EFFECTS OF ALCOHOL AND ERROR CRITICALITY ON ALPHANUMERIC TARGET ACQUISITION

by

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(ABSTRACT)

Eight male subjects searched for target alphanumeric characters using a touch-input equipped CRT under four levels of blood alcohol concentration (BAC), 0.0, 0.05, 0.07, and 0.09 percent. Participants visually searched randomly generated 108-character arrays for imbedded target characters, touching the CRT surface at target locations when located. Half of the search trials used arrays containing no target, providing the opportunity for "giving up" any search trial at the discretion of the participant. A monetary incentive/penalty system was used to define low- and high-criticality search trials. Search time, touch accuracy, the number of trials completed, percent "give-ups," and hand travel time were all significantly degraded by the alcohol dosages used. An alcohol-by-criticality interaction was observed for percent give-ups, and an alcohol-by-target presence interaction was

observed for mean search times. Changes in search time due to alcohol were observed only for trials containing no target.

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INTRODUCTION

Problem Statement

In 1980, the U.S Department of Health and Human Services estimated the industrial losses in America due to alcohol-related absenteeism to be just under 25 billion dollars for that year (U.S. Department of HHS, 1981). These economic losses do not include lost productivity due to alcohol-impaired workers who remain on the job, although it has been estimated that alcoholics comprise five percent of the current American workforce and that alcohol abusers constitute another five percent (Schramm, Mandel, and Archer, 1978). Estimates of annual productivity losses due to alcohol on the job are more complex to develop than estimates of absenteeism because worker rights to privacy preclude the direct gathering of data in the workplace. Such estimates can be made using laboratory simulations of industrial tasks and projected frequencies of on-the-job alcohol impairment per occupation type.

Past laboratory studies do not provide a base from which to make satisfactory productivity inferences. The literature on alcohol and human performance is focussed upon the general areas of automobile driving, general psychological issues, and pharmacological issues. Studies dealing with general issues in psychology usually investigate the effects of alcohol on behavioral processes under various conditions. Alcohol research found in the pharmacological literature is concerned with such issues as rates of absorption, dosage levels, and physiological effects of alcohol.

Research directly concerned with the effects of alcohol on industrial productivity is relatively rare. A few studies have used facsimile industrial tasks to evaluate effects of alcohol on industrial productivity (Barbre and Price, 1982; Price and Flax, 1982; Price and Hicks, 1979; Price and Liddle, 1980; and Tergou and Price, 1982). These studies evaluated alcohol effects on tasks performed in industry while manipulating variables such as complexity, incentives, workload, and pacing.

The research proposed here is the sixth in a series of alcohol studies conducted at the Safety Projects Office at the Virginia Polytechnic Institute and State University. The general purpose of this group of studies is to provide estimates of the effects of alcohol on the performance of tasks found in industrial operations. The approach taken in selecting tasks has been to use tasks which as a group cover a large portion of the range of observable operator behaviors in industry. An established taxonomy of tasks developed by Berliner, Angell, and Shearer (1964) was used to classify generally the various tasks used in the series within the motor, perceptual, or mediational task domain. The purpose of the series of studies is to samply parsimoniously and in a systematic fashion a wide array of industrial task elements while maintaining a reasonable level of fidelity to the "real-world". In other words, the intent has not been to employ "pure" tasks which necessarily exclude other behaviors in the taxonomy. The research proposed here is designed to emphasize the mediational processes involved with visual search and perceived error criticality.

Visual search is unquestionably a pervasive task component in modern industry (Schoonard, Gould, and Miller, 1973). It occurs in a multitude of settings, such as radiological evaluation (medical and industrial), production line inspection, food and drug inspection, and inspection involved in the electronics technologies. These are examples of jobs that include complex sets of perceptual behaviors of which target acquisition is a component. Many, if not most, so-called white-collar occupations require substantial amounts of visual search and detection during job performance. Examples of search tasks in business settings include such as balance sheet interpretation, inventory control, and management of accounts receivable, in which locating various target character strings is a principal element in successful task completion.

Since the mid-70s and the popularization of mini- and microcomputers, computer interaction has become commonplace on the job in many types of business. The present frequency with which workers at various levels perform their jobs using video display terminals (VDTs) has certainly exceeded most expectations. Tasks such as word processing, data management (especially using canned business programs such as Visicalc), drafting, and circuit design are all tasks now routinely performed using VDTs, and all require varying amounts of visual search and detection for their successful completion.

A common criticism of research involving industrial task simulation is that errors made by experimental participants cannot be considered representative of "real-life" errors, especially when the actual errors can result in seriously adverse consequences. Simulating accidents in the laboratory has proven to be especially difficult to achieve to the satisfaction of most critics, and exotic attempts have been made to provide substitutes for actual consequences. For example, the government-funded Injury Control Research Laboratory has equipped simulated hazardous machinery to spray careless operators with water or stamp dangerously placed hands with ink (U.S. Dept. of HEW, 1972).

The concept of punishing participants to motivate careful performance is to be approached cautiously. It might be argued that using monetary incentive/penalty systems is among the most reasonable solutions, where portions of money gained through instances of productive performance are lost due to instances of inaccurate performance. Although difficult to equate with loss of limb (or materials or clients) which might occur due to on-the-job errors, money appears to be the most readily available "real-world" motivator which can be ethically employed in the research setting. It may in fact be the case that incentive/penalty systems are the best available solution to the general problem of accident simulation given the strict limitations placed on attempts to punish research participants. Incentive systems have been successfully used to direct the performance of participants toward more accurate or more rapid responding, although penalties have not themselves been included (Price and Flax, 1982; Swensson, 1972). There is no readily apparent reason to assume that a monetary system which includes penalties along with incentives could not be succesfully used to define levels of error criticality in an experimental setting. A highly critical task could in this case involve a greater monetary loss for improper execution than a task defined as having relatively low criticality.

The problem, therefore, which is addressed by this research is to obtain laboratory data on the effects of alcohol ingestion on the performance of a visual search task similar to that found in industry. This is in order to contribute to a data base for general estimates useful to industry.

Literature Review

There is no doubt that alcohol use on the job is in general detrimental to job performance. Little is known regarding which aspects of job behavior are most affected by alcohol and at what dosage levels performance changes begin to appear. Several reviews of the literature have been published (Carpenter, 1962; Jellinek and McFarland, 1940; Wallgren and Barry, 1970), but characteristics of the available research have in each case prevented substantial interrelating of results among studies.

The problems commonly encountered with attempts to integrate the alcohol research have been summarized by Levine, Greenbaum, and Notkin (1973) in a study which attempts to classify and integrate the findings. First, studies have utilized a variety of tasks with a wide range of independent and dependent variables, with no consistant index of performance being used. It is noted that this is a particular problem for comparisons among studies. Also, experiments differ in the method of determining proper alcohol dosages. For example, some studies have used fixed dosages for all subjects, committing the serious error of disregarding body weight as a factor in determining intoxication levels. Often, important characteristics of the subject population are not considered, such as participant sex and typical drinking habits (e.g., heavy drinkers and abstainers). Further, studies differ in the type of alcohol administered, using pure ethanol, synthetic ethanol, whiskey, brandy, beer, vodka, and wine, even though absorption rates differ for each of these beverages. As a result, little information is gained from studies which report dosages but not blood alcohol concentrations (BACs) or estimates thereof, such as breath test results. Finally, various temporal aspects unfortunately are ignored in many alcohol studies, where the time allowed to ingest dosages or the time between ingestion and task performance is allowed to vary or is not reported.

As mentioned above, limited knowledge exists regarding the dosages at which performance changes normally occur. This situation is partly due to a common shortcoming in alcohol studies, where only a single dosage is administered and performance is compared to a placebo condition of some sort. It is usually the case that a main effect of alcohol is expected, but this does not diminish the importance of specifying the magnitude of the effect, which is often not linear across dosages (Price and Flax, 1982). Additionally, attempts to compare results across studies are usually difficult due to the variety of dosage schemes used in the single-dosage studies. This could be easily avoided by varying dosages in each study.

The following is a brief summary of the alcohol literature as classified by the effects of alcohol in the sensory, motor, psychomotor, and cognitive task domains.

Sensory effects. Visual acuity, the ability to perceive differences in luminance which delineate shape, appears to have a very limited susceptibility to the effects of alcohol, even when dosages are given which physically incapacitate the participant (Brecher, Hartman, and Leonard, 1955; Marquis, Kelly, Miller, Gerard, and Rapoport, 1957;

Mortimer, 1963;). Participants have been seen to exhibit a lowered resistance to glare when intoxicated (Forster and Starck, 1959; Newman and Fletcher, 1941). Dark adaptation seems to be largely insensitive to the effects of alcohol and has been seen to actually improve during intoxication (Blomberg and Wassen, 1959; Yudkin, 1941). Color perception studies using alcohol indicate in general that intoxicated participants are less sensitive to color changes and that there is a relatively greater loss of sensitivity toward the red end of the visual spectrum than toward the blue end (e.g., Schmidt and Bingel, 1953).

Auditory functioning appears to be similarly insensitive to alcohol, where sensitivity _per se_ is less affected than the ability to discriminate among sounds, pitches, and rhythms (Pikhanen and Kauko, 1962). However, gustatory and olfactory abilities seem to be easily diminished by relatively small doses of alcohol (Irvin, Ahokas, and Goetzl, 1950). Tactile sensitivity has been reported to be affected very little by alcohol, while sensitivity to pain can be shown to be decreased during intoxication, as might be expected (Wolff, Hardy, and Goodell, 1942).

Motor effects. Standing steadiness has been demonstrated to be easily disrupted by alcohol ingestion, a situation which is intensified when the eyes are kept open during testing (Begbie, 1966). This is in contrast to the effects of alcohol on steadiness while walking, where behavior is less impaired when the eyes are kept open (Fregly, Bergstedt, and Graybiel, 1967). Hand steadiness has also been shown to be sensitive to the effects of alcohol in studies by Muller, Tarpey, Giorgi, Mirone, and Rouke (1964) and by Price and Liddle (1980), although hand steadiness in the latter study cannot be separated from body sway.

Psychomotor effects. Reaction time is the most commonly employed measure in studies examining the effects of alcohol on psychomotor abilities. In general, alcohol increases response latency at higher BAC levels (greater than 0.1 percent), but findings are inconsistent at lower dosages (Blum, Stern, and Melville, 1964; Carpenter, 1962; Tarter, Jones, Simpson, and Vega, 1971). Reaction time paradigms which use visual rather than auditory stimuli have reported less pronounced effects of alcohol (Talland, 1966). Increased task difficulty seems to intensify alcohol's effects on response latency, as in the cases of complex discriminations or secondary loading tasks (Carpenter, 1959). Performance on tasks which require a high degree of motor coordination along with quick responding is relatively more sensitive to alcohol than on simple reaction time tasks. For example, typewriting errors have been shown to increase dramatically with only slight decreases in speed (Joyce, Edgecombe, Kennard, Weatherall, and Woods, 1959). The trend has been for response latency to be less sensitive to alcohol dosages when tasks are used which emphasize motor dexterity than when tasks are used which emphasize correct responding to complex stimuli (Lawton and Cahn, 1963; Levine, Greenbaum, and Notkin, 1973; Muller, Tarpi, Giorgi, Mirone, and Rauke, 1964; Takala, Siro, and Tiovainen, 1958).

Cognitive effects. As interpreted by Levine *et al*. (1973), the effects of alcohol on problem-solving abilities are variable and there is an apparently greater disruptive effect of alcohol on measures of accurate rather than speedy responding. In tests of arithmetic problem solving, decrements in performance have been shown to range from about 10 to about 30 percent between higher and lower dosages (0.33 and 0.66 grams of alcohol per kilogram of body weight). Exemplary studies are those by Frankenhauser, Myrsten, and Jarpe (1962) and Ekman, Frankenhauser, Goldberg, Hagdahl, and Myrsten (1964). Tasks performed while being presented with delayed auditory feedback were found to be sensitive to a relatively small dose of alcohol (0.5 g/kg), in which scores on a series of tests involving counting, reading, and arithmetic were decreased by an average of 31 percent (Forney and Hughes, 1965; Hughes, Forney, and Richards, 1965).

The ability of participants to judge subjectively the passage of time has been reported to be significantly degraded by alcohol intoxication. An 82 percent increase in the estimation of a moment of time was reported by Joerger (1960). Tasks requiring generally more complex intellectual functions such as solving logic problems using verbal concepts are reported to be slightly but consistantly affected in a negative fashion by alcohol (Hutchison, Tuchtie, and Gray, 1964; Nash, 1962). The effects of alcohol on learning and memory have been investigated to some extent as well. In their review of the literature, Wallgren and Barry (1970) note that the detrimental outcomes reported for short-term memory performance (i.e., Hutchison et al., 1964) could alternately be attributed to impaired learning, retention, or attentiveness during learning or retention. Studies investigating alcohol effects on long-term memory have shown performance deficits which are less pronounced if material is recalled under the same alcohol condition as during learning of the material, indicating an interaction between alcohol and cueing (Storm and Caird, 1967).

Touch entry devices. This investigator found no research on operating touch entry devices (TEDs) at various BACs. TEDs are switches which place the site of VDT interaction on the same surface as information displayed by the associated computer. As such, TEDs take advantage of the natural response of pointing with the finger as a communication mode. An infrared (IR) touch entry device was used for this research. This type of switch consists of an intersecting network of horizontal and vertical infrared beams which in effect create a matrix of X-Y coordinates. These beams are directed across the front surface of a CRT, and are interrupted when the CRT is touched with the finger. The location of such an interruption in the X-Y grid is quantified by the computer, at which point it is relatively simple to guide software functions as if these quantities had been input via a more conventional input device. This provides a unique means for collecting alcohol data relevant to a variety of eye-hand coordination issues because touch locations can be used for measurement of variables such as touch accuracy and target identification. By including a means of specifying concurrent real-time values, measures of visual search time and touch latency are also made available.

Much of the research on TEDs has investigated their usefulness in Air Traffic Control (ATC) settings. Bauerschmidt and LaPorte (1979), for instance, reported that interaction times using one TED-display configuration were almost three times faster than those using a track ball and keyboard system. In the United Kingdom, a great deal of TED research was conducted at the ATC Evaluation Unit in the late 60s. This research involves one type of TED, called the Johnson switch, which consists of an overlay for the CRT, containing rows of exposed wires through which touch-activated changes in capacitance are detected. This type of switch has been in use in ATC in the U.K. for several years and interested readers can refer to publications by Allinson, Johnson, Hopkin, and Allnut (1967) or Orr and Edinborough (1969).

Objectives of the Research

The primary objective of this research was to detect changes in the perseverance of participants searching for a possible visual target when alcohol dosage and the criticality (monetary cost) of missed targets are varied. Perseverence was measured as the percentage of search trials in which a target was present and the intoxicated participant "gave up." This was to examine the "willingness" of mildly intoxicated participants to continue performance of an optional task, namely continuing to look for a target which may or may not be present. The consequences of failing to detect targets involved the money earned by participants, lending at least some amount of actual error criticality to the laboratory task. The practical relevance of this measure lies in the possibility of detecting in the laboratory reliable changes in the decision-making behavior associated with this type of open-ended search task being performed by alcohol-impaired workers on the job.

A further objective of this research was to evaluate changes in processing time which might occur for different alcohol dosages as separated from concurrent changes in motor response time. That is, an evaluation of alcohol effects on search time in a targeting task was deemed to be a worthwhile contribution to the alcohol literature. Information of this type may at present only be found in reaction time studies which report total task times as well as response latencies. Normally this happens by accident only and is consequently rare. Almost by definition, the pure reaction time (RT) studies tend to minimize the number of stimulus and response elements in their tasks, making them hard to relate to most applied issues.

The third general objective of this research was to measure touch accuracy in the intoxicated and sober participants. Measures of accuracy are useful to alcohol researchers, because these measures serve as anchor points for comparing otherwise esoteric tasks in the literature. Further, the accuracy of performance using various touch entry devices is generally unknown (Schulze, 1982). Given that accuracy might vary for different TEDs, any data provided for a new device using a generalizable task would be a meaningful contribution to that body of knowledge.

METHOD

Task Description

This thesis examines the effects of alcohol on the performance of an alphanumeric target acquisition task using a VDT equipped with a touch entry device (TED). A system of monetary incentives and penalties was used to define high or low criticality of incorrect performance in detecting targets. Subjects performed the detection task after ingesting a mixture of 80-proof vodka and orange juice which was calculated to produce one of four BAC levels--0.0, 0.05, 0.07, or 0.09 percent. The mean attained BACs are presented in Appendix A.

Measurements were made of changes in total task time, search time, percentage of give-ups, hand travel time, touch accuracy, number of trials completed, and money earned per session. In addition, measures of near visual acuity were made using an Orthorater to detect any change on this measure in intoxicated subjects.

The targeting task in the study required participants to visually locate and then touch a target alphanumeric character located in a field of non-target characters.

Participants attempted to locate the target character (there are 36 possible, A-Z and 0-9) which was randomly located on a monochromatic CRT display and touch the surface of the TED in the area of the located target. In effect, the participants were asked to "touch the target". The target occupied one coordinate of a completely occupied 9 x 12 matrix. An additional 107 non-target characters (three sets of the remaining alphanumerics, plus either two or three random non-target characters repeated a fourth time to complete the matrix of 108 locations) were randomly distributed at the other coordinates of the matrix. Thus, each search trial involved a total of 108 characters to be examined. No-target trials were randomly interspersed with target trials such that, in the long run, half of the trials contained no target. During these trials participants still searched a field of 108 characters. This created the scenario in which participants might give up the search for a target which was actually present, thinking that the trial was a no-target instance. The rationale for presenting no-target trials is that participants must at some point choose to give up the search for a target if one is not found, thus providing a metric of perseverance under different alcohol dosages and criticality levels.

Participants began each trial by pressing and holding closed a small pushbutton switch located beneath the right forefinger and mounted on the armrest of the chair used in the study. This caused a computer to display the target character for a few seconds and produce an auditory indication of error criticality for the trial. After 22 seconds, the screen was erased and the computer presented the field of 108 characters randomly dispersed in the center area of the screen. At this point the field may or may not have contained the target character. From the time of presentation of this array, the participant visually searched the screen while maintaining contact with the fingertip switch. If a target was visually located, the participant then touched the area of the screen over the located target as quickly as possible. Activation of the TED by this touch caused the screen to be erased. Upon resumed contact with the fingertip switch the next target character was introduced, thereby beginning the next search trial. If no target could be located before a participant felt compelled to proceed to the next trial, the participant would release the switch and touch an area on the screen apart from the search area and defined as a "no-target" indicator. This erased the screen until the next trial was begun by again pressing the armrest switch.

Computer measurement of the interval between array presentation and loss of contact with the switch provided an estimate of search time. Measurement of the interval between loss of contact with the switch and the touching of the screen provided data for hand-travel time evaluation. The level of criticality (high or low) was randomly determined for each search trial, such that 50 percent of the trials were of high criticality and 50 percent were of low.

Independent Variables

There were three independent variables, blood alcohol concentration, error criticality, and target presence.

1. Blood alcohol concentration was manipulated by administering dosages to participants based on sex and body weight, using amounts of alcohol shown in previous research to be appropriate (Barbre and Price, 1982; Tergou and Price, 1982). For a complete description of alcohol dosage procedures used see Appendix A.
2. Error criticality was manipulated by increasing or decreasing the amount of money lost by participants due to errors in target search. Participants were informed of the criticality for each trial

beforehand. The exact amounts involved are specified under "Money earned" below.

3. The absence or presence of a target within each field to be searched was varied by including targets on only half of the search trials, thus providing the scenario for optional maintained searching during no-target trials.

<u>Dependent</u> <u>Variables</u>

There were nine dependent variables. These were total task time, search time, hand travel time, percent hits, distance off-target, percent give-ups, number of trials completed, money earned, and near visual acuity. A description of each is provided below.

1. Total task time was defined as the sum of the search time and hand travel time values for each search trial. This measure was only computed for trials containing a target, since hand travel times for no-target search trials were not measured. The reason for not collecting these hand travel time data is that the touch area for partipant indication of "no target" was located in the upper left corner of the display. The distance required for the hand to travel in order to touch this region was considered

to be nonequivalent to the distances required to touch target characters, and for this reason these data were not collected.

2. Search time was defined as the interval from presentation of the array to be searched to loss of contact with the fingertip switch. Analyses were conducted on mean search times, which were computed at the end of each 15-minute task session (of about 25 to 30 trials).
3. Touch accuracy was defined by two variables, namely the percentage of screen touches which activated the target switch site (percent hits) and the mean distance of touches from target sites (distance off-target). Units of distance are specific to the particular TED-monitor combination used and are approximately 0.5 cm in this instance.
4. Percent give-ups was the proportion of instances in which the no-target area of the TED was activated during trials in which a target was actually present.
5. Hand travel time (HTT) was defined as the interval from loss of contact with the switch to activation of the TED. It was not possible to cause a false HTT value to be stored by releasing the pushbutton prior to array presentation.

6. The number of trials completed included all trials regardless of errors made.
7. Money earned per session was the dollar amount earned by participants according to the following payoff scheme. Payment was made by providing a starting dollar amount and thereafter providing a reward for every search trial completed. The largest reward was given for correct detection ($ .15), the second largest was given for failing to detect "low-criticality" targets ($ .12), and the lowest reward was given for failing to detect "high-criticality" targets ($ .07). Thus, each trial completed was rewarded such that the amount of money gained above the starting amount could not be negative at the end of a task session.
8. Near visual acuity was measured using an Orthorater before and after each alcohol dosage. Differences in these scores, for example 20/18 and 20/20, were compared for each subject at each alcohol level used.

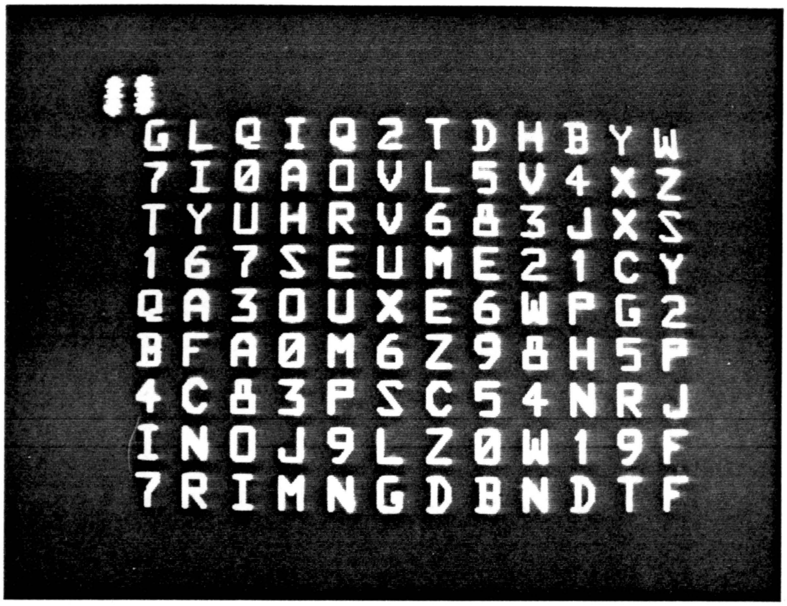
<u>Subjects</u>

The subjects were eight male students from the Virginia Polytechnic Institute and State University. All participants were righthanded to accommodate the equipment configuration, all were at least 21 years of age (mean age was 21.5), and all had corrected near visual acuity of 20/25 or better using both eyes (mean was 20/19). The subjects were screened for contraindications of safe ethanol consumption by University Health Services personnel prior to participation, using records on file at the University. All subjects were treated in accordance with American Psychological Association ethical standards. Subjects were paid $3.00 for a one-hour training session prior to data collection. Other payments were made to the participants at the end of the second and fourth task sessions.

Apparatus

Computer configuration. An Apple II computer with 48K RAM and high resolution graphics was used to display search arrays, collect data, and control hardware processes. A listing of the BASIC program used to present search fields and record data is provided in Appendix D. The 7 pixel x 9 pixel uppercase Huddleston font (Snyder and Maddox, 1978) was implemented using shape tables. Photographs of sample search fields using this font are presented in Figure 1. The cluster of asterisks at the upper left of the display denotes the region for "no-target" indication. A small five-volt, spring-loaded pushbutton switch was connected to the game paddle port in the Apple and was used to mark the beginnings and ends of search times and HTTs. This switch was attached at the front end of the right armrest on the office chair used, such that it could be pressed easily with the right forefinger of any seated participant. A photograph of the location of this switch is provided in Figure 2.

Monitor. A black-and-white, 31 cm diagonal, Clinton CRT with a P-4 phosphor was used to display search arrays. Display characteristics of the CRT were optimized to reach the maximum modulation attainable at the highest spatial frequency which could be displayed. This was done by setting the contrast and luminance at arbitrary levels, photometrically determining the luminance modulation at those levels, resetting the levels, rescanning, etc., until modulation was maximized. Scans were accomplished as described below, and were the result of other research being done in the Human Factors Laboratory.



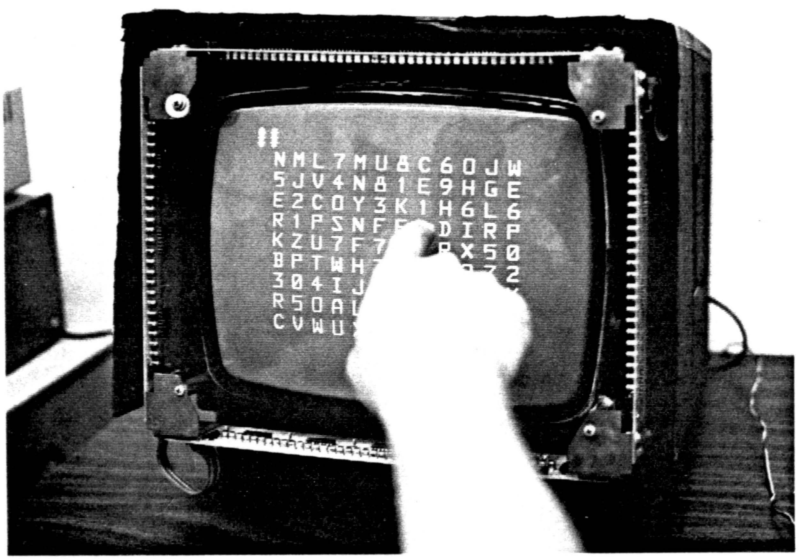


Figure 1: Photographs showing Typical Search Fields

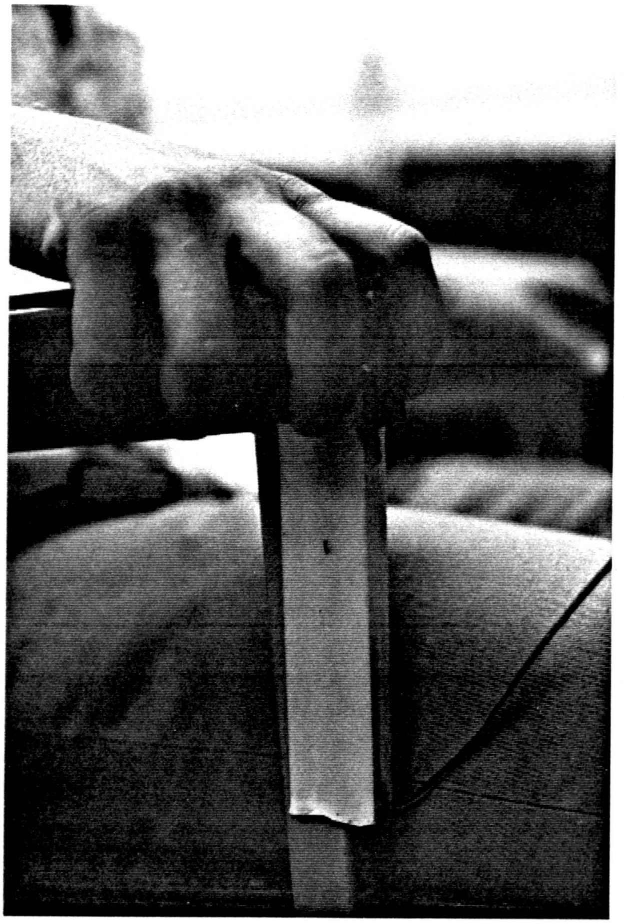


Figure 2: Photograph of Fingertip Switch Location

The active area of the screen was made into a 23 cm square, and a scanning eyepiece assembly was focussed on the displayed image at the center of the screen. The eyepiece assembly consisted of a scanning eyepiece (Gamma Scientific, Model 700-10) with a 0.025 x 2.5 mm slit aperture. The eyepiece was fitted with a 2.4X objective. The scanning optics were connected to a digital photometer (Gamma Scientific, Model 2400) by means of a fiber optics cable. The photometric system was calibrated to a National Bureau of Standards traceable light standard designed and constructed in the Human Factors Laboratory at VPI and SU. The scanning eyepiece assembly was mounted on an Aerotech 260D X-Y positioner. The positioner and the photometric system were controlled by a Digital Equipment Corporation PDP 11/55-LPS 11 computer system.

The luminance and contrast settings were preset by adjusting the black level and video gain circuits of the monitor. Scanning was accomplished by first positioning the microscope at the center of a raster line and focussed. The computer system then caused the eyepiece to traverse a 10 mm distance at a sampling rate of 1000 Hz. This scan was done vertically and horizontally.

Touch entry device. The monitor was equipped with a Carroll infrared TED (Model TSKF/40x24, Figure 1). This switch consists of a 24 x 40 network of intersecting infrared beams. Software interpreting TED input was sensitive to each node of the network. Characters to be searched were placed directly under those nodes which created a less dense network of 9 x 12 locations. These nodes, or switch sites, were the candidate target locations and the unused sites among these were the areas where inaccurate touches could occur. Touch accuracy was measured in two ways, namely as the proportion of touches which did not activate the target switch site and as the distance between the target coordinate and the nearest activated site.

Procedure

1. Prior to participation, subjects answered questions about their weekly alcohol consumption and drug use. Participants completed a questionnaire regarding customary alcohol and drug intake. Individuals who were normally abstainers or who were "morning drinkers" did not participate in the study. A copy of the medical questionnaire used is provided in Appendix E.
2. Participants were screened by Health Services personnel.

3. Participants were given a test of near visual acuity, using a Bausch and Lomb Orthorater.
4. Participants were given printed and tape-recorded instructions regarding consent and the details of the experiment. These instructions included assurances regarding their rights to privacy and specified their obligation not to drink alcohol for 24 hours prior to participation and not to eat or drink anything except water for four hours prior to participation. A copy of the informed consent form and the transcribed recorded instructions are presented in Appendices B and C, respectively.
5. Subjects underwent a practice session while sober, consisting of the number of search trials needed to reach a performance level such that no more than a five percent change was observed between three consecutive sets of 10 trials. This measure was the amount of money which would have been paid to participants for an entire 15-minute task session during which only 10 trials were completed. Three sets of 10 trials were performed and then each of the next three sets was compared to the average money earned for the first three sets. In every instance, only six sets were required to reach the stability criterion of five percent.

6. Subjects participated in four weekly evening task sessions, during which they ingested vodka mixed with orange juice, provided breath specimens as required for breath analysis, received an Orthorater examination, and underwent a 15-minute session of target search trials.
7. Participants were then given another breath test and another vision test, and waited to detoxify as needed to below 0.03 percent BAC.
8. Participants were driven home by the experimenter when breath tests indicated no BAC level at or above 0.03 percent (there were four participants in the laboratory during each evening session).
9. Participants were paid following the second session and were paid and debriefed following the final task session. Subjects were paid a base amount of $12.00 for each of the four evening sessions. This amount was augmented according to the payoff system described above.

RESULTS

One-way analyses of variance (ANOVAs) were conducted on average money earned per session (MO) and differences in near visual acuity (NVA). Potential alcohol-criticality interactions were investigated using 4 x 2 x 8 ANOVAs for total task time (TTT), hand travel time (HTT), percent hits (PCH), distance off-target (DIST), number of completed search trials (NT), and percent give-ups (PGU). A 4 x 2 x 2 x 8 ANOVA was used to investigate a potential alcohol-criticality-target presence interaction for mean search time (MST). Summaries of these ANOVAs are provided in Tables 1 through 12 below.

TABLE 1

ANOVA SUMMARY OF MONEY EARNED

Source	df	MS	F	p-value
Subjects (S)	7	.0964		
Alcohol (A)	3	.2084	17.51	<.0001
A x S	21	.0119		
Total	31			

TABLE 2

ANOVA SUMMARY OF NEAR VISUAL ACUITY

Source	df	MS	F	p-value
Subjects (S)	7	2.143		
Alcohol (A)	3	.0833	0.09	.9667
A x S	21	.9643		
Total	31			

TABLE 3

ANOVA SUMMARY OF TOTAL TASK TIME

Source	df	MS	F	p-value
Subjects (S)	7	18.2857		
Alcohol (A)	3	4.5467	1.18	.3408
A x S	21	3.8505		
Criticality (C)	1	.1504	.15	.7079
C x S	7	9.5585		
A x C	3	.4473	.80	.5081
A x C x S	21			
Total	63			

TABLE 4

ANOVA SUMMARY OF HAND TRAVEL TIME

Source	df	MS	F	p-value
Subjects (S)	7	.7924		
Alcohol (A)	3	.5873	7.87	<.002
A x S	21	.0746		
Criticality (C)	1	.0042	2.47	.1614
C x S	7	.0017		
A x C	3	.0016	.64	.6018
A x C x S	21	.0025		
Total	63			

TABLE 5

ANOVA SUMMARY OF PERCENT HITS

Source	df	MS	F	p-value
Subjects (S)	7	360.370		
Alcohol (A)	3	419.841	9.01	<.0005
A x S	21	46.614		
Criticality (C)	1	.631	.33	.5836
C x S	7	1.911		
A x C	3	.236	.33	.8047
A x C x S	21	.720		
Total	63			

TABLE 6

ANOVA SUMMARY OF DISTANCE OFF-TARGET

Source	df	MS	F	p-value
Subjects (S)	7	13.3751		
Alcohol (A)	3	11.4614	10.26	<.0002
A x S	21	1.1171		
Criticality (C)	1	.0046	.13	.7273
C x S	7	.0349		
A x C	3	.0617	.59	.6271
A x C x S	21	.1043		
Total	63			

TABLE 7

ANOVA SUMMARY OF NUMBER OF COMPLETED TRIALS

Source	df	MS	F	p-value
Subjects (S)	7	7.3571		
Alcohol (A)	3	5.9583	13.00	<.0001
A x S	21	.4583		
Criticality (C)	1	5.0625	.85	.3885
C x S	7	5.9911		
A x C	3	2.1042	.38	.7693
A x C x S	21	5.5565		
Total	63			

TABLE 8

ANOVA SUMMARY OF PERCENT GIVE-UPS

Source	df	MS	F	p-value
Subjects (S)	7	.365		
Alcohol (A)	3	64.177	82.12	<.0001
A x S	21	.781		
Criticality (C)	1	255.636	2824.7072	<.0001
C x S	7	.091		
A x C	3	3.443	8.715	<.0006
A x C x S	21	.395		
Total	63			

TABLE 9

SIMPLE-F SUMMARY FOR PGU A x C INTERACTION

LOW CRITICALITY:

Source	df	MS	F	p-value
A	3	20.0779	50.82	<.0001
S x A x C	21	.3951		

HIGH CRITICALITY:

Source	df	MS	F	p-value
A	3	47.5428	120.33	<.0001
S x A x C	21	.3951		

TABLE 10

ANOVA SUMMARY OF MEAN SEARCH TIME

Source	df	MS	F	p-value
Subjects (S)	7	21.2268		
Alcohol (A)	3	67.7148	14.30	<.0001
A x S	21	4.7346		
Criticality (C)	1	35.9015	43.36	<.0003
C x S	7	.8279		
Target (T)	1	2591.0195	865.66	<.0001
T x S	7	2.9931		
A x T	3	38.1907	10.23	<.0002
A x T x S	21	3.7328		
C x T	1	30.6386	17.76	<.004
C x T x S	7	1.7256		
A x C	3	.2657	.33	.8057
A x C x S	21	.8120		
A x C x T	3	.4867	.98	.4203
A x C x T x S	21	.4959		
Total	127			

TABLE 11

SIMPLE-F SUMMARY FOR MST A x T INTERACTION

TARGET PRESENT:

Source	df	MS	F	p-value
A	3	6.3117	1.69	>.05
S x A x T	21	3.7329		

TARGET NOT PRESENT:

Source	df	MS	F	p-value
A	3	99.59	26.68	<.01
S x A x T	21	3.7329		

TABLE 12

SIMPLE-F SUMMARY FOR MST T x C INTERACTION

TARGET PRESENT:

Source	df	MS	F	p-value
C	1	.1042	.06	.7592
S x C x T	7	1.7256		

TARGET NOT PRESENT:

Source	df	MS	F	p-value
C	1	66.4358	38.5	<.01
S x C x T	7	1.7256		

It should be noted that some of the insignificant F-ratios presented above are considerably smaller than unity. With respect to this situation, both Hayes (1963) and Winer (1971) state that an F-ratio smaller than one can only be attributed to sampling error or to violation of some of the assumptions required for the model. The Kolmogorov-Smirnov test for normality failed to reject this assumption in every instance. It is difficult to account for the very small F-ratios presented above, and therefore inferences about population effects should be made cautiously in these instances.

Mean search time decreased with higher BAC (Figure 3). The Tukey HSD procedure detected significant differences at the .01 level between 0.0 and 0.07, and between 0.0 and 0.09 percent BAC.

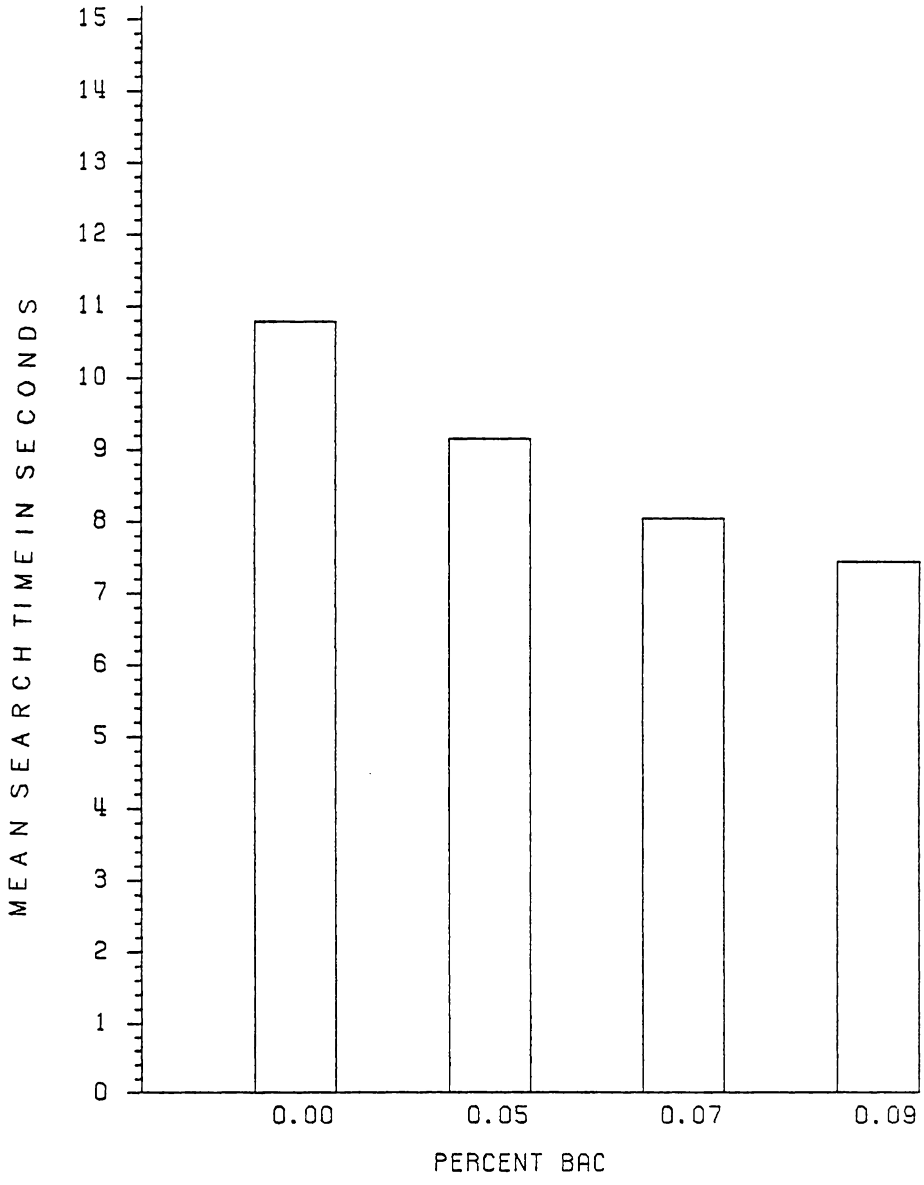


Figure 3: Main Effect of BAC on Mean Search Time

A significant alcohol-by-target presence interaction was observed for mean search time (Figure 4). The simple-F test indicated that the search time means for the four BAC conditions were significantly different only when targets were not present (Table 11). The differences within the pairs of means were significant at the .01 level for all four BAC levels. For no-target search trials the differences between the placebo and the two highest BAC levels were significant at the .01 level. For each of the four no-target means there were three remaining differences which were significant at the .01 level. Each of these no-target means were significantly different from the "target-yes" means for the other three BAC conditions (e.g., the mean search time for BAC 0.0, no-target, was different from the "target-yes" means of the other three BAC conditions, etc).

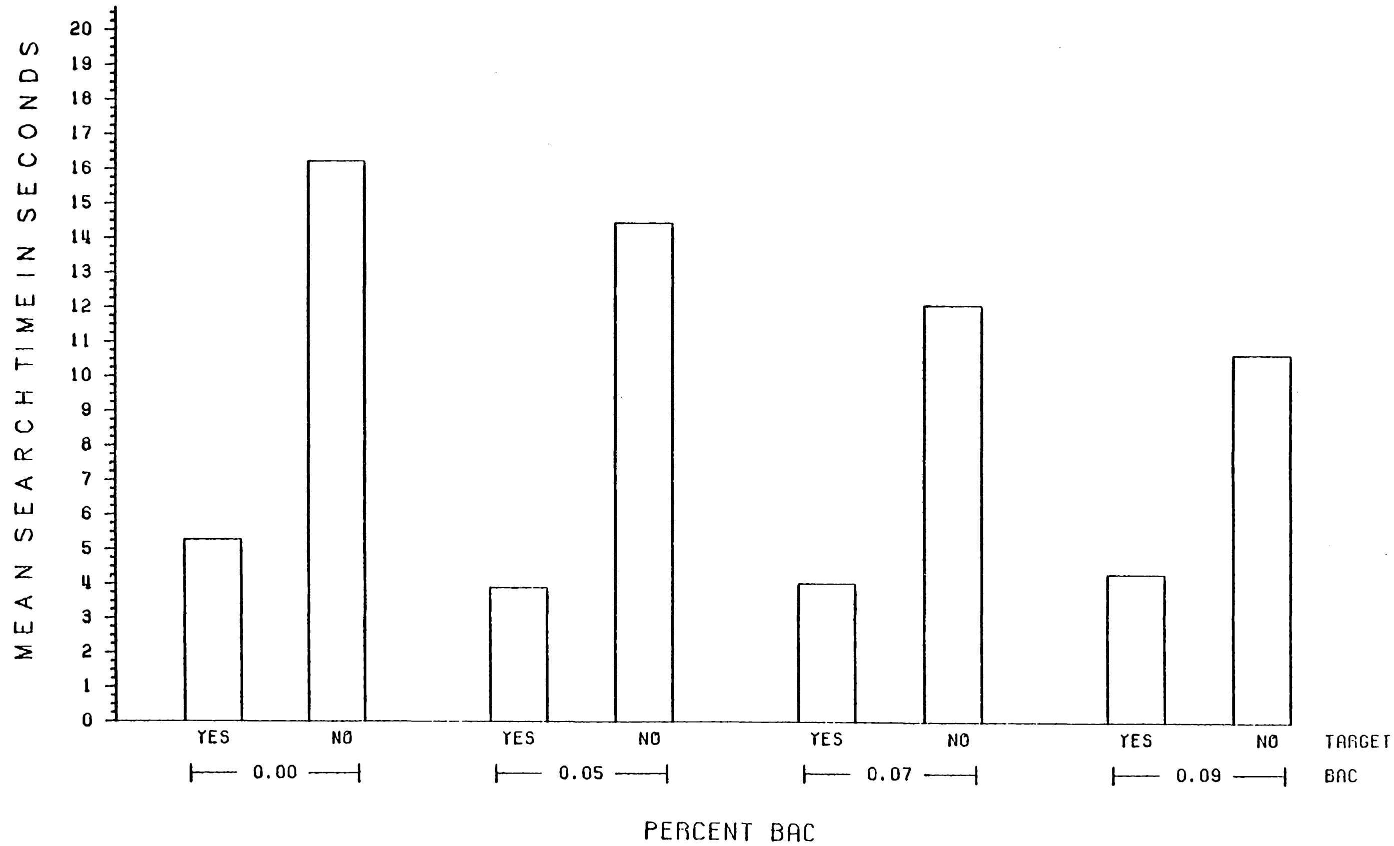


Figure 4: BAC-Target Presence Interaction for Mean Search Time

Mean search time was significantly shorter for trials in which targets were present (Figure 5), and for low criticality search trials (Figure 6).

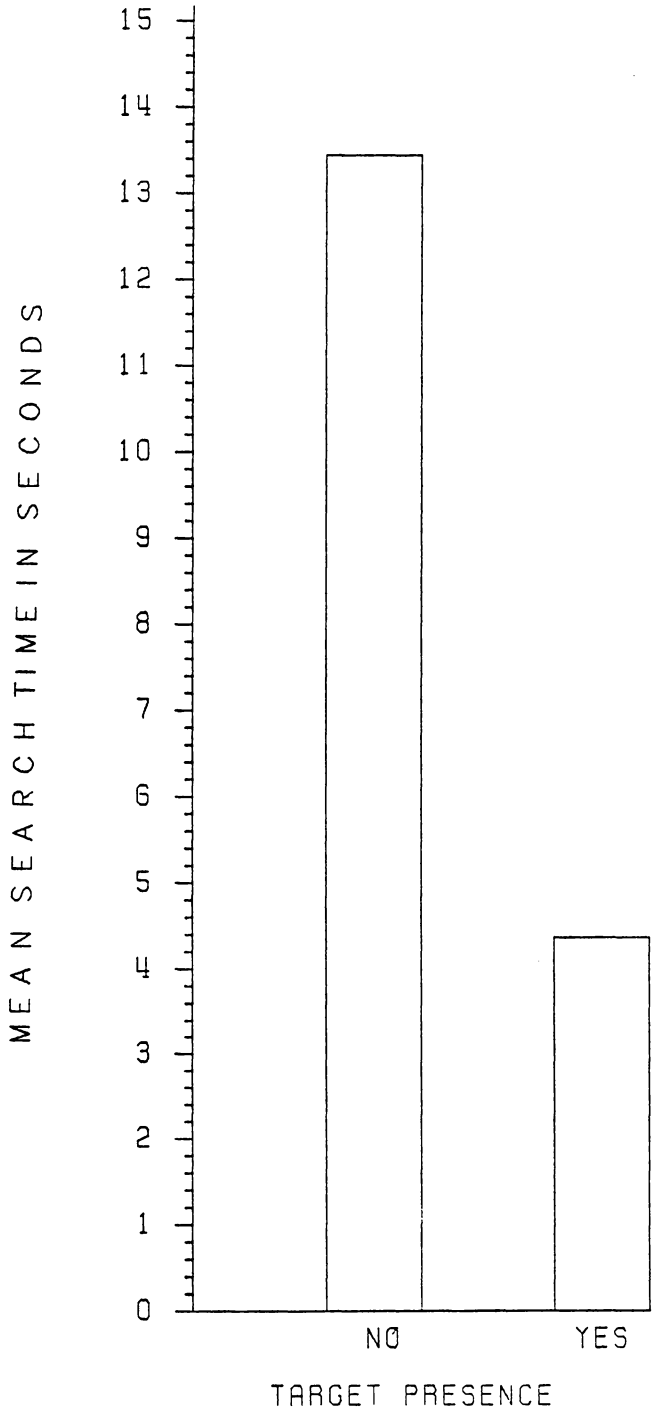


Figure 5: Main Effect of Target Presence on Mean Search Time

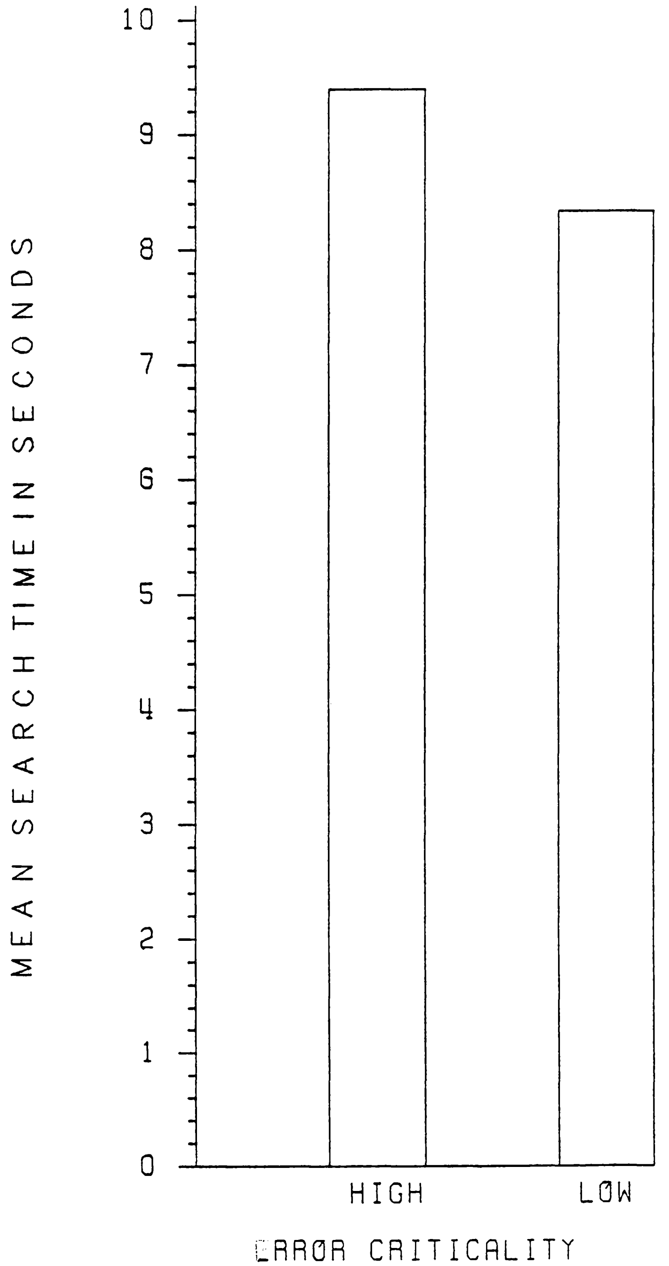


Figure 6: Main Effect of Criticality on Mean Search Time

Mean search times were significantly affected by error criticality only when targets were not present. This interaction between target presence and error criticality is illustrated in Figure 7. The significant differences were between the no-target, low criticality mean and the other three means and between no-target, high criticality and both of the target-present means (at the .01 level).

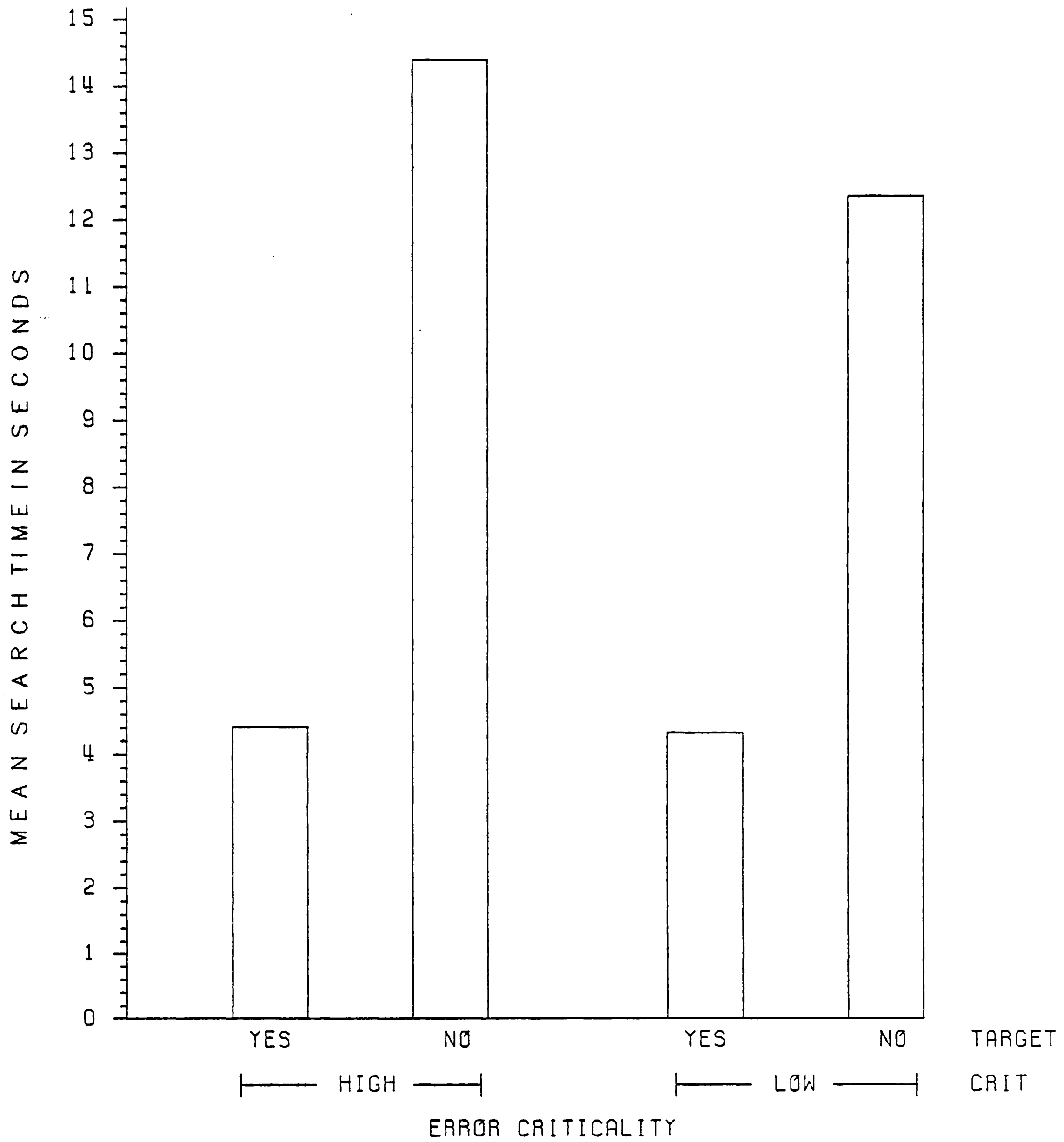


Figure 7: Target Presence-Criticality Interaction for Mean Search Time

Hand travel time increased significantly with higher BAC (Figure 8). The Tukey procedure located a significant difference at the .01 level between the highest and lowest BACs. The differences between hand travel time between 0.0 and at 0.07, and between 0.05 and 0.09 percent BAC were significant at the 0.05 level.

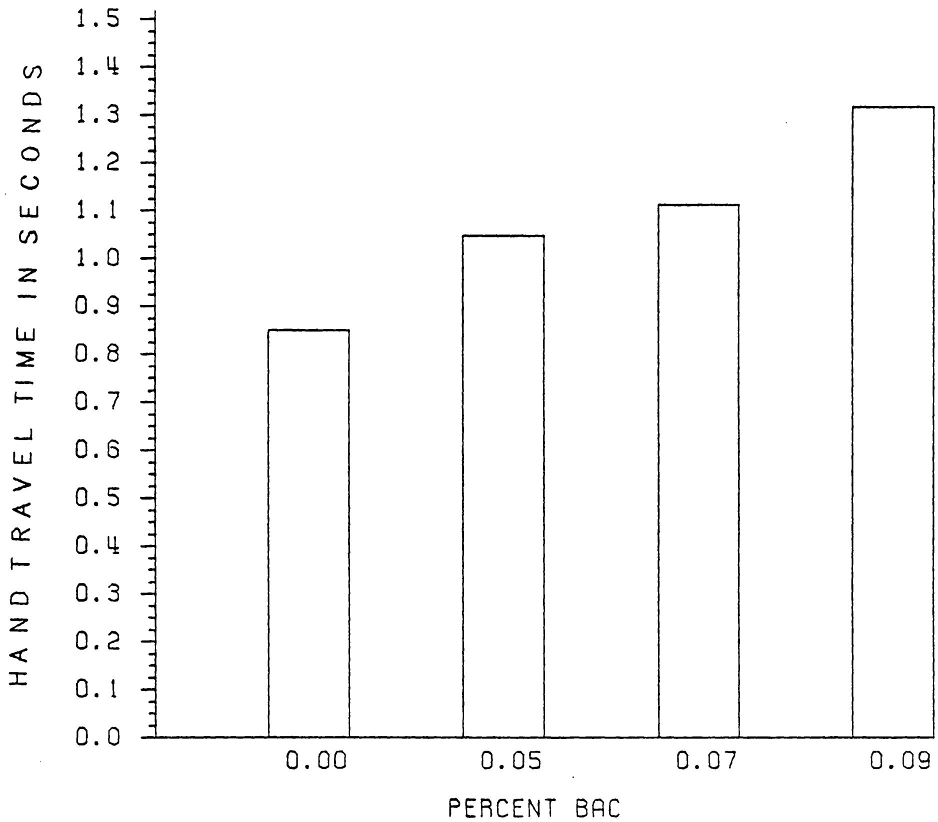


Figure 8: Main Effect of BAC on Hand Travel Time

Percent give-ups increased with higher BAC (Figure 9). All paired differences were significant at the .01 level.

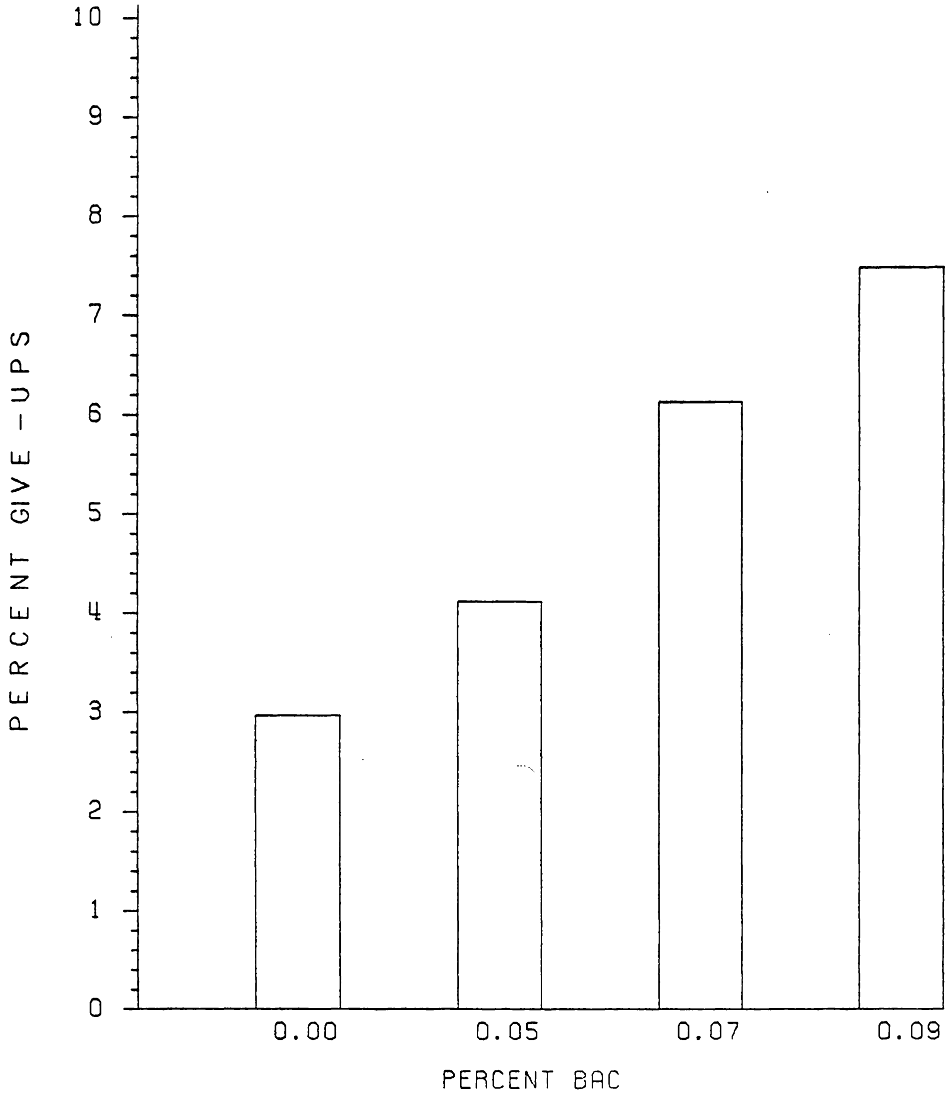


Figure 9: Main Effect of BAC on Percent Give-ups

The percentage of give-ups was significantly higher for low criticality search trials than that for high (Figure 10).

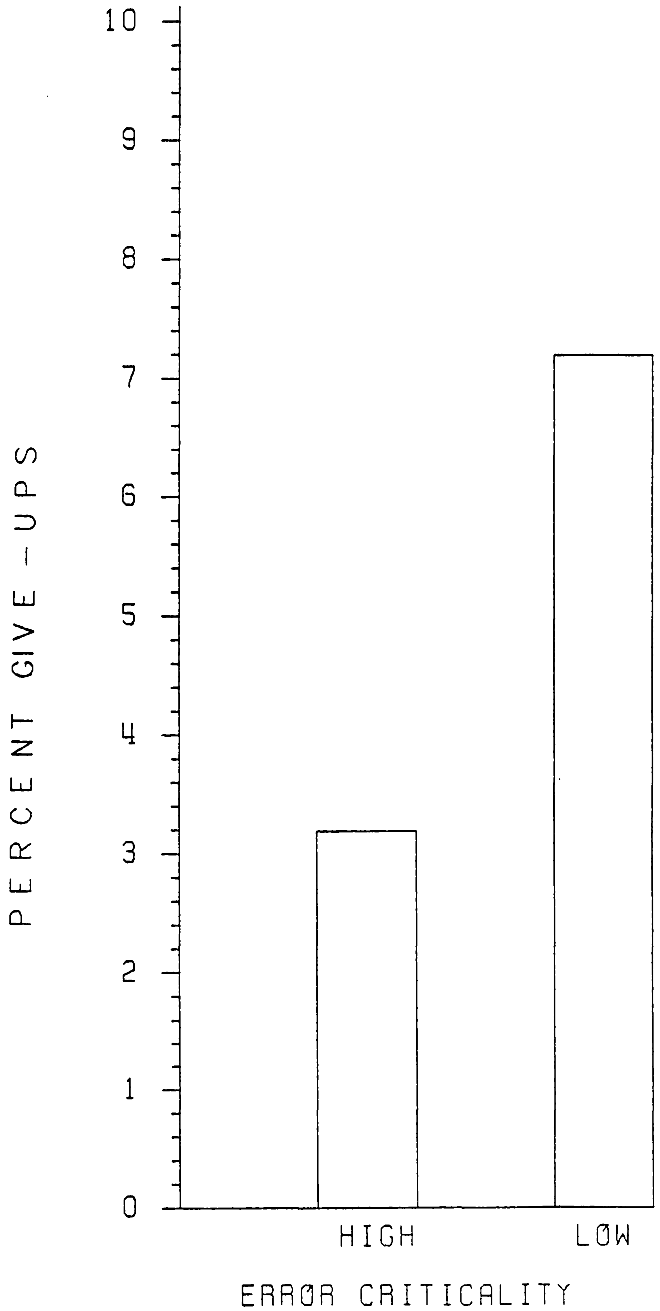


Figure 10: Main effect of Criticality on Percent Give-ups

A significant interaction between BAC and error criticality was observed for percent give-ups (Figure 11). As presented above, the simple-F procedure indicated a significant difference across BAC at both levels of criticality. The Tukey procedure located significant differences as described below. The differences between criticality levels within each BAC were all significant at the .01 level, except at 0.09 BAC, where the difference was significant at the .05 level. For low criticality trials, the significant differences were between BAC levels 0.0 and 0.07 (.05 level), 0.0 and 0.09 (.01 level), and between 0.05 and 0.09 (.05 level). For high criticality trials, the significant differences were between 0.0 and 0.07, 0.0 and 0.09, and 0.05 and 0.09 (all at the .01 level). The remaining significant differences were found between pairs of different criticality and different BAC. These were 0.0/Low and 0.05/High, 0.0/High and 0.05/Low, 0.0/High and 0.07/Low, 0.07/Low and 0.05/High, and 0.09/Low and all three of the other BAC/High means. All of these differences were significant at the .01 level.

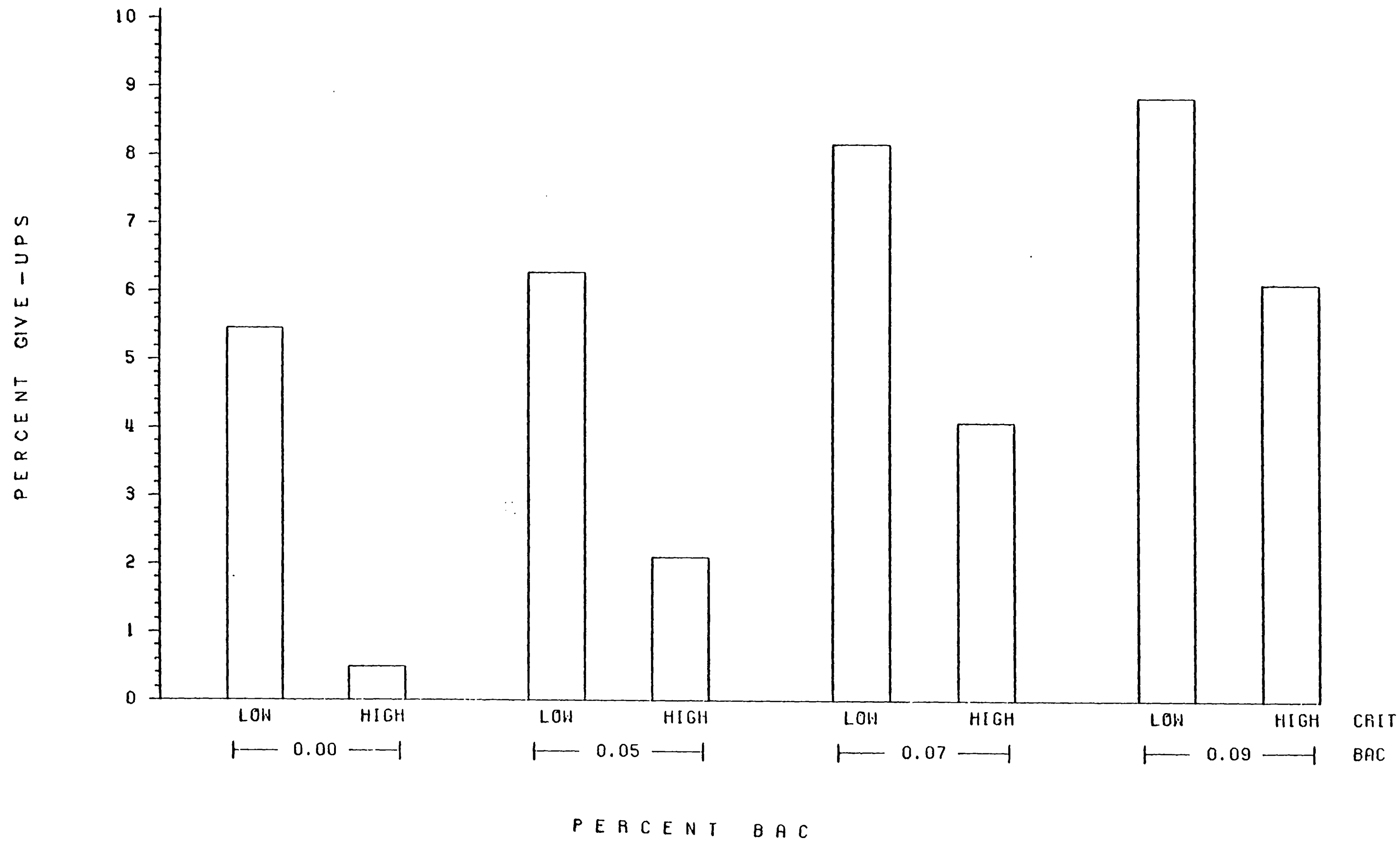


Figure 11: BAC-Criticality Interaction for Percent Give-ups

There was a significant increase in distance off-target with higher BAC (Figure 12). The significant differences were between the placebo and the the three other BAC levels, and were significant at the .05 level.

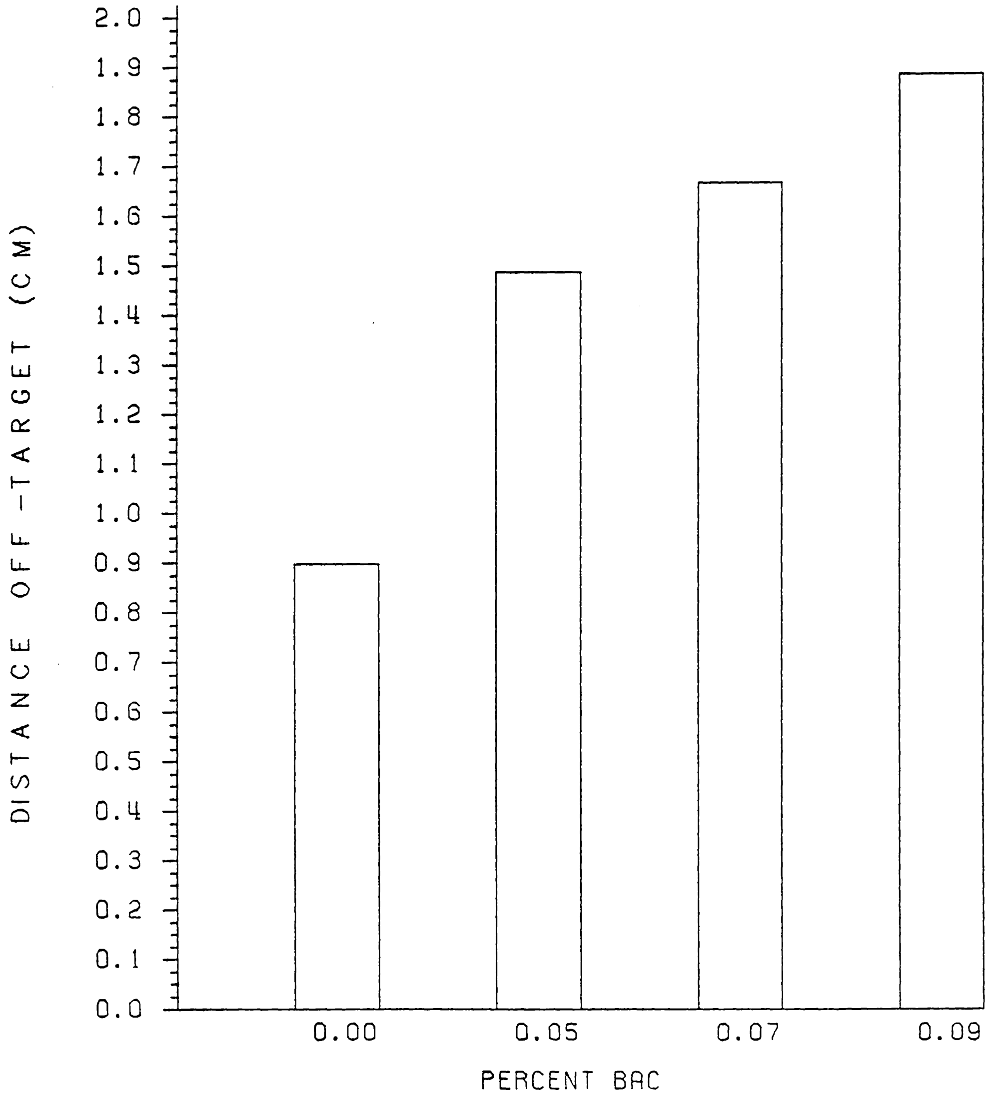


Figure 12: Main Effect of BAC on Distance Off-target

The percentage of hits decreased with higher BAC (Figure 13). The Tukey procedure located the significance between 0.0 and 0.09 BAC, 0.05 and 0.09 BAC (.01 level in both cases), between 0.0 and 0.05, and between 0.07 and 0.09 percent BAC (at the .05 level in both cases).

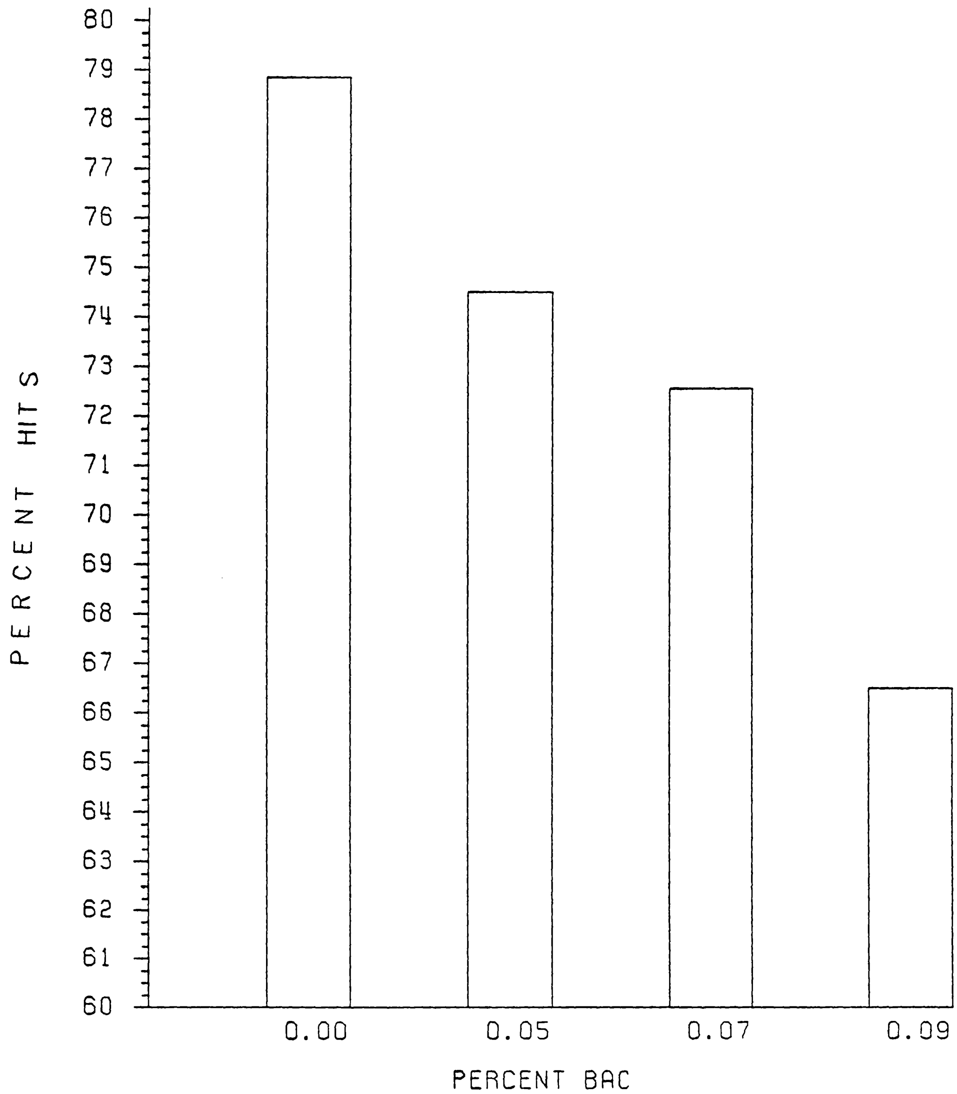


Figure 13: Main Effect of BAC on Percent Hits

The number of search trials completed per session decreased with higher BAC (Figure 14). The significant differences were between the placebo and two highest BAC levels (.01 level), and between the 0.05 percent BAC condition and the highest and lowest BAC levels (.05 level).

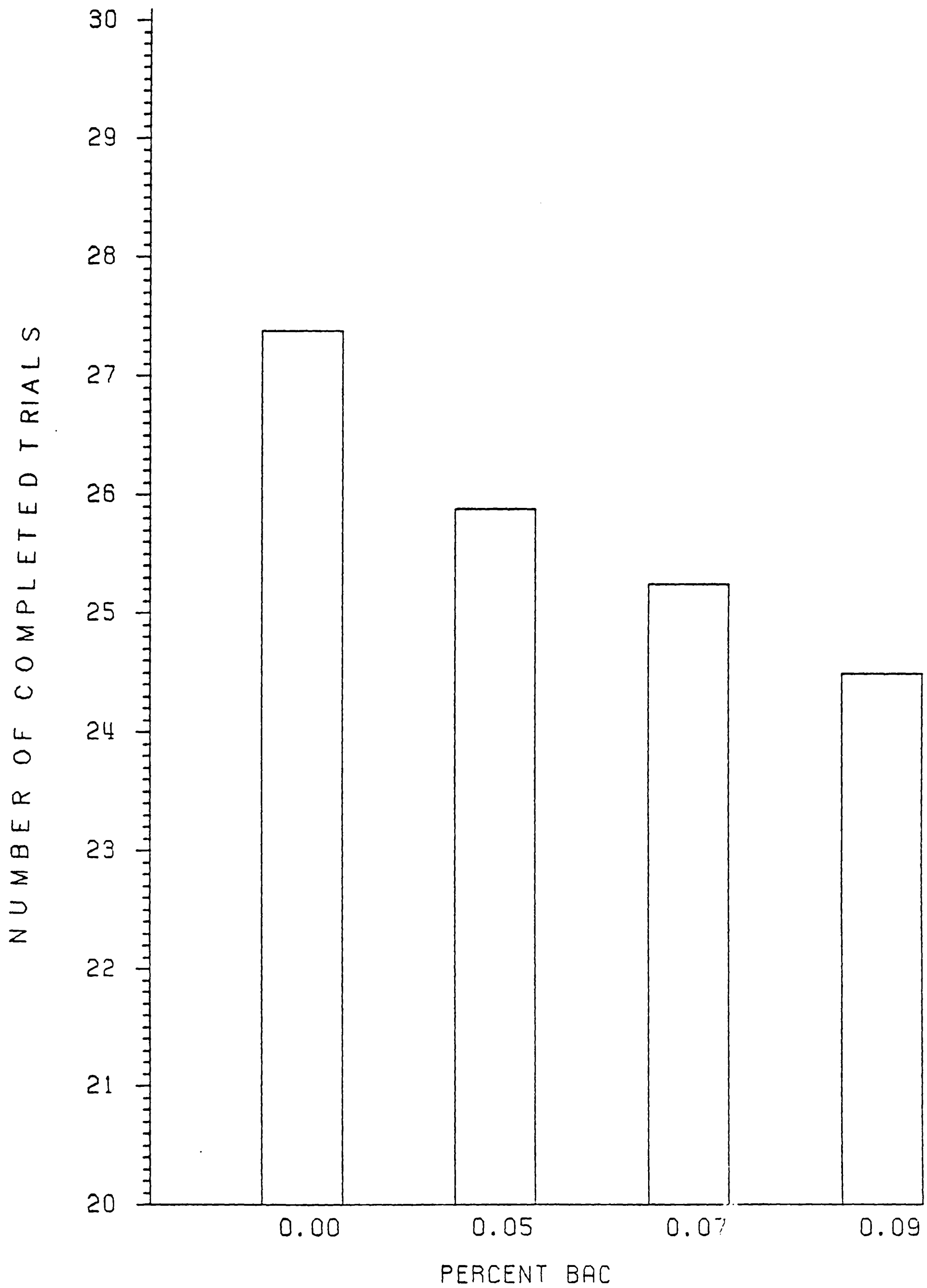


Figure 14: Main Effect of BAC on Number of Completed Search Trials

The average amount of money earned per session decreased with increased BAC (Figure 15). Significant differences were between the placebo and the three other BAC levels, and between 0.05 and 0.09 percent BAC (at the .01 level). The difference between 0.07 and 0.09 percent BAC was significant at the .05 level.

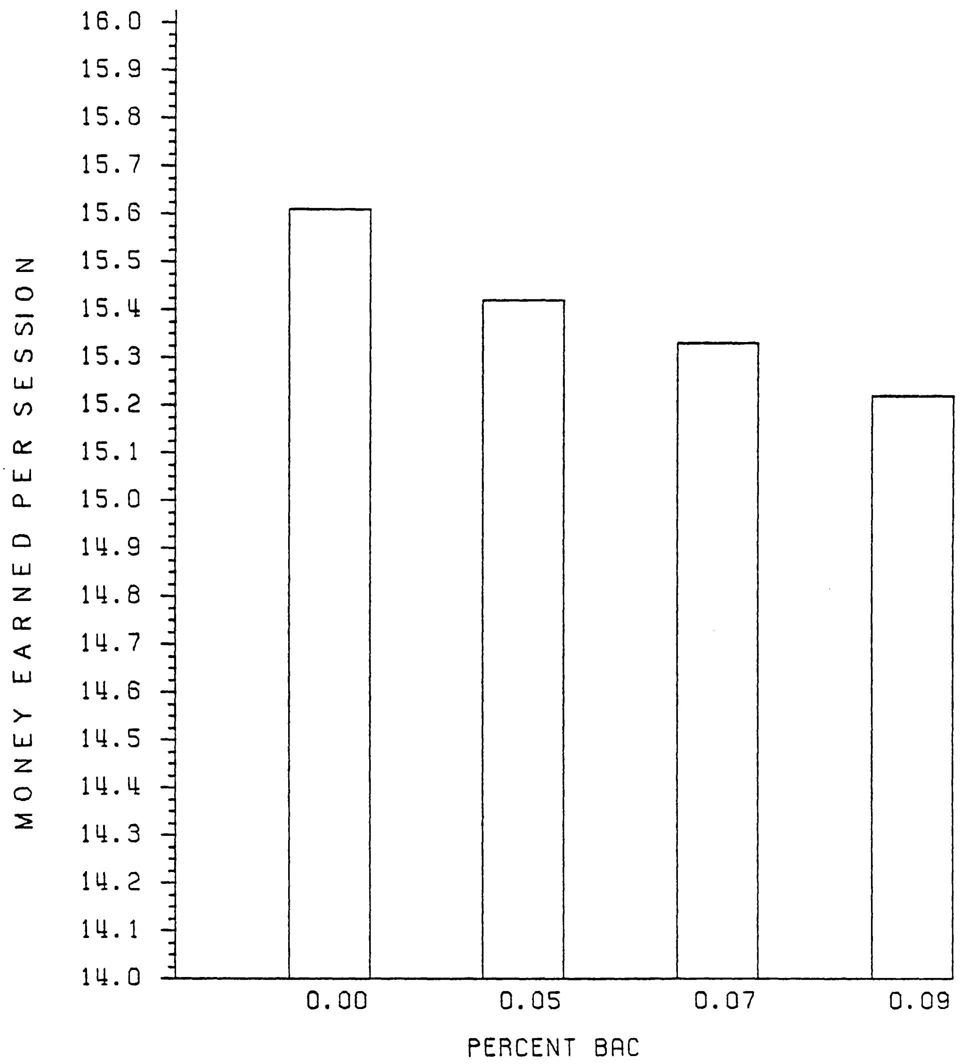


Figure 15: Main Effect of BAC on Money Earned Per Session

SUMMARY OF RESULTS

In the alphanumeric search task performed by mildly intoxicated and sober participants using a touch entry equipped VDT, significant effects of alcohol, criticality, and target presence were detected.

Overall, participants at 0.09 percent BAC gave up on 7.5 percent of the targets presented, and participants in the placebo condition gave up on three percent of the targets presented. Target search time decreased by 31 percent from the placebo to highest BAC condition. No significant change in total task time was observed across BAC levels.

Touch accuracy was degraded by alcohol. The mean distance from touch to target increased from 0.9 cm to 1.9 cm for participants at the 0.0 and 0.09 percent BAC levels, respectively. The percentage of targets touched without error, decreased with increased BAC. Sober participants achieved an average of 78.85 percent compared to the most intoxicated participants, who correctly touched 66.5 percent of the targets located.

Intoxicated participants also completed fewer search trials and earned less money per session than did sober participants as BAC was increased. The near visual acuity of participants did not change significantly as a function of BAC. Hand travel time increased 48 percent from the placebo to the 0.09 percent BAC level. The respective average times were .89 s and 1.32 s.

An interaction of BAC and error criticality was observed for the percentage of erroneously abandoned target searches. This interaction was characterized by a decreasing effect of criticality as BAC levels were increased. A significant interaction of BAC and target presence was observed for mean search time. Search times did not change significantly when targets were present, but decreased markedly when targets were not present.

An overview of the percent changes observed between the placebo and 0.09 percent BAC conditions appears in Table 13 below.

TABLE 13

OVERVIEW OF PERCENT CHANGES DUE TO ALCOHOL

SEARCH TIME	DECREASED	30.89	PERCENT
HAND TRAVEL TIME	INCREASED	55.29	PERCENT
PERCENT HITS	DECREASED	15.66	PERCENT
DISTANCE OFF-TARGET	INCREASED	108.80	PERCENT
PERCENT GIVE-UPS	INCREASED	151.85	PERCENT
NUMBER OF COMPLETED TRIALS	DECREASED	11.76	PERCENT
MONEY EARNED PER SESSION	DECREASED	2.50	PERCENT

DISCUSSION

The percentage of give-ups increased with higher BAC, indicating that intoxicated individuals become less stringent in taking the risk of missing targets as BAC increases. This effect is mediated somewhat by error criticality, in that low criticality search trials result in a less pronounced increase in PGU as BAC increases (Figure 12).

Total task time was not significantly affected by BAC. As mentioned above, search time decreased as a function of BAC only when targets were absent from the search field (Table 12, Figure 4). The stability of total task time across BAC is therefore not surprising because this measure is the sum of search time and hand travel time for only those trials in which targets were present. Although hand travel time did increase with higher BAC, the magnitude of this change was not great enough to cause a significant increase in total task time.

The participants in this study took greater risks of missing targets, exhibiting shorter search times as they experienced higher levels of intoxication. The criticality of the errors involved does not interfere with this effect to a significant extent, implying that participants still look longer for the more critical targets, along with looking for less time as BAC increases. Since subjective estimation of time passage is impaired and inflated by alcohol (Joerger, 1960), there is a chance that participants in fact thought they were being just as careful when intoxicated as when sober.

The number of search trials completed per 15-minute task session decreased with higher BAC, as mentioned above. It appears that intoxicated participants were failing upon occasion to keep the fingertip switch in a closed position for the time that the computer was generating new screens to be searched. This interval lasted for 22 seconds per trial, provided the switch was depressed for the entire duration prior to presentation of each search field. If the button was inadvertently released during this period, the search field would not be presented until a total of 22 seconds had passed with the switch closed. In effect, the computer would simply wait for the button to be depressed before proceeding, thus creating the possibility of having fewer completed trials along with shorter search times. This unanticipated result indicates that inadvertant control errors such as this are to be expected as a result of BAC, a result which could be explored by researchers in the future.

The stability of the near visual acuity of participants' across BACs either serves to indicate that the small dosages used do not affect near visual acuity or perhaps that the measure was not sensitive enough to detect the change. If there is in fact an effect being missed here, it could be that alcohol-related blurring is due to a higher level cause than BAC alone.

APPLICATIONS

With respect to visual inspection tasks in industry, "give-ups" could be expected to occur more frequently when inspectors are even mildly intoxicated on the job. Highly critical inspection tasks might be especially susceptible to this increased risk-taking behavior and it is strongly recommended that worker rights to privacy regarding their BAC levels be reassessed where failure to detect targets involves risk to others.

A 31 percent decrease in search times for no-target trials was observed, giving an indication that people take greater risks of missing targets as they experience higher levels of intoxication. This large loss of stringency at the 0.09 percent BAC level (which is considered marginally legal for driving in most states) is a situation that should cause substantial concern in industry. It is strongly recommended that good estimates of the frequency of occurrence of mild intoxication at this and the lower BACs be provided. Some estimates are available on the frequency of on-the-job alcohol use per occupation type (e.g., Hitz, 1973), but these do not include BAC levels, and so do not permit productivity estimates.

It appears that mildly intoxicated individuals do not require significantly more time to locate targets that are present in search fields similar in difficulty to those used in this study. People concerned with the effects of alcohol on industrial productivity should collect more data in this area before concluding that visual search times are not degraded by BAC, but at this time it appears that they are not. It is recommended that other mediational tasks be examined for sensitivity to alcohol.

Touch accuracy on tasks in industry which require considerable levels of manual dexterity could be expected to be degraded by small amounts of alcohol. Tasks such as typewriting and keypunch operation could be expected to be degraded by increased BAC on the job. Workers interacting with touch entry devices might be expected to require larger touch areas for reliably accurate performance. This would be especially relevant for touch-activated systems that use continuous rather than "compartmentalized" touch surfaces. It should be kept in mind that ten percent of the public sector TED users could be expected to be intoxicated on the job.

Subjects lost an average of 2.5 percent of the money earned for participation when peforming the search task at 0.09 percent BAC relative to the placebo condition. It is doubtful that the penalty system used could outweigh the gain in job "enjoyment" presumably experienced as a result of intoxication at work.

It is unfortunate that prohibitive subject costs did not allow the use of female participants in this research. In light of the increased numbers of female workers in the U.S. it is recommended that women be included in future research involving alcohol, search tasks, and touch accuracy as they apply to industrial productivity.

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Appendix A

ALCOHOL DOSAGE CALCULATIONS

The four target BAC levels used in the study were achieved by administering an amount of vodka per kilogram of body weight. The vodka was 80-proof; in other words, 40 percent pure ethanol. The total vodka for one person's body wieght was mixed with cold orange juice, such that the total drink volume was always held constant with respect to body weight.

The procedure for creating this beverage starts by taking the participant body weight in pounds, dividing that by 50, and multiplying this new quotient by four. This value is the total drink volume in ounces, which when divided by .03381 becomes the volume in milliliters.

For the placebo condition of 0.00 percent BAC, this amount of orange juice is administered with a few drops of the vodka floated on the top for taste. The three actual dosage levels used involved equivalent amounts of pure ethanol per kilogram of body weight, the amounts having been shown in previous research to be accurate. Namely, for 0.09, 0.07, and 0.05 percent BAC to be attained, the amounts of pure ethanol required per kilogram were .913, .717, and .5365 milliliters, respectively.

Multiplying these values by body weight (still kilograms), and then dividing this product by 0.4 yields the amount of vodka needed for each BAC. Of course, the amount of orange juice needed is now simply the difference between the vodka needed and the total drink volume explained above.

This beverage, when consumed steadily over a 20-minute period, will yield a BAC very close to the one desired, provided the participant is in the fasted condition required in the study. Specifically, no alcohol is to be consumed for 24 hours prior to drinking the experimental beverage, and no food or drink for four hours, except for small amounts of water. allow the participant to rest for 15 minutes, rinse the mouth with water, and then administer the breath test. The participant will remain close to the desired BAC for about 15 minutes only, so this is to be taken into consideration when designing tasks.

The mean BACs attained in this study were 0.09112, 0.06967, 0.051233, and 0.0 for the four obvious levels, respectively.

Appendix B

FORM FOR INFORMED CONSENT

Alcohol Project

The purpose of the alcohol project is to look at the effects of alcohol on the ways different perform a task where they search for special letters and numbers on the T.V. screen of a computer terminal. Mr. Barbre will meet with you on four occasions for about five hours each time. On each meeting he will ask you to drink a mixture of vodka and orange juice and will give you a breath test like the one used by many police departments. Then you will be asked to spend about 15 minutes looking for letters and numbers on the T.V. screen. After this you will rest in the laboratory until your body has metabolized (used up) almost all the alcohol remaining in your body.

During the time you spend resting, Mr. Barbre will be happy to answer any questions you may have regarding the experiment. You will be paid a minimum of $12.00 for each session, and $3.00 for a short training session which you will have before the experiment begins.

Being in an experiment can make some people nervous, even when they know that there are no good or bad scores they can make when they are in an experiment. If you find yourself getting nervous, or you want to stop being in the experiment for any other reason, you can stop just by saying that you want to.

If you do decide to stop being in the experiment before it is over, you will be paid the $12.00 for that session. You will be required to stay in the laboratory until the percent of alcohol in your bloodstream is below 0.03.

In return for the fee you will be paid, you are obligated to not drink alcohol for 24 hours prior to any session. You are also obligated not to eat or drink anything except water for four hours prior to any session.

I, ______________________________ agree to be in the alcohol project. I understand that the project is about how alcohol affects my performance on a symbol-searching task.

I give my permission for any information collected about me during the project to be used for educational and/or scientific purposes either at the Virginia Ploytechnic Institute and State University or at other scientific or educational institutions.

I understand that the people running this project will know who I am, but that if any information about the alcohol project is shown to other people, my name will not appear on it anywhere.

I understand that I can stop being in the project at any time, and that my legal rights, regarding negligence and the liability of the institution and its agents, are not waived.

If you wish, you will be informed of the results of this experiment after it is completed. If you want a summary of the results sent to you in about three months, include your printed name and your address along with your signature below. If you would like any further information, please contact the Human Factors Laboratory, 961-5358, and a full report will be made available to you.

During each session you spend in the laboratory, you may or may not be in an intoxicated condition. You might experience blurred vision, dizziness, nausea, loss of balance, and difficulty with speech.

It is your responsibility as a participant to advise Mr. Barbre of any medical problems that arise in the course of the experiment. Should you for some reason suffer injury, we will not offer care or compensation other than first aid.

Should you have any additional questions or problems, contact Dr. Dennis L. Price, Associate Professor, IEOR Department, at 961-5635, or Mr. Charles D. Waring, Chairman, Institutional Review Board for Research Involving Human Subjects, at 961-5284.

Your assistance in this experiment is intended to be an interesting experience for you, and the people involved greatly appreciate your contribution as a participant.

Your signature below indicates that you have read and understood the above statements regarding your rights and obligations as a research participant. If you include your printed name and address below, a summary of the results will be sent to you.

---------------------------------- --------

Signature of the Research Subject Date

---------------------------------- --------

Witness Date

Appendix C

TRANSCRIPT OF RECORDED INSTRUCTIONS

This experiment is concerned with your performance on a simple visual inspection task. You will go through a series of inspecton trials, each lasting about 30 seconds. The task is very simple, but some training is required so that you know the task very well before starting with the experiment. It might be helpful for you to think of the task as if you were inspecting products from an assembly line in industry. That is, you will be paid some money for each inspection you complete, and you will lose some of that money for mistakes that you make, for example if you miss some defects that occur in the product. In this experiment you can make low or high criticality mistakes. That is, some defects will be more important that you not miss than will be other defects, as you will see during the practice trials you are about to experience. In the inspection task for this experiment, the defects will be letters and numbers which you will look for on a TV screen. Each trial will first show you the defect you are to look for, and then tell you the criticality of finding that defect. Then you will be given a large number of characters to search through, looking for the particular defect for that trial. Just like in actual inspection tasks, there will be many trials in which there is no defect present. The computer in this experiment will present a defect in about 50 percent of the search trials, and will present no defect in the remaining trials. There will never be more than one defect per trial. Since half of the trials will have no defect, you will have the option of saying there is no defect, and going on to the next trial. Since you are being paid for each trial you complete, you will want to complete as many as possible, or in other words, to work as quickly as possible. During the experiment, you will be paid 15 cents for each trial you complete correctly. For each high criticality defect that you fail to detect, you will lose eight cents of that 15 cents. For each low criticality defect that you fail to detect, you will lose three cents from the 15 cents. Therefore it is important that you remember the criticality for each trial. You will find this easy to do. During this training session, you will be paid a flat three dollar fee. The payoff system just described will go into effect beginning on the first night of the experiment. At that time you will be paid 12 dollars for each of the four session, and you will have the opportunity to earn up to an additional four dollars and 50 cents by working as quickly and as carefully as possible. Now you will learn how to do the inspection task.

Appendix D

BASIC PROGRAM LISTING FOR RANDOM SEARCH

```
100  REM !INTEGERX2,Y2,TT,QD,QE,XT,YT,CC,A,B,C,VD
110 D$ =  CHR$ (4)
111 HC$ = "HIGH CRITICALITY":LC$ = "LOW CRITICALITY"
112 DIM
    X1%(120),X2%(120),Y1%(120),Y2%(120),CR(120),TAR%(120),
    TT(120),ST(120)
113 NH =  - .04:NL =  - .02:NT = .05
114 SLOT = 5
115 M$ = ""
120 HELLO$ = "RUN RS.3.OBJ"
130 AM = 1
140 PT = 1: ONERR  GOTO 1330
150  PRINT D$;"BLOAD HUDDLESON LARGE.F,A$1000"
160  PRINT D$;"BLOAD IMAGE PROC.OBJ"
170  PRINT D$;"BLOAD HUDDLESON SMALL.F,A$4000"
180  REM  INVERSE SCREEN
190  REM  POKE 856,4
200  PRINT D$;"BLOAD DC V2"
201  HOME : INPUT "ENTER SUBJECT NUMBER ";N$
202  PRINT : INPUT "ENTER B.A.C. ";BA$
```

```
203  PRINT : INPUT "ENTER TIME LIMIT IN MINUTES ";LT
204  LT = LT * 60: REM  MAKE IT SEC.
205  PRINT : INPUT "S/N <1-3> ";QC
206  PRINT : INPUT "SZ  <0-2> ";SZ
207  PRINT : INPUT "VD  <0-1> ";VD
210  REM   IF AM = 2 THEN  PRINT D$;"BLOAD DECODE TSD.OBJ0"
220  REM   IF AM <  > 4 THEN  GOTO 250
230  REM   IF AM = 4 THEN  PRINT D$;"OPEN CONFIGURATION":
     PRINT D$;"READ CONFIURATION"
240  REM   INPUT SL: INPUT XA: INPUT YA: INPUT XB
   : INPUT YB: INPUT XC:
     INPUT YC
   : INPUT XD: INPUT YD: PRINT D$;"CLOSE"
250  REM   XX = (XB - XA) / 2:XY = (XB + XD - XZ - XC)
     / 4:XZ = (XD -
     XC) / 2
    :YX = (YC - YA) / 2:YY = (YC + YD - YA - YB) / 4:YZ = (YD -
     YB) / 2
260  DIM AR%(36)
270  SC = 0:VP = 770:XL = 768:XH = 769:I1 =
     PEEK (816) +  PEEK (817) *
     256
    :I2 =  PEEK (818) +  PEEK (819) * 256
280  DEF  FN A(X) =  PEEK (X + 1024 +  PEEK (40)
  +  PEEK (41) * 256)
```

```
290  DEF  FN B(X) = AR%(CC): REM (SZ * 36)
300  DEF  FN C(X) =  NOT (XT = 40 AND YT = 24)
     AND (T1 = TP OR (T1 <  >
     TP AND
     CC + 1 <  > TC)) AND  FN A(XT - 1) =
     160 AND  NOT (YT = 18 AND XT <
     10)
310  GOSUB 6000: REM  STRING
320  LG$ = "":SM$ = "":UP$ = ""
330  ONERR  GOTO 1250
340  PRINT D$;"VERIFY SUBJECT-INFO"
350  PRINT D$"OPEN SUBJECT-INFO": PRINT D$;
     "READ SUBJECT-INFO": INPUT SB
   : INPUT EX: INPUT TR: PRINT D$;"CLOSE":A =
     FRE ( - 1 * (SB + EX
     TR))
360  ONERR  GOTO 1340
370  CALL 3072: PRINT LG$;: POKE VP,32: POKE XH,8:
     PRINT "RANDOM SEARCH"
   : PRINT SM$: POKE VP,72: POKE XH,4: PRINT "* DEPT OF
     INDUSTRIAL
     ENGINEERING
     *": POKE XH,3: PRINT "**    AND OPERATIONS
     RESEARCH      **"
380  POKE XH,4: PRINT "* VIRGINIA POLYTECHNIC
```

```
     INSTITUTE *": POKE VP,112
   : POKE XH,7: PRINT "SYSTEM CONFIGURATION:": POKE XH,12
   : PRINT "APPLE II PLUS W/ 48K RAM"
390  POKE VP,184: POKE XH,7: PRINT " TOUCH SCREEN TO CONTINUE";
   : POKE 33,41: PRINT ".";: POKE 33,40: VTAB 1: GOSUB 900
400  HOME : POKE VP,0: POKE XH,0: PRINT : PRINT D$;"PR
     0": PRINT D$;"IN
     0"
   : TEXT : HOME
420 TT = 0
430  GOSUB 2000
440 ST = T:TF = ST + LT
510 TS = TS + 1
511  GOSUB 2000
512  IF T > TF THEN  GOTO 3000
513  IF TS > 119 THEN  GOTO 3000
515  CALL 3088
516  HOME : TEXT : HOME
517  GOSUB 6000
520  FOR QD = 1 TO 36:AR%(QD) = 0: NEXT : FOR QD = 1 TO 36
530 QE =  INT ( RND (1) * 36) + 1: IF AR%(QE) > 0 THEN 530
540 AR%(QE) = QD: NEXT :XT = 4:YT = 4
550  REM  VD SZ
560 TC =  INT ( RND (1) * 36) + 1: POKE 1468, ASC ( MID$
    (ST$,AR%(TC),1)) + 128
```

```
561 R1 =  RND (1):R2 =  RND (2)
562  IF R1 >  = .5 THEN  PRINT  TAB( 12);
     HC$;"":CR(TS) = 1: GOTO 565
564  IF R1 < .5 THEN  PRINT ""; TAB( 12);LC$:CR(TS) = 0
565  IF R2 >  = .5 THEN TAR%(TS) = 1
566  REM  IF VD THEN CALL I2
567  IF R2 < .5 THEN TAR%(TS) = 0
568  IF TAR%(TS) = 0 THEN  GOSUB 5000
569  IF TAR%(TS) = 1 THEN  GOSUB 6000
570 X =  PEEK (49346): PRINT "";: PRINT "";
       : IF  NOT (SZ) THEN  PRINT
        "";
580 T1 = 0:CC = 0:TP =  INT ( RND (1) * QC)
590 T1 = T1 + (CC = 36):CC = CC * (CC < 36)
    : VTAB YT: HTAB XT
    : POKE VP,(YT - 1) * 8 - (4 * (SZ > 0)): POKE XH,XT - 1
594  IF  FN C(X) THEN CC = CC + 1: PRINT  MID$
       ST$, FN B(X),1);
      : IF T1 = TP AND CC = TC THEN H1 = XT - 1:V1 = YT - 2
596  IF TAR%(TS) = 0 THEN H1 = 0:V1 = 0
597  REM
600  IF CC = TC - 1 AND T1 <  > TP THEN CC = CC + 1
610  IF CC = 36 AND T1 = QC - 1 THEN 630
620 XT =  INT ( RND (1) * 13) * 3 + 1
621  IF XT < 3 OR XT > 37 THEN 620
```

```
622 YT =  INT ( RND (1) * 11) * 2 + 2
623  IF YT < 3 OR YT > 20 THEN 622
624  GOTO 590
630  VTAB 1: HTAB 1
631  FOR N = 1 TO 3
632  VTAB N
633  POKE VP,(N - 1) * 4
634  POKE XH,0
635  PRINT "!!"
636  NEXT N
637 YT = 18:XT = 7: VTAB YT: HTAB XT: POKE VP,
    (YT - 1) * 8 - (4 * (SZ >
    0))
   : POKE XH,XT - 1: PRINT  MID$
    (ST$,AR%( INT ( RND (1) * 35 + 1)),1);
638 YT = 18:XT = 4: VTAB YT: HTAB XT: POKE VP,
   (YT - 1) * 8 - (4 * (SZ > 0))
   : POKE XH,XT - 1: PRINT  MID$
   ST$,AR%( INT ( RND (1) * 35 + 1)),1);
639  IF VD THEN  CALL I1
640  POKE 49232,0: POKE 49236,0: POKE 49234,0
642  GOSUB 2000:TX = T
650  GOSUB 800
660 X1%(TS) = X2:Y1%(TS) = Y2:X2%(TS) = H1:Y2%(TS) = V1
670  REM  BELL
```

```
700  GOTO 510
720  ONERR  GOTO 1250
770  REM   TM$ = FT$:TN$ = ET$: GOSUB 1230
   : PRINT D$;"OPEN RANDOM-DATA";AM;MT",L128"
   : PRINT D$;"WRITE RANDOM-DATA";AM;MT",R0"
   : PRINT  STR$ (T3): PRINT D$;"CLOSE"
780 PT = 2: ONERR  GOTO 1300
790  POKE 2048,0: POKE 2049,0: POKE 2050,0
   : REM    ?D$;"VERIFY ";HELLO$: PRINT D$;"RUN ";HELLO$
800  REM
810  IF  PEEK ( - 16287) > 127 THEN 810
820  GOSUB 2000: REM  READ TIME
830 TY = T
900  CALL 17152
910  IF  PEEK (0) < 128 THEN 900
920  GOSUB 2000
930 TZ = T
940 ST(TS) = TY - TX:TT(TS) = TZ - TY
960  REM
970 X =  PEEK (1):Y =  PEEK (2): IF X < 11 THEN X = 10
980  IF X > 70 THEN X = 70
990  IF Y < 4 THEN Y = 4
1000  IF Y > 40 THEN Y = 40
1010 X2 = X - 10:Y2 = Y - 4
1020 X2 = X2 * 2 / 3 + .40
```

```
1030 Y2 = Y2 * 11 / 18 + .5
1040 X2 = 3 *  INT (X2 / 3)
1050 Y2 = 2 *  INT (Y2 / 2)
1055  PRINT ""
1060  RETURN
1240  END
1250  IF  PEEK (222) = 0 OR  PEEK (222) > 15 THEN 1340
1260  PRINT "PR
      O": TEXT : HOME :
     : VTAB 12: HTAB 5: PRINT "SUBJECT DATA
      DISK NOT IN DRIVE 2"
     : VTAB 15: HTAB 15: PRINT "INSERT DISK"
1270  VTAB 20: HTAB 8: PRINT "PRESS ANY KEY WHEN READY"
1280  IF  PEEK ( - 16384) < 128 THEN 1280
1290  POKE  - 16368,0: GOTO 330
1300  IF  PEEK (222) = 0 OR  PEEK (222) > 15 THEN 1340
1310  PRINT "PR
      O": TEXT : HOME :
     : TEXT VTAB 12: HTAB 5: PRINT "PROGRAM DISK NOT IN DRIVE 1"
     : PRINT : HTAB 13: PRINT "INSERT DISK"
     : PRINT : HTAB 4: PRINT "AND PRESS ANY KEY TO CONTINUE"
1320  IF  PEEK ( - 16384) < 128 THEN 1320
1330  POKE  - 16368,0: ON PT GOTO 160,790
1340  PRINT "PR
      O": HOME : TEXT : PRINT "SYSTEM ERROR CODE:";
```

```
      PEEK (222);"--"; PEEK (218) +  PEEK (219) * 256: END
2000  REM
        CLOCK ROUTINE
2001 D$ =  CHR$ (4)
2002  REM   POKE 49232,0: POKE 49236,0: POKE 49234,0
2003  VTAB 1: PRINT
2010  PRINT D$;"IN 5"
2020  PRINT D$;"PR 5"
2030  INPUT " ";T$
2031  VTAB 1
2040  PRINT D$;"IN 0"
2050  PRINT D$;"PR 0"
2060 H =  VAL ( MID$ (T$,7,2))
2070 M =  VAL ( MID$ (T$,10,2))
2080 S =  VAL ( MID$ (T$,13,6))
2090 T = S + M * 60 + H * 3600
2100  RETURN
3000  REM
TERMINATION ROUTINE
3010  PRINT ""
3015 N$ = "DATA " + N$ + " " + BA$
3020  PRINT D$;"IN
      0": PRINT D$;"PR
      0": TEXT : HOME
3021  VTAB 11
```

```
3022  PRINT "INSERT THE DATA DISK."
3023  INPUT "IS DATA DISK IN DRIVE
      1 ";YN$
3024  IF YN$ = "YES" THEN  GOTO 3030
3025  GOTO 3020
3030  PRINT D$;"OPEN ";N$
3040  PRINT D$;"WRITE";N$
3050  PRINT TS
3060  FOR I = 1 TO TS - 1
3070  PRINT X1%(I): PRINT Y1%(I)
3080  PRINT X2%(I): PRINT Y2%(I)
3090  PRINT CR(I): PRINT TAR%(I)
3091  PRINT TT(I): PRINT ST(I)
3092  NEXT I
3140  PRINT D$;"CLOSE ";N$
3150  PRINT D$;"LOCK ";N$
4000  END
5000  REM
      CHANGE ST$
5005 M$ = ""
5010  FOR I = 1 TO 36
5015 A =  ASC ( MID$ (ST$,I,1)) + 128
5016 B =  ASC ( MID$ (ST$,AR%(TC),1)) + 128
5020  IF A = B THEN LL =  INT ( RND (1) * 35 + 1):
      L$ =  MID$
```

```
      (ST$,AR%(LL),1)
      : GOTO 5040
5030 L$ =  MID$ (ST$,I,1)
5040 M$ = M$ + L$
5050  NEXT I
5060  REM  BELL
5065 ST$ = M$
5070  RETURN
6000  REM
      STRING
6010 ST$ = "ABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789abcdefgh
     ijklmnopqrstuvwxyz&'()*+,-./ABCDEFGHIJKLMNOPQRSTUVW
     YXZ0123456789"
6020  RETURN
```

Appendix E

MEDICAL 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) ________ *glasses per week.*

c) Fortified Wine (port or sherry) ________ *glasses per week.*

d) Hard (distilled) liquor (whiskey, gin, etc.) ________ *ounces per week.*

2. During the course of a week, on which days do you normally 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 for the entire week.)

	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, etc.) If so, please list the type of drug and when taken.*

   yes / no ____

   ____

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