonstrate more impairment on memory tasks.

Interestingly, a study from a Denver mental health center (Horn, Wanberg, and Adams 1974) reported that women more often use alcohol to improve job performance.

Sensori-motor effects. In general, alcohol causes a depressant effect on the central nervous system functions which regulates sensory and motor performance, motivations, and emotions. Most performance tests require coordination between sensory input and motor output (Levine, Greenbaum, and Notkin, 1973).

Thus, degree of vigilance and the susceptibility of performance to motivational factors can be affected by a task such as assembly. One of the most frequently used tests to measure the alcohol effects on sensori-motor performance is reaction time (Levine, Greenbaum, and Notkin, 1973). The results indicate that alcohol slows the speed at blood alcohol levels above 0.1 percent. Moreover, alcohol level has an effect on accuracy. The higher the blood alcohol concentration (B.A.C.), the more difficult a task will seem, and the slower it will be performed, and probably with a decrease in accuracy.

Drew, Calquhoun, and Long (1955) indicated that very low alcohol doses are sufficient to impair the ability to

track objects in motion, and errors are progressively increased by higher doses.

Motor effects A study of the perceptual judgement of the passage of time (Sterzinger, 1935) suggests that alcohol slows the subjective process so that time seems to pass more quickly and the response designating an estimated time interval is made with a longer latency. Joerger (1960) reported that 0.5g/kg caused prolongation by 83 percent the estimation of a "moment" of time. In addition, motor behavior is controlled and influenced by sensory inputs as well as by various portions of the central nervous system, and the alcohol effects have been tested on certain motor functions in which differential effects of sensory stimulation are minimized in order to obtain a pure measure of motor effects. Voluntary motor control tests, measured by the subject's ability to perform tasks which measure muscular steadiness shows various magnitudes of depressant alcohol effects, with little evidence for stimulating effects (Levine et al., 1973).

#### Paced Versus Unpaced Task

The human component within a man-machine system of either industrial, urban or other socio-technical nature is frequently requested to perform at a pace or rhythm which is dictated by pacers such as machines, conveyors production lines, traffic flow, committees and/or various financial incentives.

The human operator working adjacent to a conveyor belt is often forced to perform either over or under his freely chosen performance rate (Salvendy and Pilitsis, 1971).

Farmer (1921), and Barnes (1968) used the theories of rhythm to determine the time and motions required to optimize the performance of motor skilled tasks. Rhythm was defined as "... the speed or the rapidity with which repeated motions are made".

During paced performance, the natural rhythm of the operator is disturbed. Mahadeva and Corlett (1970) suggests the existence of an optimum rate of work for each individual operator performing a submaximal physical task, at which the energy expenditure per cycle or movement is minimized. Since this natural rhythm is disturbed during pacing, numerous psychological studies have been conducted to determine effects on output (Conrad, 1960), intra- and inter-individual variability of performance over time and motion effectiveness (DeJong, 1962). These studies have shown decreases in work output and increases of performance times as the task becomes more stringently paced. Psychophysiological studies by Salvendy (1969) on paced and unpaced performance have shown that an optimum rate of work exists within a region where optimization occurs since the energy expenditure and errors per unit of external work are minimized while human efficiency is maximized. Working either above or below this exhibited freely chosen pace has

been shown to maximize the psychological cost per unit of work and minimize human body efficiency.

### Workload

Definitions. Workload has many different connotations and categorization of this literature is diverse and almost intuitive.

Meister (1976) interpreted workload as a multidimensional construct and may be conceptualized in various ways. Workload can be expressed as the amount of physical effort required by a task or performed by the operator independent of task performance itself (Senders, 1970).

It may also be related to a concept of stress. Specifically the time required to execute a series of tasks divided by the time available to perform those tasks (Siegel and Wolf, 1969). In addition, it can be defined in terms of how much attention is demanded by a task and the consequent reduction in attention available for other tasks (Knowles, 1963). On the other hand, Wierwille and Williges (1978) have stated that "there is no single, agreed upon definition of mental workload, and there is no single, universal metric of it". They write that mental workload is "a theoretical construct, and as such, might best be defined operationally".

Workload may be expressed and experienced both as a subjective operator state (e.g., the task is difficult) and as an objective consequence (e.g., reduced performance). The existence of workload can be determined only by "comparison" with some baseline performance (Meister, 1976). Thus load can be inferred only when performance "changes" significantly because a changed input has been introduced. Actually, in the field, as differentiated from a formal experiment, it may be difficult to distinguish a performance change resulting from a load input from normal operator variability, particularly when changes in input conditions are not highly visible.

Finally, Chiles (1977) uses the task demands placed on the operator by the system, as a definition of workload.

Estimation techniques Wierwille and Williges (1978) classify workload estimation techniques into four categories: subjective opinions, spare mental capacity, primary task, and physiological measures. In workload assessment applications, primarily two general approaches have been used with the subjective opinions. The more systematic approach deals with the use of rating scale procedures for obtaining pilot opinions; whereas, the second area deals with less structured approaches using a variety of interview and questionnaire procedures.

The evaluation of the concept of spare (residual or reserve) mental capacity is the largest body of research

data dealing with the measurement of human operator workload. The approach assumes that an upper bound exists on the ability of the human operator to gather and process information. Spare mental capacity, then, is the difference between the total workload capacity of the operator and the capacity needed to perform the task. As spare mental capacity decreases, the operator's workload increases until a point of overload is reached.

On primary task measures, Wierwille and Williges (1978) added that as the mental workload of a human operator increases, the performance of that operator may change, ordinarily in the direction of degradation. If such a change does in fact occur, its measurement would be an indication of increased workload. This hypothesis the primary task performance method of assessing workload.

Albanese (1977) suggested that "successful mission completion" is a measure of workload. In other words, if the operator completes his mission successfully, there is no overload. On the other hand, if he fails to complete it, an overload is presumed to have occurred. In their last method of assessing operator workload, the physiological measures, Wierwille and Williges (1978) write that the physiological method generally involves the measurement and data processing of one or more variables related to human physiological processes. As operator workload changes, involuntary changes take place in the physiological

processes of human body (body chemistry, nervous system activity, circulatory or respiratory activity, etc.).

Finally, the class of workload techniques termed physiological can generally be discriminated from other workload estimation techniques by the fact that the changes occurring in measures are largely involuntary.

#### Speed-Accuracy Tradeoff

In this study, productivity and quality (as discussed in the previous portions of this literature) will be referred to as speed and accuracy respectively for some parts of the research. Jennings, Wood, and Lawrence (1976) examined the speed-accuracy tradeoff. It refers to the observation that the subjects can achieve increases in speed at the cost of decreases in accuracy, and vice versa, over a substantial range. Thus, variations in subjects bias or criterion for speed versus accuracy (i.e., the particular compromise between speed and accuracy adopted in a given situation) can produce substantial changes in reaction time, even under constant experimental conditions. Jennings, et al, also state that, at fast reaction times, accuracy is low but unaffected by alcohol, while at slower reaction times,

accuracy is higher, and affected by alcohol.

### Rationale

Because of the 40 percent increase in the number of female assemblers during the decade from 1960 to 1970 (Hunt, 1979), this study investigated the effects of various levels of alcohol on women performing a manual assembly task under paced and unpaced conditions. A search of the literature indicates these variables have not been previously investigated in alcohol research. Research with female subjects is needed because among the 1.3 million assemblers in the U.S., 53.4 percent are women assemblers (Women Special Labor Force Report, 1979).

## HYPOTHESES

As shown in the foregoing, previous studies have investigated alcohol and its effects on industrial and psychomotor tasks. This research deals with the alcohol effects on women performing a paced and unpaced assembly task.

These variables have not been previously investigated. The hypotheses are stated as follows:

- (1) Assembly task performance will be negatively affected by alcohol ingestion.
- (2) Production speed will increase with increasing workload levels, up to the operationally defined 100% workload.
- (3) As both BACs and workload increase, the production speed will be slower, whereas the assembly errors will be higher.
- (4) For the unpaced condition, when the speed criterion is imposed over the accuracy criterion, the production speed and the assembly errors will be higher.
- (5) When the accuracy criterion is imposed over the speed criterion, both the production speed and the assembly errors will be lower under the unpaced condition.

- (6) Both the production speed and the assembly errors will be higher at 100% workload in the paced condition than in the unpaced condition.

## METHOD

### Experimental Design

In this experimental design, a two way Analysis of Variance was used for each one of the paced paradigms. The main effects for each ANOVA are described below.

Independent Variables Due to the two distinct pacing paradigms used in this study, each one of these paradigms included two independent variables, alcohol and task condition.

1. Blood Alcohol Concentration Alcohol dosages were obtained by deriving the following third-order polynomial equations:

$$\% \text{ BAC} = 0.1666d - 0.0803d^2 + 0.0348d^3$$

Where d is milliliters of pure ethanol per kilogram of body weight. The data base for deriving this equation was obtained from previous research (Greenblatt, and Shuckit 1976).

Four BAC levels were used:

- (1) 0.00% BAC (placebo condition)
- (2) 0.05% BAC (d = 0.356)
- (3) 0.07% BAC (d = 0.529)
- (4) 0.09% BAC (d = 0.707)

The respective attained mean values are shown in Appendix G. See Figure 2 for a plot of these mean values. Also see Appendix D for more details on alcohol dosage calculations.

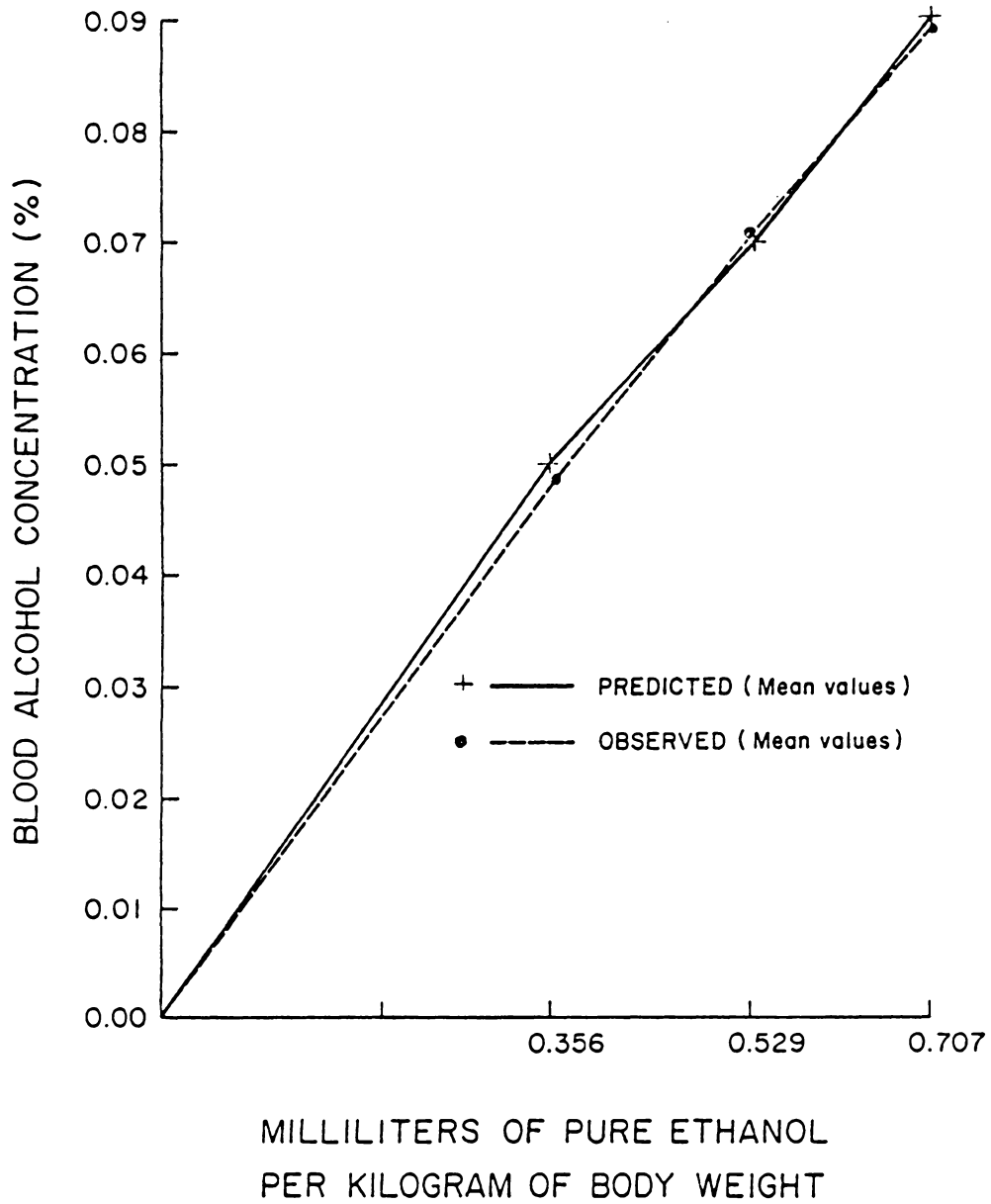


Figure 2. Predicted versus Observed Alcohol Mean Values

2. Paced Task Conditions Three levels of task conditions were used in this pacing phase. The first level, 100% workload, was obtained from the maximum effort of each participant working at maximum speed. The other two levels were 75% and 50% of the maximum workload (See Procedure Section).

3. Unpaced Task Condition This independent variable included two levels of task conditions, speed and accuracy. Both criteria were emphasized explicitly to the participant.

#### Dependent Variables

Seven dependent variables were used in this study:

- 1) Number of correctly completed circuit boards.
- 2) Number of orientation errors, occurring when one of the two resistor pins is misplaced and the other is in the correct hole.
- 3) Number of position errors, occurring when both pins miss the correct hole.
- 4) Number of improperly selected resistors.
- 5) Magnitude of meter adjustment errors, occurring when a reading deviates by 0.01 K. ohms or more from the target value.
- 6) Frequency of meter adjustments errors, defined as the number of times a reading deviates from the target.
- 7) Number of incomplete units.

#### Control variables

To ensure reduction of the between-subject variability

in the study, each subject was her own control and received all levels of all treatments.

The order of presentation of treatments was counterbalanced for alcohol levels and task conditions using latin-squares.

### Subjects.

The subjects were eight female university students. All the participants were at least 21 years of age, and the average was 22. Subjects answered questions about their weekly alcohol consumption and drug use. Their weekly overall average number of beers was 3.5. They also averaged 1.5 hard distilled liquor drinks per week. None of the participants consumed regular or fortified wine.

The selected participants signed a release form allowing University Health Services personnel to review their medical history. Should this review had indicated any problems which could interfere with safe ethanol consumption, individuals in question would have been eliminated from the study. This did not occur.

Participants starting their menstrual periods within two days of a session were rescheduled for further sessions. This is because alcohol levels have been shown to be affected significantly by different stages of the menstrual cycle (Greenblatt and Shuckit, 1976). All subjects were treated in accordance with APA ethical standards. The

subjects were allowed to see their data immediately after the experimental sessions if they so desired.

After that, the data were assigned a number for record-keeping and analysis purposes. All subjects were paid for their participation. The experiment was conducted at Virginia Polytechnic Institute and State University.

### Apparatus.

A guarded conveyor belt was used to carry boxes containing unassembled parts to the workstation. Five resistors (2K, 3.3K, 3.9K, 12K, 33K) were selected for their similar color coded bands.

Electronic circuit grid boards (100 mm x 100 mm) were used for the placement of the three similarly coded resistors. A timer equipped with a flashing light signaled when to manually load a box on the conveyor. This light could not be seen from the subjects work area.

Two voltmeters, one analog and one digital were connected such that dial adjustments made by subjects on the analog meter could be accurately determined by the experimenter through visual inspection of the digital meter.

Blood Alcohol Concentrations were measured using a breathalyzer (Smith and Wesson Model 900A). See Figure 3 for a representation of the apparatus and the assembled parts.

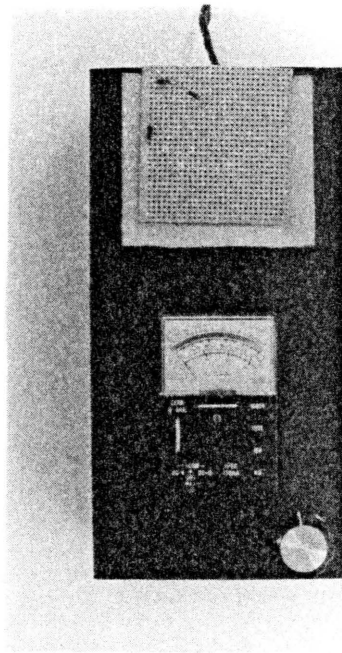


Figure 3. Assembly Parts and Representation of Apparatus

Procedure

- 1) Subjects were screened by health services personnel.
- 2) Subjects were given instructions about the experiment. These instructions included assurances that their rights to privacy would be observed. They could not drink alcohol for 24 hours, and had to limit their intake to only water for four hours prior to the experiment. Breath analyses were administered prior to the experiment beginning.
- 3) Subjects were asked to sign a statement saying that they had read, understood and agreed to the procedures as put forth in the instructions (provided in Appendix B).
- 4) Subjects were asked to fill out a questionnaire concerning their drinking and drug habits (provided in Appendix C).
- 5) Subjects were given practice sessions on the assembly task. These sessions were used as a means to determine individual workloads and to train participants to asymptotic performance levels. These issues were resolved by placing unassembled parts on the conveyor belt at intervals determined by a light adjusted to flash at a stable rate. A box containing five resistors and a section of bread board was placed on the conveyor at the time of each light flash. The intervals between boxes were continuously decreased by the experimenter until

overload occurred (specifically, the rate whereby a box of unassembled parts arrived at the workstation before assembly of the previous box of parts had been completed). At this point, the value displayed on the light timer adjustment dial represented the maximum workload for that particular subject. Theoretically, at this point, the operator saturates -- that is the demand imposed on her by the input equals her capacity to perform.

The other two workload levels were based on 75 percent and 50 percent of the reading at that maximum level. When executing this phase, the constant spacing between the boxes depended on the timer reading. In the unpaced condition, subjects had full control of the assembly line, in that subjects were given unassembled parts by the experimenter as each previous set of parts was completed.

- 6) Subjects were instructed in the research task (see Appendix H).
- 7) Alcohol dosages were administered to subjects as 80 proof vodka mixed with orange juice in accordance with body weights.
- 8) Subjects received one of the four alcohol conditions during every session in which they participated. Within each of these dosage levels, participants performed the five levels of workload, depending on which criterion was emphasized.

- 9) Subjects ingested the alcohol mixture over a 20 minute period. An additional 10 minute period was allotted for absorption into the system.
- 10) A breath test was given 10 minutes after finishing the drink.
- 11) Subjects performed the five task conditions. Each condition lasted 2 minutes.
- 12) Breath tests were given to the participants immediately after performance and intermittently until a BAC of less than 0.03% was reached. This level was judged by the Institutional Review Board to be the maximum level under which subjects could leave the observation area.
- 13) Subjects were driven home by the experimenter.

#### Safety Considerations

Safe performance of the task under levels of alcohol ingestion was emphasized in the experiment. The safety provisions were designed not only to minimize the potential of physical risk but where possible to eliminate such potential. No lasting detrimental effects were anticipated due to the low levels of blood alcohol concentration.

The work station was safely designed in an attempt to eliminate any hazards that might occur when subjects reached and grasped the boxes. The driving gear belt as well as the motor were guarded to keep the subjects out of any physical risk. If for any reason the researcher felt that the

experiment should be interrupted, or in the case of an emergency situation, the equipment could have been quickly and easily shut down. The design of the equipment for safety was personally approved by the Chairman of the Institutional Review Board for research involving human subjects (see Appendix A).

### Scoring

Each resistor was set up by using Cartesian coordinates principles as follows:

1) Resistor 1 (22k): (4,0) and (0,6)

The first number (i.e., 4) denotes the fifth hole from a specific location identified as the origin of the circuit board (X-coordinate) and the second number (i.e., 0) denotes the first hole, the origin, of the circuit board (Y-coordinate).

2) Resistor 2 (3.3k.): (10,0) and (16,0)

3) Resistor 3 (33k): (6,8) and (8,12)

Performance on the dial adjustment task was assessed by analog dial readings as converted to digital values. Further, resistors (3.9k. and 12k.) were included in the boxes as distractors.

### Practice

To minimize learning effects, each subject attended three one hour practice sessions prior to starting the

experiment. These sessions were used for determining the individual workloads and train each participant to asymptote (see Appendix H for instruction details).

Practice trials were administered until the subjects reached their "maximum workload and asymptotic levels", which was the rate whereby a box of unassembled parts arrives at the workstation before assembly of the previous box of parts had been completed.

#### Alcohol Condition and Presentation Orders

In this study, all subjects received the four BAC conditions which were: 0.00 percent, 0.05 percent, 0.07 percent, and 0.09 percent.

At the placebo level (0.00 percent BAC), a trace of vodka was added to the orange juice, to provide a slight taste of alcohol without affecting BAC levels.

During each one of these alcohol conditions, the subjects performed all five task conditions depending on which criterion was emphasized. A fully counterbalanced order of presentation was maintained for alcohol condition, task order, and which criterion condition would be presented first.

Figure 4 shows the order of presentation of alcohol and task conditions. Two four by four latin squares, followed by the unpaced condition for the first four subjects and also preceded for the last four subjects, assigned the order

of presentation of the task conditions. Also, two four by four balanced latin square were used to assign the order of alcohol conditions.

Order of Presentation of Alcohol Conditions for  
Each Subject

Subject	*Alcohol Level
1 2 3 4 5 6 7 8	
A* B C D D C B A	A = 0.00% BAC
B C D A B C A C	B = 0.05% BAC
D A B C C A D B	C = 0.07% BAC
C D A B A B C B	D = 0.09% BAC

Order of Presentation of Task Conditions  
For Each Subject

Subject	1	2	3	4	5	6	7	8
1**	2	3	4	5	5	5	5	5
2	3	4	1	1	2	3	4	4
4	1	2	3	2	3	4	1	1
3	4	1	2	4	1	2	3	3
5	5	5	5	3	4	1	2	2

\*\*Task: 1 = max workload (paced condition)  
 2 = 75% max workload (paced condition)  
 3 = 50% max workload (paced condition)  
 4 = unpaced condition/accuracy  
 5 = unpaced condition/speed

Figure 4. Order of Presentation of Alcohol,  
and Task Conditions

## RESULTS

Two separate Analyses of Variance were utilized to evaluate the experimental results.

A single ANOVA procedure would not be appropriate because of the two distinct paced paradigms used in this study. That is, there are two task conditions in the unpaced condition, speed and accuracy. The former of these cannot meaningfully interact with any of the three task levels in the paced condition: 100%, 75%, and 50% of that maximum speed of work (wherein speed is implicitly predefined at the outset).

### Hypothesis 1: Alcohol effect

Assembly task performance was negatively affected by alcohol ingestion.

Paced Condition. With the exception of the meter adjustment errors, paced condition analyses (see Table 1, and see Appendix I, Tables 3 - 9) indicated significant BACs effect for the number of completed units, position errors, orientation errors, frequency of meter adjustment, improperly selected resistors, and incomplete boards.

Table 1. ANOVA SUMMARY  
(Paced Condition)

Independent Variables	Paced Task:		
	Alcohol (A)	% Workload (PT)	Interaction (A x PT)
Completed units	**	**	**
Position errors	**	*	
Orientation errors	**	*	
Frequency of Meter Adj.	**		
Magnitude of Meter Adj.			
Improper resistors	**		
Incompleted units	**	**	*

\*\* p < 0.01

\* p < 0.05

Performance decline and impairments shown by the subjects confirmed the results of this hypothesis. Very low BACs are sufficient to impair the operator and affect her performance.

Post Hoc Analysis, shown in of Appendix I, Tables 3 - 9, using the Tukey Honestly Significant Differences Test, revealed significant decreases ( $p = 0.01$ ) of 39.8% in the number of completed units when comparing performance at placebo to that at 0.09% BAC. A significant decrease ( $p = 0.01$ ) of 28.7% in the number of completed units also occurred when comparing performance at 0.05% BAC to that at 0.09% and of 29% when comparing performance at placebo to that at 0.07%.

There were increases of 24.17% in the number of position errors, 24.04% in the number of orientation errors, 25.54% in the frequency of meter adjustment errors, 34.54% in the number of improper resistors, 19.53% in the number of incomplete units when comparing each one of these performance measures at placebo to that at 0.09%.

Unpaced Condition. The unpaced condition analysis indicated a significant BACs effect for the number of completed units, position errors, orientation errors, improper resistors, frequency of meter adjustment errors, and incomplete units (see Table 2 and see Appendix J, Tables 10 - 16).

Table 2 ANOVA SUMMARY  
(Unpaced Condition)

Independent Variables	Alcohol (A)	Unpaced Task: Speed, Accuracy (UT)	Interaction (A x UT)
Completed units	**	**	**
Position errors	**	**	**
Orientation errors	**	**	
Frequency of Meter Adj.	**	**	
Magnitude of Meter Adj.			
Improper resistors	**	**	**
Incomplete units	**	**	

\*\* p < 0.01

By using the Tukey Honestly Significant Differences Test on the data related to Appendix J, Tables 10 - 16, the number of completed units decreased ( $p < 0.001$ ) by 45.5% when comparing performance at the placebo to that at 0.09%, 32.09% decrease when comparing performance at the 0.05% BAC to that at 0.09%, and 18.65% decrease when comparing performance at the placebo to that at 0.07%. The number of incomplete units decreased by 34.19% when comparing performance at the placebo to that at 0.09%, 22.6% increase when comparing performance at the 0.05% BAC to that at 0.09% and 21.7% increase when comparing the placebo to that at 0.07%.

When comparing performance at the placebo to that at 0.09% respectively, percent differences increase by 32.68% for the number of position errors, 34.00% for the number of orientation errors, 47.16% for the frequency of meter adjustment errors occurred. A difference from 0.0, for the placebo, to 1.25, for the 0.09% BAC, for the number of resistor errors was observed.

The Tukey Honestly Significant Differences test was selected over the Newman-Keuls test because the latter results in more Type I errors. For Type II errors, The Tukey Honestly Significant Differences is more powerful (Williges, unpublished class notes). In addition, the Tukey Honestly Significant Differences was developed to maintain the experimentwise error at  $\alpha$  for pairwise comparisons.

This will increase the sensitivity and the reliability in detecting differences.

The foregoing results indicate:

- (1) the production speed was slower under 0.09% BAC than under the placebo condition,
- (2) in general, assembly errors increased as a function of increased BACs (up to 0.09%) or of higher workload levels (up to the operationally defined 100% workload).

Hypothesis 2: Workload Effect

Production speed increased with increasing workload levels, up to the operationally defined 100% workload.

This hypothesis was also confirmed, in that, significant effect of paced task condition (maximum, 75%, 50% workload) was evident for the number of completed units, position errors, orientation errors, and incomplete units.

Subjects received more units to assemble at increasing workload levels which resulted in an increase of both number of completed units and assembly errors.

Increases of 34.53% in the number of correctly completed units, 41.17% in the number of incomplete units, 17.28% in the number of position errors and 21.62% in the number of orientation errors were observed for the significant paced task condition when 100% workload was imposed rather than 50% (see Table 1 and see Appendix I, Tables 3, 4, 5, 9).

Hypothesis 3: Alcohol, Task Interaction

As both the BACs and workload increased, production speed was slower, whereas assembly errors were higher.

Paced condition. Evident hypothesis confirmation was obtained by the BACs and paced task conditions interaction. The significant interaction was observed only for the number of completed units and the number of incompleting units (see Table 1 and see Appendix I, Tables 3, 9).

Increasing BACs slow the individual performance while increasing workload levels decrease the accuracy of that performance, as shown in the results related to the previous two hypotheses. Use of Omega-Square (Dodd and Schultz, 1973) showed a higher relative contribution of alcohol to the interaction (see Figures 5 and 6). However, an examination of Figure 6 shows that performance at 0.05% BAC is sensitive to workload. As workload increases performance decreases at this level of alcohol at a rate greater than the rates shown at other BAC levels. This result is especially important because many investigators consider 0.05% BAC to be the level below which the person is considered detoxified.

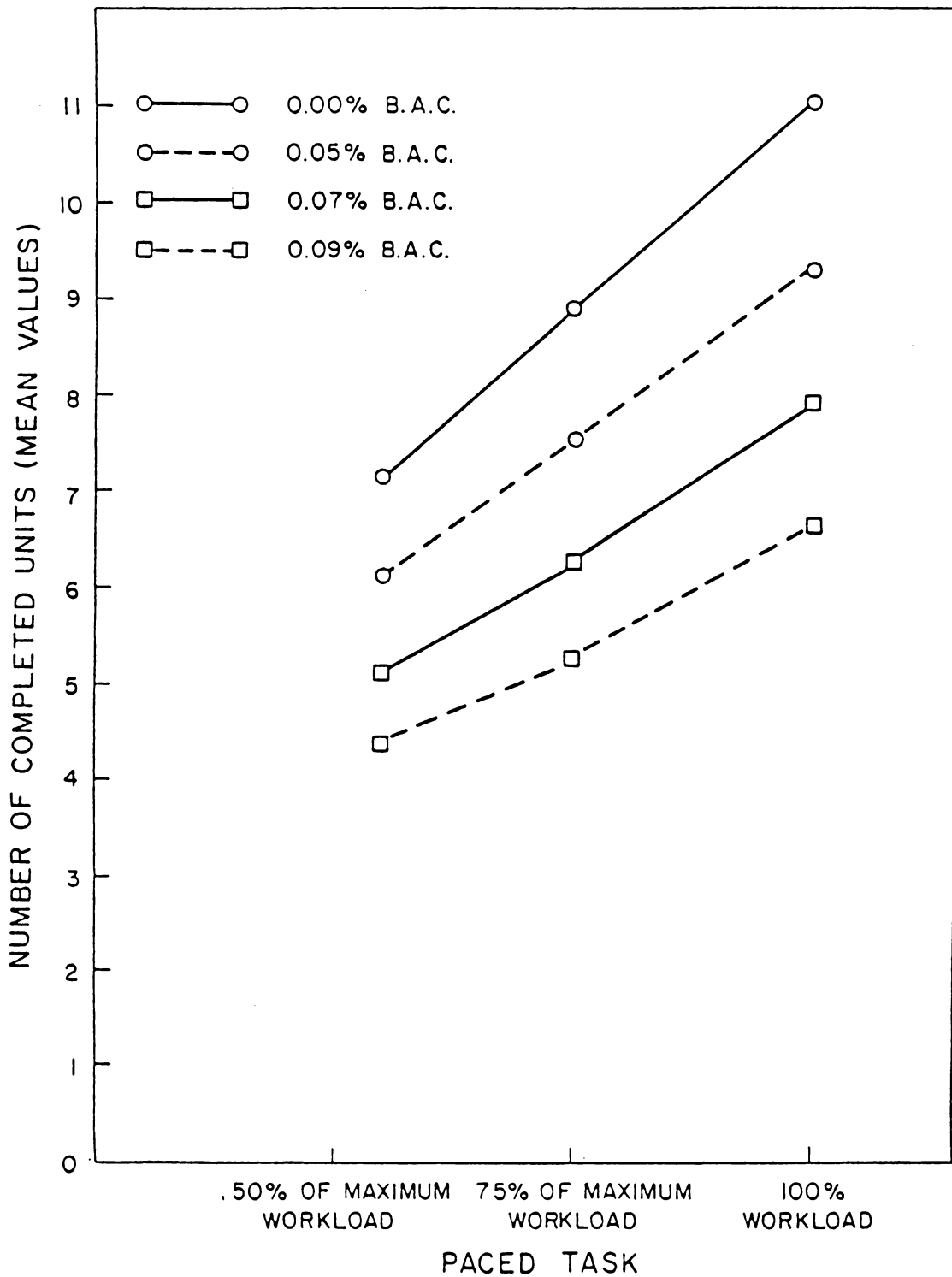


Figure 5. Alcohol, Task Interaction

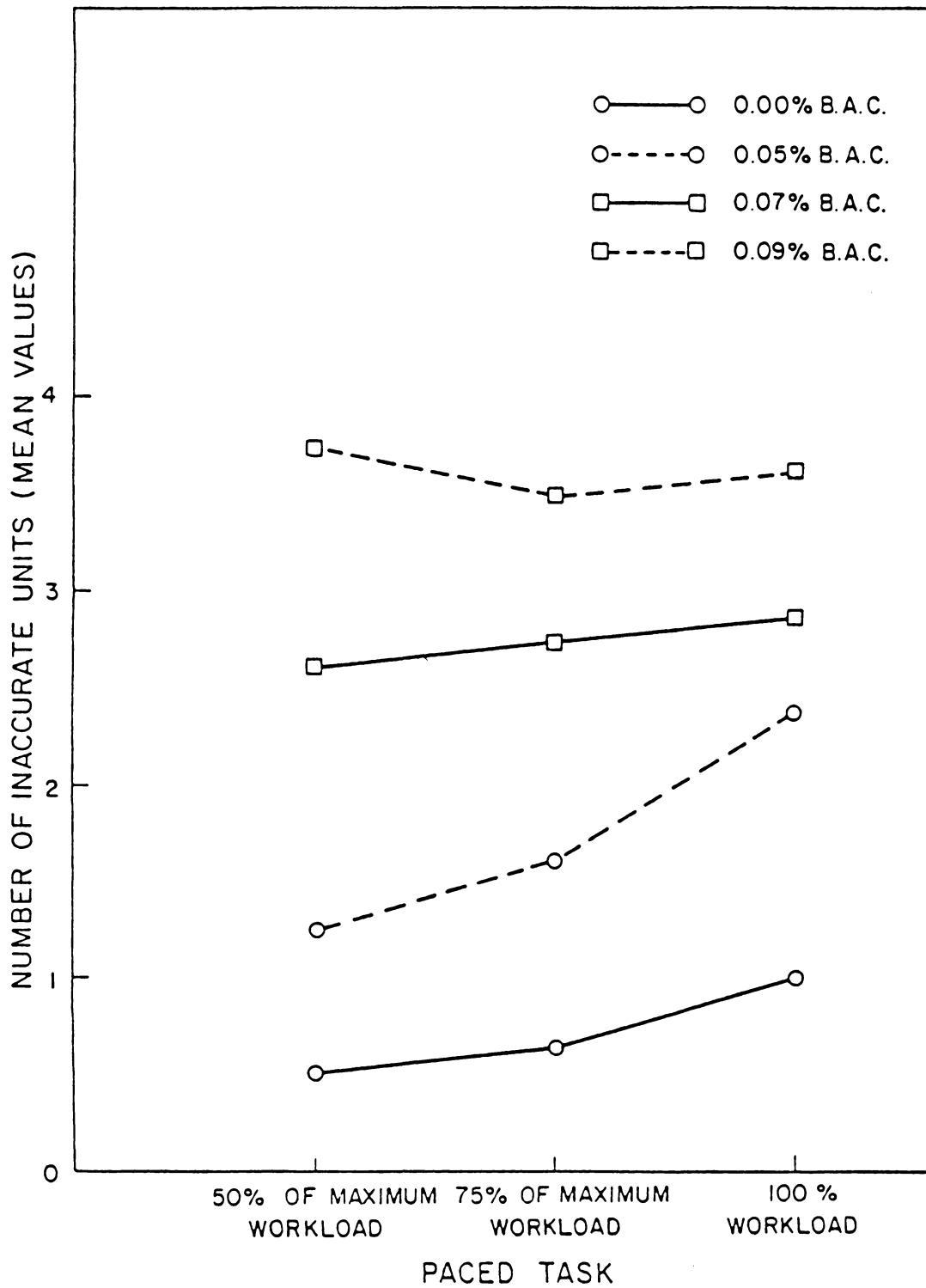


Figure 6. Alcohol, Task Interaction

Unpaced condition. Hypothesis 3 showed significant interaction between BACs and the unpaced task condition (see Table 2 and see Appendix J, Tables 10, 12, 15) for the three dependent variables: number of correctly completed units, number of position errors, and number of improperly selected resistors.

Alcohol effect contributed relatively more in the significant interaction with unpaced task conditions for the number of position errors and the number of resistor errors. An inverse relative contribution of alcohol effect was obtained for the number of completed units (see Figures 7, 8, 9).

#### Hypothesis 4: Speed Criterion

Both production speed and assembly errors were higher when the speed criterion was imposed over the accuracy criterion.

This hypothesis, as well as hypothesis 7 below, are both confirmed (see Table 2, and see Appendix J, Tables 10 - 16) by the speed-accuracy tradeoff. The results show that the degradation of accuracy occurs with increases in emphasis on performing with speed, and vice versa. This result is in accordance with Jennings, et al (1976).

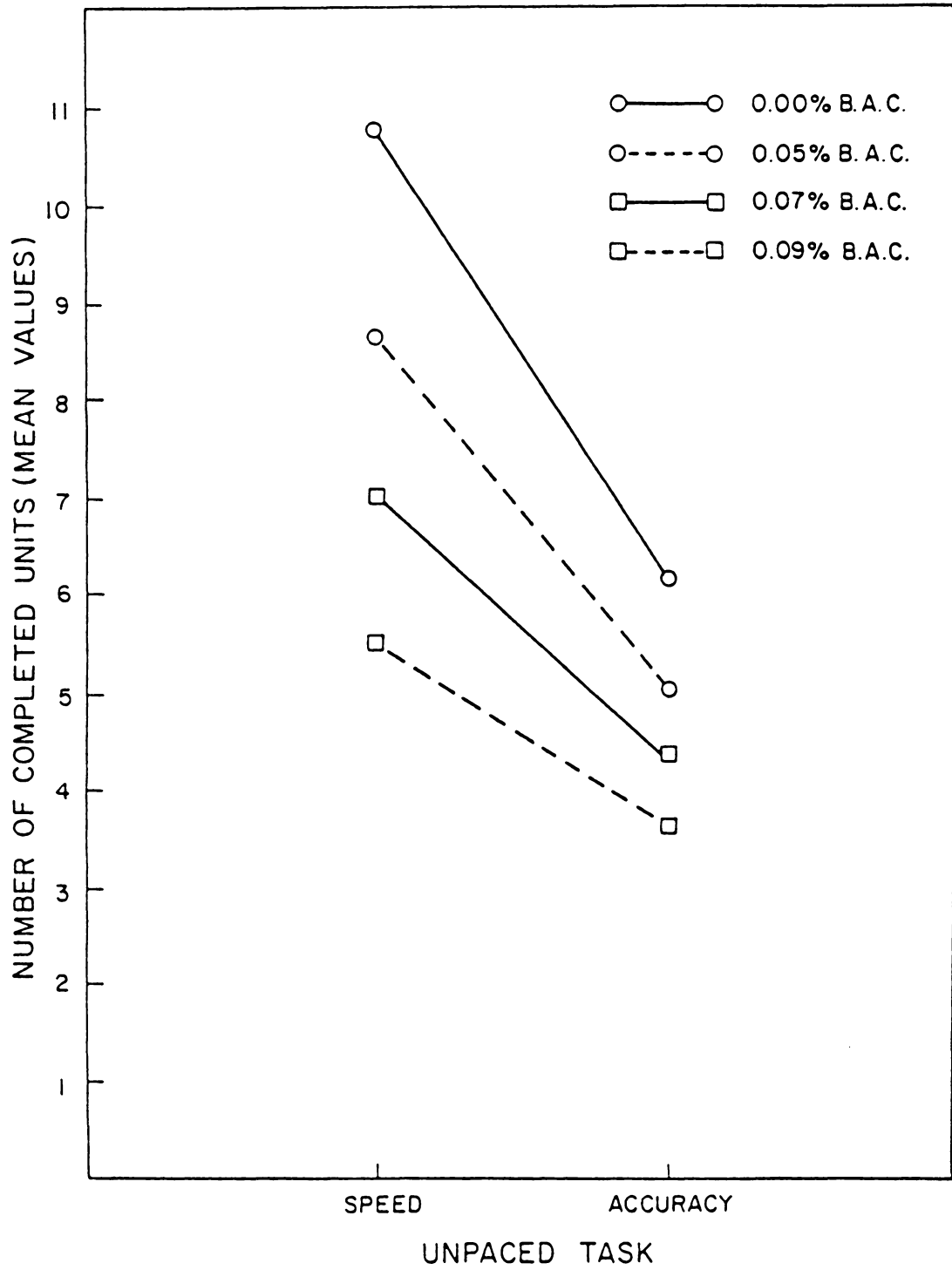


Figure 7. Alcohol, Task Interaction

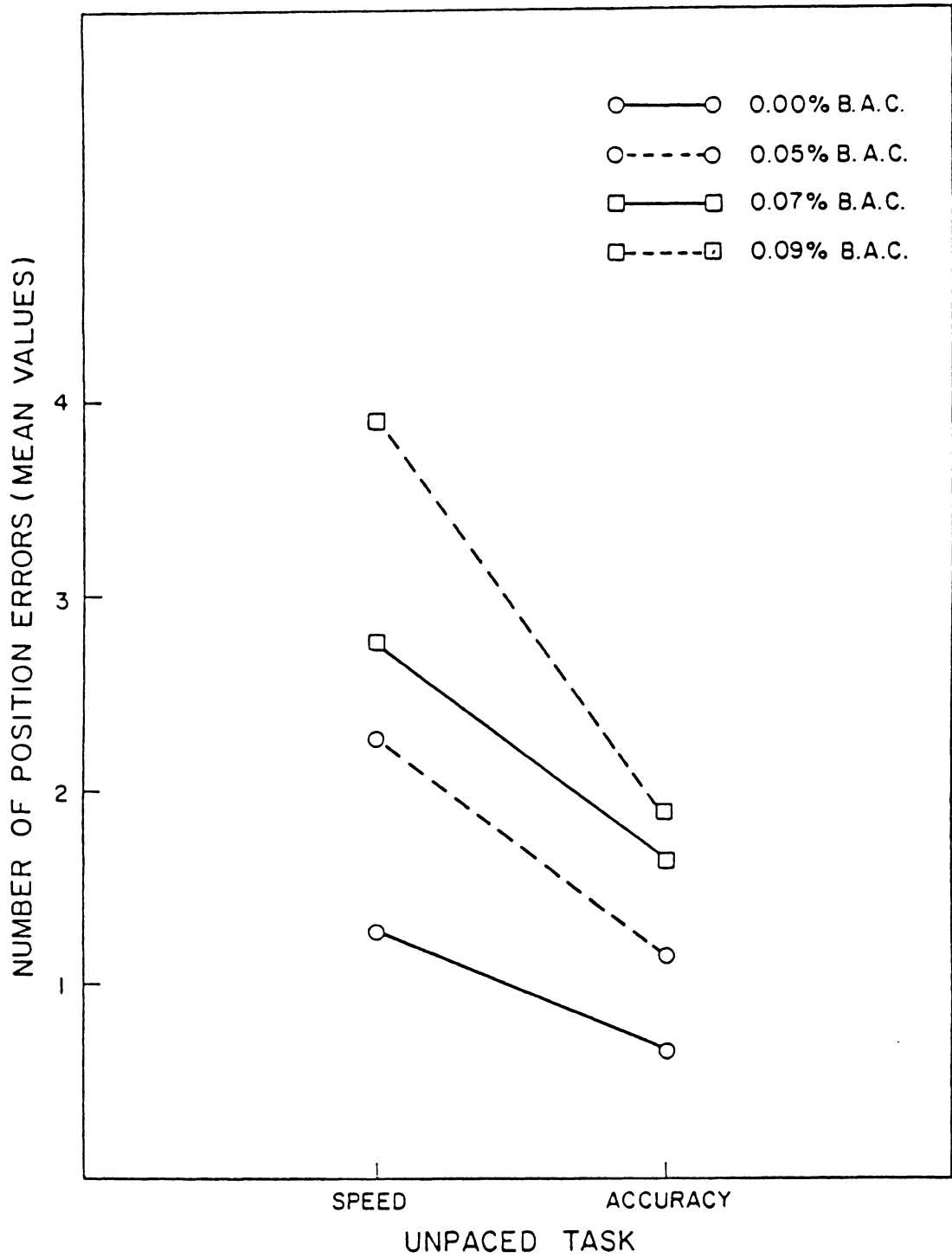


Figure 8. Alcohol, Task Interaction

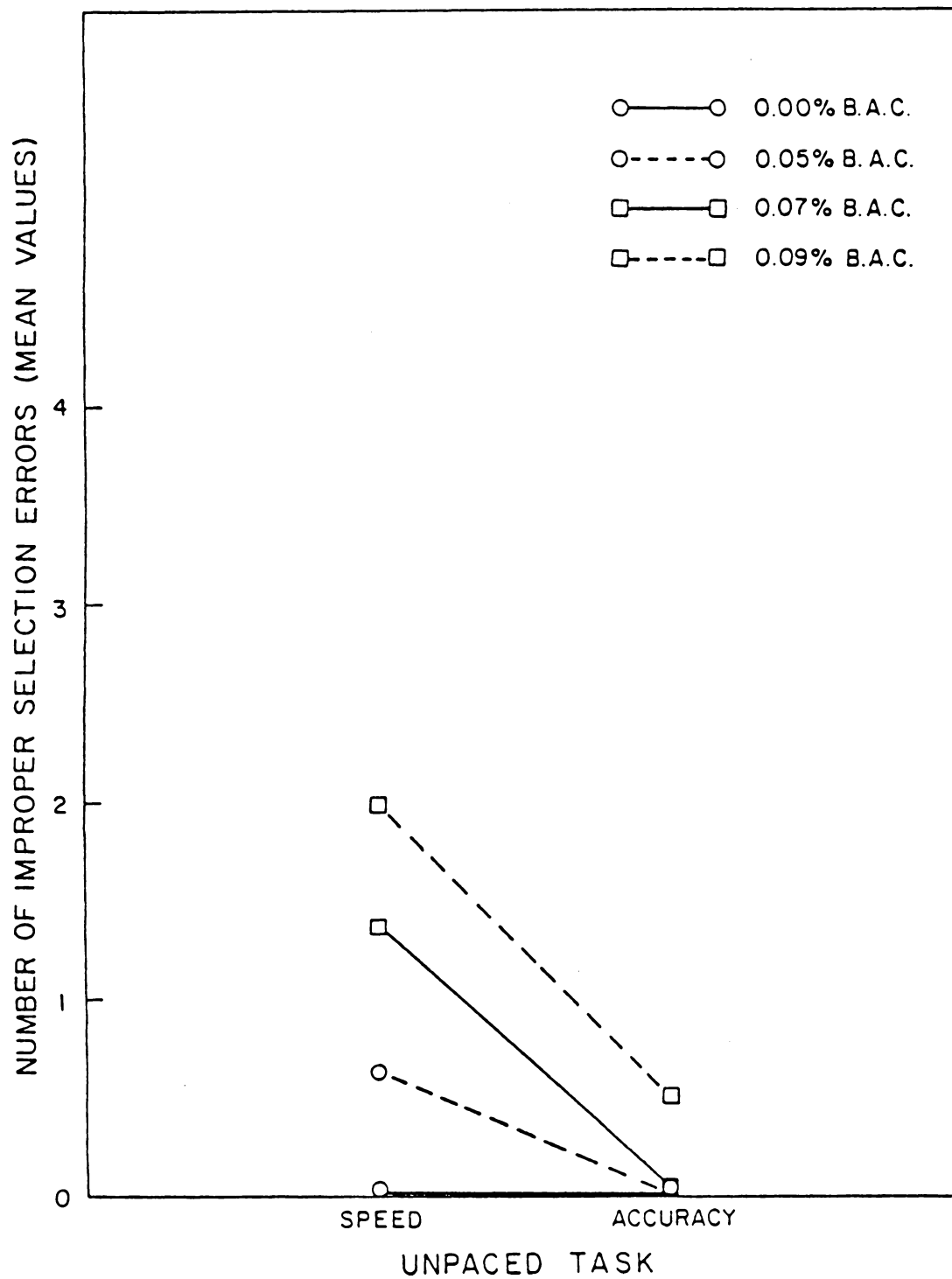


Figure 9. Alcohol, Task Interaction

### Hypothesis 5: Accuracy Criterion

Both production speed and assembly errors were lower when the accuracy criterion was imposed over the speed criterion.

This hypothesis (see above) is confirmed by the results that showed degradation of speed occurring with increases in emphasis on performing with accuracy. When accuracy was imposed over speed in the unpaced task conditions, the results indicated decreases of 39.76% for the number of completed units, 46.9% for the number of position errors, 43.24% for the number of orientation errors, 12.5% for the number of resistor errors, and 49.03% for the number of inaccurate units (see Table 2, and see Appendix J, Tables 10 - 16).

### Hypothesis 6: Paced Versus Unpaced

Both production speed and assembly errors were higher at 100% workload in the paced condition than the unpaced speed condition.

The Studentized T Test was used to examine the population means difference between the 100% workload and the unpaced speed condition. Hypothesis 7 was accepted for the number of completed units, position errors, orientation errors, frequency and magnitude of meter adjustment errors, improper resistors, and incomplete units.

The above result might be attributed to motivation. With a decrease in accuracy, subjects performance was higher when they did not dictate their own pace. This hypothesis was in contradiction to Salvendy (1969). See Appendix E and F for the overall means values.

## CONCLUSION

With the few exceptions, results from this study confirmed all the stated hypotheses.

A general summary is below:

- (1) At high BACs, participants showed more impairments and contributed more to the decline of their performance.
- (2) When the interval between boxes was shortened (up to subject's maximum performance) , production speed increased. Participants received more boxes to assemble at high workload levels than at low levels.
- (3) Assembly errors (except magnitude of meter adjustment errors) increased when higher BACs and workload were respectively administered.
- (4) Participants worked with greater speed of production and more assembly errors in the unpaced condition, when speed was emphasized over accuracy. An opposite result occurred when accuracy was emphasized over speed.
- (5) Both the production speed and the assembly errors were higher at 100% workload in the paced condition than speed in the unpaced condition. This hypothesis was a partial contradiction to Salvendy

(1969) who stated that the assembly errors are minimized and performance is maximized under unpaced condition of work.

(6) As both BACs and workload increased, production speed was low, whereas the assembly errors were high.

Extending these results to the population of workers who drink on the job, the impact on the industrial workload of the production of poorer quality work is considerable. Money is lost due to the rejection of inferior work, and the hours spent producing inferior products are wasted.

## RECOMMENDATIONS

The following are suggested recommendations for further studies on alcohol:

- 1) A duplicated research involving men as participants. Performance comparison between men and women would be appropriate.
- 2) Research which would investigate alcohol's effects on actual assembly tasks that are performed on the job.
- 3) Research utilizing video tape recordings and background grids to assess the alcohol's effects on micromotions that occur during the task.
- 4) Research which would generalize a more accurate alcohol dosage formula. The data base used in this study to develop the alcohol dosage formula was based on a small pilot sample and previous existing data.
- 5) Research which would investigate the alcohol's effects on decision making of a white collar task.

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## APPENDIX A

### IRB PROPOSAL

#### Research Project Involving Human Subjects Using Alcohol Ingestion

The basic purpose of this research was to investigate the effects of alcohol for a paced and unpaced assembly task.

#### General Procedure for Experimentations

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

- (1) A breath analysis prior to alcohol ingestion;
- (2) alcohol ingestion over a 20 minute period,
- (3) an additional period of about 10 minutes to allow absorption of alcohol into the system;
- (4) breath tests after the 10 minutes absorption.
- (5) a practice run of the experimental task;
- (6) the experimental task;
- (7) another breath test following the experimental task;
- (8) direct observation and intermittent breathalyzer tests on the premises until the breathalyzer tests indicate a blood alcohol level less than 0.03 percent;
- (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 consisted of female university students. Subjects were not used whose ability to give voluntary informed consent may be in question. No minors served as subjects.

### Safety Procedure

Safety performance of the task under levels of alcohol ingestion was emphasized in the experiment. The safety provisions were designed not only to minimize the potential of physical risk but where possible to eliminate such potential. No lasting detrimental effects were anticipated due to the levels of blood alcohol concentration which were not high.

Subjects participating in this experiment signed a release form allowing Health Services personnel to review their medical history. Should this review have indicated any problems which could interfere with safe ethanol consumption, individuals in question would have been eliminated from the study.

The work station and the conveyor belt were safely guarded in an attempt to eliminate any hazards that may occur when subjects access the workstation, reach for, or grasp the boxes. In addition, it was recommended to the subjects to work with short sleeves.

The subjects were transported home after the experimental session by the experimenter in his car.

The design of these equipment for safety was personally approved by the chairman of the Institutional Review Board for research involving human subjects.

#### Consent Procedures

The experimenter, either a staff member or a graduate student, provided the subject with a set of instructions. This set of instructions included a participants informed consent form (provided in appendix B).

#### Subject Privacy

In each experiment, numbers were assigned to subjects' names. The name associated with each number was discarded if a subject did not require her data. This protected the subject by providing anonymity for her data.

#### Potential Benefits

A great deal of research has been accomplished on the effects of alcohol on performance of psychomotor tasks. This essentially has been on elemental tasks such as reaction time, tracking, etc. Other than this, there is very little information which can be used to estimate effects on industrial productivity, quality control, and safety. Research on women performing an industrial task is very limited.

Although the potential benefits to the subject involved with the experiment is fairly limited, specific information about the effects of various levels of ingestion of alcohol on her performance capabilities will be gained. The potential benefit to whom this study is concerned is considerable. It is also of some significance to the legal rights, safety, and well being of employers and employees.

#### Risk-Benefit Comparisons

As described above, the potential benefits are considerable; the risks are relatively small. Thus, the evaluation of risk-benefit ratio for this series of research is qualitative.

The risks involved are much less than those inherent to the tasks which are performed every day in industry. Specifically, this research deals with low levels of alcohol which are relatively mild.

## APPENDIX B

### 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 that level generally defined, by law, to constitute intoxication.
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 be paid 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 concentration is less than 0.03 percent.
4. The session should take approximately four hours. During the first half-hour you will ingest the alcohol.

During the second half-hour you will perform the experimental tasks. Detoxification will occur during the last three hours. It may take less than the full three hours.

5. At the end of the experimental session you will be paid for your participation including the time you spent detoxifying at the rate of \$3.00/hr.
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 concentration, indicated by a breathalyser test, is less than 0.03 percent.

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. Stombler, Chairman, Institutional Review Board for research involving human subjects at 961-5283.

We hope that you will find this experiment an interesting one. The faculty and graduate students involved greatly appreciate your help as a participant. If you have any question 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 prebias the experimental results.

YOUR SIGNATURE BELOW INDICATES THAT YOU HAVE READ YOUR ABOVE STATED RIGHTS AND OBLICATIONS 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 \_\_\_\_\_

\_\_\_\_\_

APPENDIX C

QUESTIONNAIRE

Subject Number: \_\_\_\_\_

Age: \_\_\_\_\_ Sex: \_\_\_\_\_

Weight: \_\_\_\_\_ on \_\_\_\_\_; \_\_\_\_\_ on \_\_\_\_\_  
\_\_\_\_\_ on \_\_\_\_\_; \_\_\_\_\_ on \_\_\_\_\_  
\_\_\_\_\_ on \_\_\_\_\_; \_\_\_\_\_ on \_\_\_\_\_  
\_\_\_\_\_ on \_\_\_\_\_; \_\_\_\_\_ on \_\_\_\_\_

Please Note:

The following questions are intended to give the experimenters information regarding the general levels of alcohol and caffeine consumption to which your body is accustomed. You may ignore any questions which are offensive to you.

1. How much of the following do you consume per week?

a) Beer (number of cans, bottles, or glasses)

\_\_\_\_\_ per week.

b) Wine (Table wine; i.e., white, red, rose)

\_\_\_\_\_ per week.

c) Fortified Wine (port of sherry)

\_\_\_\_\_ per week.

d) Hard (distilled) liquor (whiskey, gin, etc)

\_\_\_\_\_ per week.

2. During the course of a week, on which days do you nor-

mally consume alcoholic beverages? (Circle correct days).  
 Monday Tuesday Wednesday Thursday Friday Saturday Sunday

3. Indicate the percentage of your alcohol consumption associated with each of the days you may have circled in question 2; writing the correct percentage values in the spaces provided for morning, afternoon, and evening. (Remember that the total of these percentages should equal 100)

	M	T	W	H	F	S	S
morning	___	___	___	___	___	___	___
afternoon	___	___	___	___	___	___	___
evening	___	___	___	___	___	___	___

4. How much coffee do you drink?

- a) Morning \_\_\_\_\_ cups per day.
- b) Afternoon \_\_\_\_\_ cups per day.
- c) Evening \_\_\_\_\_ cups per day.

5. Are you presently taking any prescribed drugs? If so, list the type of drug and when taken.

yes / no \_\_\_\_\_  
 \_\_\_\_\_

6. Are you presently using legal non-prescribed drugs? (cold capsules, vitamins, pamprin, etc.) If so, please list the type of drug and when taken.

yes / no \_\_\_\_\_  
 \_\_\_\_\_

7. Are you presently taking oral contraceptives?    yes / no

## APPENDIX D

### ALCOHOL DOSAGE CALCULATIONS

1. Convert body weight in pounds by the conversion factor 2.205.

Example: for a 105 lb. person,  $105/2.205 = 47.62$  kg.

2. Calculate the required amount of ethyl alcohol in grams by multiplying body weight in kg. by:

0.356 for 0.05 percent B.A.C.,

0.529 for 0.07 percent B.A.C.,

0.707 for 0.09 percent B.A.C.,

Example: For 0.07 percent B.A.C.,  $47.62 \times .529 = 25.19$ ml.

3. Calculate the required amount of vodka in milliliters by dividing the ethyl alcohol in milliliters by the percentage of alcohol in the vodka.

Example: using 80 proof vodka which is 40 percent alcohol,  $25.111/0.4 = 62.97$  ml. of 80 proof vodka.

4. Calculate the total volume of the drink in ounces by dividing the person's weight in pounds by 50. Then multiplying that quotient by 4 (which serves the purpose of giving 4 ounces of liquid per 50 pounds of body weight).

Example:  $(105/50)(4) = 8.4$  oz.

5. Convert the total volume in ounces to total volume in milliliters by dividing the total volume in ounces by the conversion factor .03381.

Example:  $8.4 \text{ oz} / .03381 = 248.44 \text{ ml.}$

6. Calculate the required amount of orange juice in milliliters by subtracting the amount of vodka in milliliters from the total drink volume in milliliters.

Example:  $248.44 \text{ total ml.} - 62.17 \text{ ml. of vodka} = 185.46 \text{ ml. of orange juice.}$

APPENDIX E

PACED CONDITION: OVERALL MEANS

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	<u>CU</u>	<u>PE</u>	<u>OE</u>	<u>FMA</u>	<u>MMA</u>	<u>IS</u>	<u>IU</u>
0.00% BAC	9.00	0.875	0.7916	0.958	1.994	0.666	0.708
0.05% BAC	7.62	2.083	1.75	2.791	1.991	0.75	1.75
0.07% BAC	6.41	2.5	2.2083	3.33	1.989	1.08	2.75
0.09% BAC	5.41	3.62	2.291	3.75	1.983	1.91	3.62
50% W/L	5.6875	2.093	1.82	2.96	2.001	1.093	2.46
75% W/L	6.9875	2.187	1.906	2.84	1.984	0.812	2.12
100% W/L	8.6875	2.531	2.312	3.062	1.983	1.031	1.03

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APPENDIX F

UNPACED CONDITION: OVERALL MEANS

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	CU	PE	OE	FMA	MMA	IS	IU
0.00% BAC	8.37	0.937	0.967	1.75	1.9975	0.00	0.9375
0.05% BAC	5.81	1.75	1.43	2.43	1.9962	0.312	2.00
0.07% BAC	5.68	.18	2.12	3.16	1.9875	0.687	2.875
0.09% BAC	4.56	2.87	2.75	3.31	1.9868	1.25	3.875
Speed	7.93	2.53	2.31	3.25	1.989	1.0	3.25
Accuracy	4.78	1.34	1.31	2.03	1.995	0.175	1.59

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APPENDIX G

Alchol Mean Values

Predicted	Attained	Standard Deviation
0.00%	0.00%	--
0.05%	0.0491%	0.0021843
0.07%	0.0704%	0.001679
0.09%	0.0885	0.00554

## APPENDIX H

### INSTRUCTIONS

The following are the actual instructions given to the subjects:

"For this study you are going to perform an assembly task. In each of the four sessions in which you will be participating, you will perform five trials. Each trial will last two minutes. you will begin with two practice trials to help you get warmed up. There will be an emphasis on speed or accuracy in two of the five trials you will be performing. You will be given a certain amount of alcohol (Vodka) and orange juice. You will then perform the assembly task. You will have 20 minutes to ingest the alcohol, (make sure that you make your drink last for the entire 20 minutes, by sipping it slowly). After you have ingested the alcohol, 10 more minutes will be allowed for the alcohol to take effect. The assembly task will take about 10 minutes to complete. After this session has been completed, 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?"

At the beginning of each session, subjects were also instructed as follows: "In the speed condition, it is most important for you to assemble the largest number of circuit boards as possible within the two minutes. To assemble the boards as fast as you can is the best way to be productive. In the accuracy condition, it is most important for you to be as accurate as possible by assembling the proper resistors in the proper position, the proper orientation and adjusting the meter to the specified value. Consequently, any missing or defective units will be treated as incomplete units. You will begin the trial when you hear the signal, and when you hear the signal again, please stop whatever you are doing and wait for my instructions. Questions?"

The problem of subject motivation was approached by instructing each participant "work as quickly and as accurately as possible, remembering that you are expected to earn the wages owed to you here just as you would be expected to on the job." Further, each subject was told that her work performance would be compared with the work of the other subjects, and that competition is encouraged.

APPENDIX I

Table 3. Dependent Variable: Completed Units  
Paced Condition

Source	dF	MS	F	W <sup>2</sup>	Proportion of Variance
Between-subject					
Subject(s)	7				
Within-subject					
Alcohol (A)	3	57.482	145.40**	.4602	.4630
A x S	21	0.3953			
Task (T)	2	72.510	127.22**	.38645	.3906
T x S	14	0.5699			
A x T	6	0.9409	11.78**		
A x T x S	42	0.078986			
Total	95	3.913			

\*\*p < 0.01

Table 4. Dependent Variable: Position Errors  
Paced Condition

Source	dF	MS	F
Between-subject			
Subjects (S)	7		
Within-subject			
Alcohol (A)	3	30.9583	55.92**
A x S	21	0.5535	
Task (T)	2	1.6979	4.51*
T x S	14	0.376	
A x T	6	0.3645	0.86
A x T x S	42	0.4241	
Total	95	1.4416	

\*\*p < 0.01

\*p < 0.05

Table 5. Dependent Variable: Orientation Errors  
Paced Condition

Source	dF	MS	F
Between-subject			
Subjects (S)	7		
Within-subject			
Alcohol (A)	3	25.8715	29.90**
A x S	21	0.89533	
Task (T)	2	2.26041	5.15*
T x S	14	0.438988	
A x T	6	0.413194	0.92
A x T x S	42	0.448908	
Total	95	1.4209	

\*\*p < 0.01

\*p < 0.05

Table 6. Dependent Variable: Frequency of Meter  
Adjustment Errors  
Paced Condition

Source	dF	MS	F
Between-subject			
Subjects (S)	7		
Alcohol (A)	3	14.36111	24.96**
A x S	21	0.57535	
Task (T)	2	0.38541	0.84
T x S	14	0.45684	
A x T	6	0.8715218	2.08
A x T x S	42	0.419146	
Total	95	0.966667	

\*\*p < 0.01

Table 7. Dependent Variable: Magnitude of Meter  
Adjustment Errors  
Paced Condition

Source	dF	MS	F
Between-subject			
Subjects (S)	7		
Within-subject			
Alcohol (A)	3	0.000495	2.41*
A x S	21	0.0002058	
Task (T)	2	0.0033875	1.59*
T x S	14	0.0021351	
A x T	6	0.0003153	0.31*
A x T x S	42	0.0010042	
Total	95	0.0010115	

\*Not significant

Table 8. Dependent Variable: Improper Resistors  
Paced Condition

Source	dF	MS	F
Subjects (S)	7		
Within-subject			
Alcohol (A)	3	12.81944	79.77**
A x S	21	0.160714	
Task (T)	2	0.69791	2.71
T x S	14	0.25744	
A x T	6	0.267361	1.39
A x T x S	42	0.19196	
Total	95	0.61008	

\*\*p < 0.01

Table 9. Dependent Variable: Incomplete Units  
Paced Condition

Source	dF	MS	F	W <sup>2</sup>	Proportion of Variance
Between-subjects					
Subjects	7				
Within-subject					
Alcohol (A)	3	38.0833	103.19**	0.7846	0.7943
A x S	21	0.3690			
Task (T)	2	1.6979	7.66**	0.0204	0.0236
T x S	14	0.2217			
A x T	6	0.5729	2.98*		
A x T x S	42	0.19196			
Total	95	3.4246			

\*\*p < 0.01

\*p < 0.05

APPENDIX J

Table 10. Dependent Variable: Completed Units  
Unpaced Condition

Source	dF	MS	F	W <sup>2</sup>	Proportion of Variance
Between-subject					
Subjects (S)	7				
Within-subjects					
Alcohol (A)	3	42.3906	137.95**	0.3457	0.3545
A x S	21	0.30729			
Task (T)	1	159.39062	449.10**	0.442	0.444
T x S	7	0.3549			
A x T	3	5.2656	133.53**		
A x T x S	21	0.03943			
Total	63	5.6941			

\*\*p < 0.01

Table 11. Dependent Variable: Orientation Errors  
Unpaced Condition

Source	dF	MS	F
Between-subjects			
Subjects (S)	7		
Within-subjects			
Alcohol (A)	3	10.04166	22.49**
A x S	21	0.44642	
Task (T)	1	16.00	22.40**
T x S	7	0.71428	
A x T	3	1.125	
A x T x S	21	0.41071	
Total	63	1.23412	

\*\*p < 0.01

Table 12. Dependent Variable: Position Errors  
Unpaced Condition

Source	dF	MS	F	W <sup>2</sup>	Proportion of Variance
Between-subject					
Subjects (S)	7				
Within-subject					
Alcohol (A)	3	10.541667	33.42**	0.4033	0.417
A x S	21	0.31547			
Task (T)	1	22.5625	58.77**	0.2913	0.2978
T x S	7	0.38392			
A x T	3	1.35416	10.58**		
A x T x S	21	0.12797			
Total	63	1.2023			

\*\*p < 0.01

Table 13. Dependent Variable: Frequency of Meter  
Adjustment Errors  
Unpaced Condition

Source	dF	MS	F
Between-subject			
Subjects (S)	7		
Within-Subjects			
Alcohol (A)	3	7.80729	15.68**
A x S	21	0.49776	
Task (T)	1	23.7656	70.81**
T x S	7	0.33705	
A x T	3	0.55729	2.05
A x T x S	21	0.27157	
Total	63	1.12276	

\*\*p < 0.01

Table 14. Dependent Variable: Magnitude of Meter  
Adjustment Errors  
Unpaced Condition

Source	dF	MS	F
Between-subjects			
Subjects (S)	7		
Within-subjects			
Alcohol (A)	3	0.0005057	0.54*
A x S	21	0.0009283	
Task (T)	1	0.00056486	0.28*
T x S	7	0.002046	
A x T	3	0.001264	1.34*
A x T x S	21	0.0009462	
Total	63	0.001006	

\*Not significant

Table 15. Dependent Variable: Improper Resistors  
Unpaced Condition

Source	dF	MS	F	W <sup>2</sup>	Proportion of Variance
Between-subject					
Subjects (S)	7				
Within-subjects					
Alcohol (A)	3	4.625	37.00**	0.336	0.349
A x S	21	0.125			
Task (T)	1	12.25	68.60**	0.302	0.308
T x S	7	0.1785			
A x T	3	1.95833	15.67**		
A x T x S	21	0.125			
Total	63	0.6309			

\*\*p < 0.01

Table 16. Dependent Variable: Incomplete Units  
Unpaced Condition

Source	dF	MS	F
Between-subject			
Subjects (S)	7		
Within-subjects			
Alcohol (A)	3	25.0572	101.13**
A x S	21	0.24776	
Task (T)	1	43.890625	20.17**
T x S	7	0.1785	
A x T	3	0.22395	1.27
A x T x S	21	0.17633	
Total	63	2.5969	

\*\*p < 0.01

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EFFECTS OF ALCOHOL INGESTION AND WORKLOAD  
ON QUALITY AND PRODUCTIVITY OF FEMALES  
FOR A PACED AND UNPACED ASSEMBLY TASK

by

Djamel E. Tergou

(Abstract)

Eight subjects participated in an assembly task in which they assembled a simulated circuit board. The task required exact placement of three similarly coded resistors, which were chosen from a set of five resistors, followed by adjusting a voltmeter to a specified value. Participants performed the assembly task under various blood alcohol concentrations (Placebo, 0.05%, 0.07%, and 0.09%) to assess the effects of alcohol and workload on quality and productivity.

Three levels of paced task conditions and two levels of unpaced task conditions were used for the assembly task conditions. In this study, seven measures of performance were assessed: number of correctly completed units, number of orientation errors, number of position errors, frequency and magnitude of meter adjustment errors, number of improper resistors, and number of incomplete units.

A significant alcohol effect ( $p < 0.0001$ ) was evident for all the dependent variables in the two pacing paradigms with the exception of the magnitude of the meter adjustment errors.

Under the paced paradigm, the task condition was significant ( $p < 0.0001$ ) for the number of completed units, the number of position errors, the number of orientation errors and the number of completed units.

Unpaced task condition revealed significance ( $p < 0.0001$ ) for all the dependent variables with the exception of meter adjustment magnitude.

Interactions of alcohol by paced task condition were significant for the number of inaccurate units ( $p < 0.00161$ ) and the number of completed units ( $p < 0.0001$ ). Unpaced condition revealed interaction effects for the number of completed units ( $p < 0.0001$ ), the number of position errors ( $p < 0.0001$ ), the number of resistor errors.