THE EFFECTS OF ALCOHOL ON FOUR BEHAVIORAL PROCESSES: PERCEPTION, MEDIATION, COMMUNICATION, AND MOTOR ACTIVITY

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(ABSTRACT)

The research reported is concerned with the effects of alcohol on a maze-based task which had been designed to incorporate independently each of the four behavioral processes described by Berliner, Angell, and Shearer in 1968. Such a design allows study of the relative effects of alcohol on various behavioral domains. This type of comparison had not been previously accomplished in a single study. Further, if a task can be characterized according to the behavioral dimensions of which it is comprised and alcohol levels at which performance of the task is likely to occur can be postulated, regression equations might be of use in estimating performance decrements on the task under alcohol versus no-alcohol conditions without experimental manipulation. The development of such regression equations is a second aim of this experiment.

Thirty-two subjects (16 of each gender) were given four different alcohol doses (0.00, 0.05, 0.07, and 0.09% BAC) coupled with four levels of maze difficulty. A Latin Square strategy was used to assign the BAC/Maze combinations. Each combination was repeated under speed and accuracy instructions.

Analyses of variance showed that alcohol impaired performance on most independent variables in each of the behavioral domains. However, comparisons of estimated percent differences in performance across the dimensions revealed that the cognitive processes were most impaired by alcohol while the perceptual processes were most resistant to alcohol effects. Analyses of variance also indicated that there were no performance effects attributable to gender but that maze difficulty and instruction generally affected performance in the expected directions.

Regression equations which incorporated alcohol, instruction, and ratings of the contribution of each behavioral process were developed to predict task completion time. Gender did not enter into these equations. The predictions yielded by these equations are in agreement with the results found in the literature. Hence, they are satisfactory for use in estimating performance decrements due to alcohol on a task the behavioral components of which are known or can be measured.

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Finally, the author greatly appreciated the ever-cheerful input of both . Were it not for their aid, the statistical analysis involved in this dissertation would have been a monumental task.

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INTRODUCTION

Problem Statement

It is well-known that humans misuse alcohol. Often, this has a detrimental effect on their ability to perform tasks required to function optimally in the world at large as well as in the work world. Documentation of this performance degradation is abundant and will be reviewed subsequently. Such a review cannot be fully appreciated, however, until the scope of alcohol misuse, in regard to the number of people affected and to the resultant costs to society, is understood. A brief discussion of each of these topics follows.

Prevalence of alcohol misuse. The most often quoted figure regarding the incidence of alcoholism in the general population is a rate of 5%. This figure is based on the use of a formula developed by Jellinek and McFarland (1940) which predicts the number of alcoholics in the population based on the number of deaths due to alcoholism-related cirrhosis of the liver. There are several reasons to expect that the estimates yielded by such a formula are too low. First there is a mortality study of alcoholics by Pell and

D'Alonzo (1973) indicating that cirrhosis of the liver accounted for only one-tenth of deaths in the group studied. If nine-tenths of alcoholics die as a result of something other than liver disease, a large segment of alcoholics is not represented at all in Jellinek and McFarland's formula. There is also the criticism by Marden (1980) that the formula does not account for differences in incidence due to age, sex, or occupation, all of which have been shown to affect alcohol misuse (Cahalan, Cisin, and Crossley, 1969).

Using the data of the Cahalan et al. (1969) survey, Marden (1980) defined a problem drinker as one who answered 7 of the 58 survey items in the affirmative. These items sampled 11 categories, namely, frequent intoxication, binge drinking, symptomatic drinking, psychological dependence, problems with spouse or relatives, problems with friends or neighbors, job-related problems, problems related to law and the police, health problems, financial problems, and belligerence. Using these data, Marden developed a new formula and, with this formula, estimated that 11% of the adult population (ages 20 to 70) misuse alcohol.

According to Marden (1980), this 11% consists of 17% of the adult men in the general population and 4% of the adult women. Several factors suggest that even this corrected estimate is low for women. Women tend to hide their drinking (Beckman, 1975) and are often protected by their families (Senseman, 1966). Hence, accurate information on many female drinkers may not be available.

For males, the highest prevalence (24.8%) of problem drinking occurs at ages 20 to 29; for women, the highest prevalence (7.9%) occurs at ages 30 to 39. Other high incidences occur at ages 30 to 39 (16.4%) and 40 to 49 (6.8%) for males and at ages 40 to 49 (6.8%) for females. The indication, then, is that problem drinking is at its highest during the span described by Follmann (1976) as life's most productive years, namely, ages 35 to 55. During these years, people also tend to have had the same employer for a long period and the employer has a considerable investment in the employee.

Despite criticisms regarding lack of reliability of data, lack of external validity, small sample sizes, and doubt of the validity of the gender results, Marden's (1980) figure is probably the best estimate of the incidence of drinking in the general population.

As for industrial alcoholism, a figure of 10% alcohol misusers in the work force is commonly quoted (Levins, 1976; Schramm, Mandel, and Archer, 1978). This estimate is quite a bit lower than the figures arrived at using the Marden (1980) technique which yields estimates of 10.1% among professional and technical workers as a low point and up to 22% among operatives, transport workers, and farm laborers as a high.

Estimates from the military and the railroad industry tend to confirm the Marden (1980) figures. Gray, Poudrier, Shain, and Haakonson (1983) reported that there are 17% to 20% problem drinkers among the military population. Mannello and Seaman (1979) found a 19% incidence in the railroad industry. They indicated that 12% of the workers drank on duty, 5% came to work very drunk at least once, and 15% were a little drunk on the job at least once.

The idea that alcohol misuse is indeed widespread in the employment setting is also supported by a survey of 268 Virginia companies; 55% of these companies acknowledged the presence of alcohol misuse in their work force (Weimar, 1976).

At present, no estimates of the number of female alcoholics in the workplace are available. However, several studies of female alcoholic patients shed some light on the potential impact of the alcoholic working woman. Lisansky (1957) reported that 61% of his outpatients were employed. Johnson, DeVries, and Houghton (1966) surveyed Alcoholics Anonymous members and private patients and found 71% to be employed. Horn and Wanberg (1973) estimated that 20% of working female alcoholics have experienced alcohol-related loss of work time. These figures suggest that there might be substantial numbers of female alcoholics in the workplace (i.e., perhaps up to the 10% estimate for the general working population given earlier) and that these employees do have an impact on industrial costs.

Costs associated with industrial alcohol misuse. Industrial losses due to alcohol misuse no doubt have many sources. Here, costs related to absenteeism, reduced safety, and impaired productivity will be explored.

In 1981, the U.S. Department of Health and Human Services estimated that industrial losses due to alcohol-related absenteeism alone were nearly 25 billion dollars (The whole college catalog about drinking, 1981).

Several authors have evaluated alcoholic versus non-alcoholic workers on absence-related measures. Maxwell (1959) found that the average number of sickness payment cases per alcoholic employee was 2.5 times that of the control employees and that the average sickness-payment was 2.9 times greater for the alcoholic employee than for the control employee. Pell and D'Alonzo (1970) found the absence frequency rate of a group of known, suspected, and recovered alcoholics to be twice that of a control group.

In regard to safety and accident incidence, Maxwell (1959) indicated that alcoholic employees had 1.8 times more on-the-job accidents and 2.3 times more lost-time accidents than control employees. In addition to the obvious costs of insurance, workers' compensation, and repair or replacement of damaged machinery, accidents also involve hidden costs such as the interruption of productivity due to the event, the need to substitute personnel and equipment and the resultant efficiency losses, lost sales due to loss of public confidence, degraded morale resulting in productivity losses, and the involvement of personnel in accident investigation and reporting (Hammer, 1981).

Finally, one must consider losses due to impaired performance of workers who are under the influence of alcohol while on the job. The actual costs associated with performance impairment are unknown since these data often cannot be collected directly. Most likely, however, these losses are severe since problem drinkers generally do remain on the job in the early and middle stages of alcoholism (Schramm et al., 1978). Further, data from studies on general performance ability and on laboratory simulations of industrial tasks under alcohol conditions indicate significant performance decrements (see "Review of the Literature") whose effects have "dollars and cents" implications.

In addition to direct productivity losses due to impairment of the drinking worker, industry may also incur losses based on that worker's impact on other employees. These losses could occur via disruption of a work team by the behavior of an alcoholic member. Employees may be concerned for their own safety because of the drug use of a co-worker (Blum, 1969). Losses might also be incurred by a supervisor devoting extra time to the drinker; further, losses due to the eventual need to deal with the alcoholic employee either through treatment or replacement may be incurred.

Review of the Literature

This section is divided into four subsections and deals with alcohol as it relates to pharmacological and physiological issues; general psychological effects in the sensory, motor, psychomotor/sensory-motor, and cognitive domains; automobile driving; and effects on performance of industrial tasks. With the exception of the topic of industrial productivity, the information contained herein is intended to be representative rather than comprehensive.

One problem encountered in reviewing the literature is noteworthy: there is no consistent method for determining or reporting alcohol dosages. Often the formulae used for dosage administration are not reported and the basis for dosage determinations is left unspecified -- treatment factors such as sex, body weight, and ethanol content of the beverage used are unknown. Further, in many studies, blood alcohol concentration (BAC) is not reported; hence, comparisons of the reported results are often not possible.

In the following review, BACs were reported wherever possible. When no BACs were reported by the original authors, estimates were attempted. Using the information that 12.7 ml of pure ethanol filled with water to a total volume of 100 ml will yield 10 g of alcohol per 100 ml of fluid (Wallgren and Barry, 1970), the g/kg dosages often reported were converted to ml/kg. BAC was estimated[1] from the following formula:

$$\%BAC = 0.0318\ ml/kg + 0.1652\ ml/kg^2 - 0.0998\ ml/kg^3 .$$

The formula for males was employed since more males than females were used as subjects in the experiments reported herein. All BACs so estimated are noted as such.

<u>Pharmacological and physiological issues</u>. Only ethanol processed for beverage purposes is considered here. Since oral administration is the most common way of introducing alcoholic beverages into the body, as well as the method employed in the current study, discussion is limited to results expected with oral administration.

In dealing with the pharmacological issues involved with alcohol ingestion, the primary focus is alcohol's absorption into, distribution through, and elimination from the body. Gender-related issues are also discussed.

When administered orally, alcohol is absorbed from the gastrointestinal tract by simple diffusion through the cell boundaries. The distribution of alcohol is facilitated by diffusion into the vascular system and subsequent blood flow (Wallgren and Barry, 1970).

The rate of absorption is influenced by whether the stomach is empty or full. Wallgren and Barry (1970) noted that "food delays absorption producing a slower rise and lower peak value of the blood alcohol in fed than in fasting subjects" (p. 39). Absorption is reduced due to delayed gastric emptying and a reduction in the ability of the alcohol to reach the epithelial lining of the gastrointestinal tract. Alcohol accompanied by a heavy meal may require a six-hour absorption period.

There is evidence that not only does food per se affect attained BACs, but that different types of food may have different effects. Welling, Lyons, Elliot, and Amidon (1977) gave the same alcohol dose to subjects in fasted, high fat meal, high protein meal, and high carbohydrate meal conditions. In all cases, BACs after eating were lower than in the fasted condition. In the non-fasted conditions, BACs were lowest after the high carbohydrate meal, moderate after the high fat meal, and highest after the high protein meal.

Absorption rate is also governed by the type of alcoholic beverage ingested, with distilled beverages having the fastest absorption rates (Newman and Abramson, 1942). Dussault and Chappel (1974) found significant differences in the ascending portion of the blood alcohol curves when the same doses of whiskey and beer were given to fasted subjects. Since the descending portion of these curves is identical, this effect must be due to differences in absorption.

Absorption rate may also be affected by the dose given. Wilkinson, Sedman, Sakmar, Kay, and Wagner (1977) showed that with increasing dosages (drunk over the same time period as smaller doses) absorption is slowed due to slower evacuation from the stomach resulting from the retardation of the gastric emptying rate by the alcohol itself.

The substrate in which alcohol is administered may also affect absorption. Benes (1974) reported that alcohol administered in milk was absorbed more slowly than alcohol administered in water.

Even aside from the effects of food, beverage, and substrates, there is a large variability among the BACs for different individuals given the same dosage. O'Neill, Williams, and Dubowski (1983) reported on a study where male subjects were given either low or high doses corrected for body weight. The obtained BACs showed wide scatter; some subjects in the low dosage condition attained BACs near the target for the high dosage condition. This inter-individual variability is generally attributed to differences in the proportion of water in the body. Watson, Watson, and Batt (1981) explained this relationship: "since alcohol does not dissolve in body fat to any appreciable extent but is freely miscible with water, ingested alcohol will be almost totally associated with the body water" (p. 548). Hence, individuals with a higher proportion of body fat mass (thus, less body water since lean body mass is equal to total body water mass plus total lean solids mass (Watson et al., 1981)) will have higher BACs. In general, older people, women, and obese people would be expected to have high BACs since they have less total body water in which to diffuse the alcohol (O'Neill et al., 1981). This factor may also account for differences in BACs found among racial groups (Reed and Kalant, 1977).

Another factor which contributes to intra-individual variability in attained BACs is tolerance to alcohol following a period of exposure. Goldberg (1943) reported differences in BACs in abstainers and heavy drinkers given equivalent alcohol doses, with abstainers having significantly higher BACs than heavy drinkers. Kalant, LeBlanc, Wilson, and Homatidis (1974) also observed this effect. They attribute the phenomenon to less rapid absorption in the heavy drinkers. (This source of variability was controlled in the present study by excluding both abstainers and heavy drinkers from participation.)

Once introduced into the gastrointestinal tract, alcohol is distributed through the body via the blood. Hence, the alcohol content of the organs with a constant supply of blood (i.e., the brain, lungs, liver, and kidneys) quickly reaches equilibrium with that of the blood. This distribution is important primarily due to its contribution to the physiological effects of alcohol on the brain. Although the underlying mechanism is unknown (Wallgren and Barry, 1970), alcohol has several effects on nervous function: (1) nerve excitation is increased by low ethanol concentrations but inhibited by higher concentrations (Knuttson; 1961); (2) alcohol depresses neural impulse action (Posternak and Berney, 1956, in Wallgren and Barry, 1970); and (3) transmission of neural impulses at the synaptic junction is sensitive to the depressant effects of alcohol (Blume, 1925, in Wallgren and Barry, 1970).

Regardless of the mechanism, alcohol has obvious physical effects on the brain at various blood alcohol concentrations. These are summarized by Greenberg (1954): (1) at 0.05% BAC the uppermost levels of the brain, which govern inhibition and judgment, are depressed; this removal of inhibition is responsible for the illusion of stimulation under alcohol; (2) at 0.1% BAC, the lower brain center is affected and depression of sensory-motor functioning occurs; (3) at 0.2% BAC the midbrain area is affected and control of the emotions is lost; (4) at 0.3% BAC, alcohol affects even lower brain areas; this results in stupor and lack of comprehension; (5) a coma occurs between 0.4 and 0.5% BAC; and, finally (6) at 0.6% BAC, the brain centers responsible for maintenance of breathing and heartbeat are depressed and death can occur.

In regard to elimination of alcohol, one can make the generalization that ethanol elimination begins at the moment of ingestion and proceeds, after equilibration of alcohol in the system, at a uniform rate at least until the concentration reaches a very low value (Loomis, 1950). This rate is reported to be 0.0152% and 0.0185% per hr for men and women, respectively (Shumate, Crowther, and Zarafshan, 1967).

Alcohol is eliminated mainly by three routes: oxidation, urination, and breathing (Wallgren and Barry, 1970). Most of the alcohol consumed is oxidized. The byproducts of the oxidation process, carbon dioxide and water, are eliminated through breathing and urination, respectively. The oxidation rate is constant once the alcohol is absorbed into the tissues. Only a fraction of the alcohol ingested is directly eliminated through urination since alcohol is not concentrated in the urine. Direct elimination through the lungs also accounts for only a small amount of the alcohol ingested. Since the rate of pulmonary ventilation affects elimination by this route, and since work increases pulmonary ventilation, work will increase loss via this route. However, even under work conditions, elimination through the lungs will not be substantial. Due to the constant oxidation rate, elimination is almost solely a function of time and will not be greatly affected by exercise with its attendant increase in pulmonary ventilation (Begbie, 1966). Oxidation is not affected by the ingestion of coffee (Price, 1985), so the elimination process cannot be speeded up by drinking coffee.

Elimination rate is not, however, absolutely invariant. As with absorption rate, there is intra-individual variability in elimination rate (Jones and Vega, 1973).

Jones and Vega also reported that the rate of consumption of the beverage affects elimination rate with fast drinkers having slower elimination rates than slow drinkers. Further, Sturtevant (1976) noted that elimination rates vary with circadian rhythms.

Despite the fact that the biological mechanism by which alcohol is absorbed, distributed, and eliminated is the same for men and women, women become more intoxicated than men after imbibing the same amounts (in ml/kg) of alcohol. Jones and Jones (1976b) gave two men and two women three alcohol dosages (0.33 ml/kg, 0.66 ml/kg, and 1.32 ml/kg) in three sessions. At each dosage, the women achieved significantly higher BACs than the men. This effect was particularly dramatic at the highest dose.

The menstrual cycle of female drinkers as well as their use of oral contraceptives can affect alcohol metabolism. Jones, Jones, and Paredes (cited in Jones and Jones, 1976b) studied the effects of oral contraceptives on ethanol metabolism. Three groups of subjects, females taking oral contraceptives, females not taking oral contraceptives, and males, were studied. Several results important to the present research can be noted: (1) the two female groups obtained identical BACs, and these BACs were significantly higher than those obtained by males; (2) the elimination rate of ethanol (in mg/kg/hr) was significantly slower for the women taking oral contraceptives than for the women not taking contraceptives; the elimination rate of women not taking contraceptives and men was the same; (3) the disappearance rate of ethanol (percent per hr) of the females taking oral contraceptives was slower than for those not taking contraceptives; the women not taking contraceptives had higher disappearance rates than men but those females taking contraceptives had rates similar to those of males; and (4) women taking oral contraceptives took longer than women not taking contraceptives to reach zero BACs. These data combine to indicate that females taking oral contraceptives metabolize ethanol more slowly than either females not taking oral contraceptives or males. The expectation is that they would remain intoxicated longer, with a resultant longer period of impaired productivity if they were intoxicated on the job.

In the Jones and Jones (1976a) study discussed previously, one additional factor, namely, day of the menstrual cycle of the female subjects was explored. Test sessions were scheduled such that each woman was tested during two of the three stages of the menstrual cycle. These stages were defined as follows: (1) menstrual: first day of the menstrual flow; (2) intermenstrual: middle of the menstrual cycle, about day 14; and (3) premenstrual: day preceding the first day of menstrual flow, about day 28. The results showed that there was a higher mean peak BAC during the premenstrual time than during either the menstrual or intermenstrual times. Further, Jones and Jones (1976b) reported a study in which three female subjects were tested with a moderate alcohol dose (0.66 mg/kg) throughout two complete menstrual cycles. Their findings indicated that the same dose of alcohol resulted in different BACs throughout the menstrual cycle (ranging from 0.04% to 0.10% in one subject) and confirmed their earlier indication (Jones and Jones, 1976a) that the highest mean peak BACs occurred during the premenstrual time. They also found high BACs during ovulation.

These studies have obvious implications for researchers who wish to compare the alcohol-induced impairment of male and female subjects. First, different alcohol dosages must be administered to males and females to achieve the same target BACs. Second, both the use of oral contraceptives and time of the menstrual cycle must be controlled to assure accurate dosing of female subjects.

Psychological Effects

Sensory domain. Most of the literature regarding the sensory effects of alcohol has been concerned with vision. This research indicates that visual acuity is relatively insensitive to alcohol. Barbre (1983) found no effect on visual acuity at BACs of up to 0.09%. Colson (1940) and Brecher, Hartman, and Leonard (1955) reported that, even when subjects were given alcohol until they became incapacitated, only a minority of subjects experienced impaired acuity.

Other results in the visual domain have been reported. Lange and Specht (1915, cited in Wallgren and Barry, 1970) found that alcohol improved sensitivity to dim lights; at the same time it reduced the ability to discriminate between brighter lights. Verriest and Laplasse (1965) reported that alcohol had no effect on either light or dark adaptation even at rather large dosages (0.7 g/kg; estimated BAC = 0.089%); but, it did lower subjects' resistance to glare.

Alcohol also affects color sensitivity. Schmidt and Bingel (1953) reported that the amount of red, green, or yellow coloring that had to be added to a white field for subjects to discern the presence of color increased under a 0.7 g/kg (estimated BAC = 0.089%) ethanol dose. Zeiner-Henrikson (1927, cited in Wallgren and Barry, 1970) also found decreased discrimination of the three colors used by Schmidt and Bingel at dosage levels of 0.4 g/kg (estimated BAC = 0.046%) but found that this dosage increased discrimination of blue, indigo, and violet hues.

Critical fusion frequency, operationally defined as the highest intermittency rate at which a subject perceives a light as flashing, is decreased by large dosages of alcohol (0.8 g/kg; estimated BAC = 0.099%) but not by smaller doses (0.4 g/kg; estimated BAC = 0.046%) (Ikeda and Cranger, 1963; Idestrom and Cadenius, 1968). Findings of this type lead to the conclusion that alcohol impairs the ability to perceive rapidly changing events (Price, 1985).

Moskowitz and Sharma (1974) studied the effect of alcohol on peripheral vision in a task which involved either a steady or a flashing fixating light. Their results showed that alcohol effects were mediated by information load. Under the minimal load of the steady light, alcohol had no effect on the detection of the peripheral lights. Under the informational load of the flashing light, however, alcohol levels of 0.09% produced up to 85% decrement in peripheral detection. The authors suggested that their results indicate that alcohol interferes with central information processing rather than with peripheral vision.

Auditory acuity also seems to be relatively insensitive to the effects of alcohol. Schwab and Ey (1955, cited in Wallgren and Barry, 1970) using dosages of 1 g/kg (estimated BAC = 0.102%) found no impairment in either at-threshold or above-threshold tests. Other studies indicate, however, that the ability to glean information from auditorily presented material is impaired. Pihkanen and Kauko (1962), using the same dosages as Schwab and Ey, found impairment of the ability of expert listeners to discriminate between two pitches or between two rhythms, and to identify one different note presented in two successive sequences of notes. Bablik (1968, cited in Wallgren and Barry, 1970) reported impaired comprehension of numbers and words, but no impairment of the ability to detect pure tones, at BACs as low as 0.03%.

In contrast to either visual or auditory acuity, both olfactory and gustatory sensitivity are diminished under relatively low ethanol doses. Irvin, Ahokas, and Goetzl (1950) found olfactory impairment at dosages of 0.1 g/kg (estimated BAC = 0.007%). Margulies and Goetzl (1950) found similar gustatory impairment at dosages of 0.2 g/kg (estimated BAC = 0.017%).

Finally, the effects of alcohol on tactile stimulation were reviewed by Jellinek and McFarland (1940). They cited evidence that moderate doses of alcohol impaired two-point discrimination, in which the skin is touched by a sharp pointed instrument at two different locations and the subject is asked to discern whether he or she was touched at the same place. They also indicated that higher doses of alcohol diminished sensitivity to pain, but had no effect on sensitivity to touch.

Motor domain. Under conditions of alcohol intoxication, a phenomenon known as Positional Alcohol Nystagmus (PAN) is exhibited. This phenomenon consists of the tendency for the eyes of the subject who has been placed with his/her head on its side to drift upward with compensatory downward jerks. Plenkers (1943, cited in Wallgren and Barry, 1970, and Ryback and Doub, 1970) reported two stages of PAN. PAN I is described above and is reported to last 3-1/2 hr and to begin at BACs of about 0.06%. In PAN II, rapid upward eye movements occur and last 5 to 10 hr. Ryback and Doub (1970) found PAN I to last up to 15 hr and PAN II to be exhibited up to 34 hr after ingestion in some subjects. They suggested that the two phases cycle until PAN finally subsides, usually after about 15 hr. Aschan (1957) reported a similar effect which he called alcohol gaze nystagmus (AGN), in which, if the subject attempts to focus on an object at either side of the visual field, the eyes drift toward the center then jerk back to the target object. PAN and AGN suggest that alcohol may weaken ocular-motor control.

Many studies have been conducted on the effect of alcohol on muscular steadiness. The primary focus of such research has been on standing steadiness as measured by the Romberg test (in which the subject is asked to stand with feet together and eyes closed and sway is measured). Most of this research has shown great decrements at high blood alcohol levels: Goldberg (1943) found that sway increased 3.9 times at 0.10% BAC; Idestrom and Cadenius (1963) found increased swaying at BACs of 0.08 and 0.10%. Alha (1951), however, found increases in swaying with BACs as low at 0.04%. Research by Begbie (1966) sheds some light on the trend for sway to be substantially affected only at high BACs in the typical eyes-closed test. His results showed a decrement under blood alcohol levels of 0.06% when subjects' eyes were open but not when they were closed indicating that it is impairment of the visual cues, rather than the kinesthetic or vestibular ones, that takes place at the lower dosages.

Motor control of the arms and hands is also affected by alcohol. Goldberg (1943) found a 75% increase in dispersion in a test requiring subjects to bring their index fingers together under 0.10% BAC. Muller, Tarpey, Georgi, Mirone, and Rouke (1964) reported a 14% decrement in hand steadiness as indicated by the number of times a subject touched the sides of a hole while moving a stylus through it.

Psychomotor/sensory-motor domain. This section reviews material dealing with the coordination between sensory input and motor output. Hence, some reference to material covered previously is inevitable. Four general areas are explored: (1) ocular-motor performance, which is concerned with control of the muscles which govern eye movement; (2) reaction time; (3) other tasks in which speed is the dependent variable of interest; and (4) tracking and controlling objects in motion.

As Wallgren and Barry (1970) pointed out, the studies concerned with ocular-motor performance are of particular interest in light of the theory by Jellinek and McFarland (1940) which states that alcohol should have a less detrimental effect on highly familiar tasks than on novel tasks. Since ocular control is a constantly occurring activity, it represents a highly familiar task. Hence, decrements in ocular-motor performance under alcohol would conflict with the ideas of Jellinek and McFarland.

Blomberg and Wassin (1962) found a 20% decrease in the optokinetic fusion limit, measured as the maximum speed at which a subject's eyes could follow vertically spaced lines on a horizontally moving drum, under BACs as low as 0.002%. Here, however, the concern was with monocular movements. More typically, we are involved in situations which require binocular coordination. This type of coordination is also impaired by alcohol as indicated in the comprehensive study by Brecher et al. (1955) mentioned previously. These authors tested fusion speeds of subjects at BACs of 0.03 to 0.18%. Subjects were instructed to fixate on a constant light source with one eye while a flashing light was presented to the other eye and to indicate when a single image was seen. Their results showed a 14% decrement at the lowest alcohol levels and an 89% decrement at the highest alcohol levels. Further, Brecher et al. confirmed the earlier work of Powell (1938) which indicated that alcohol caused the eyes to converge at long viewing distances and to diverge at short viewing distances.

Depth perception seems to be impaired only when participants are subjected to rather high BACs (i.e., 0.1% caused deficits in a study by Starck, 1953 cited in Wallgren and Barry, 1970). The ability to judge distances also seems to be impaired by alcohol (Newman and Fletcher, 1941), but whether this impairment is a result of sensory-motor or cognitive debilitation is unclear.

Levett, Karras, and Hoeft (1975) found that alcohol affects visual accommodation and eye movement latency at BACs of 50 to 100 mg alcohol/100 ml blood. Two measures of accommodation, latency of response time (time from stimulus presentation until accommodation begins) and total accommodation time, were used. For both measures, accommodation was slower under alcohol conditions than under control conditions. Further, the degree of retardation increased with increasing BACs. Eye movement latency was concerned with measuring the time from when a stimulus began to move in a horizontal direction until the subject began to track the movement. Again, alcohol slowed the response; however, the effect did not increase with increasing concentrations of alcohol. As the authors noted, because accommodation is responsible for a clear image being projected onto the retina, impairment of accommodation can constitute a safety hazard.

In addition to decrements in tracking a single moving object, Honneger, Kampschulte, and Klein (1970) found that low alcohol dosages resulted in impairment of the subject's ability to discriminate close, but separate, moving objects.

In the work dealing with the effect of alcohol on reaction time, the general consensus is that simple reaction time is moderately increased by alcohol ingestion

(Carpenter, 1962). Further, this performance decrement increases with increasing blood alcohol concentrations (Cavett, 1938). Wallgren and Barry (1970) pointed out, however, that BACs of at least 0.07% are needed before consistent effects are found. BACs of 0.08 to 0.10% generally increase reaction time by about 10%.

Choice reaction time also increases with BAC (Linnoila, Erwin, Cleveland, Logue, and Gentry, 1978). Further, Bahnsen and Vedel-Peterson (1934) found that alcohol caused a greater percentage increase in choice reaction time than in simple reaction time. Jennings, Wood, and Lawrence (1976) reported that alcohol has more of an effect on the time taken for correct responses than for incorrect ones. At the same time, there seems to be an increase in the incidence of erroneous choices under alcohol (Martin, LeBreton, and Roche, 1957, cited in Wallgren and Barry, 1970).

Two other findings regarding alcohol and reaction time are noteworthy. Alcohol seems to have a greater detrimental effect on reaction time in response to an auditory signal than to a visual signal (Forbes, 1947). Also, there is a greater impairment of reaction time when the subject's BAC is ascending than when it is descending (Young, 1970).

The effects of alcohol on the speed of responding on sensory-motor tests such as letter cancellation, finger- and toe-tapping, and pegboard and typing tests have also been investigated. In letter cancelling, low alcohol dosages (beginning at 0.4 g/kg; estimated BAC = 0.046%) caused a 5 to 27% performance decrement (Jellinek and McFarland, 1940). Higher dosages (1.0 to 1.4 g/kg with estimated BACs of 0.102 and 0.237%, respectively) decreased performance speed by as much as 60% (Goldberg, 1943). Finger- and toe-tapping speed were also found to decrease under alcohol conditions (Carpenter, 1962). Similarly, alcohol slows the ability of subjects to transfer pegs from one set of holes to another (Lawton and Cahn, 1963; Muller et al., 1964); however, the decrement is not as great on simple motor tasks such as this (with 0.5 g/kg; estimated BAC = 0.061% producing time increases of 7 and 3% in the two studies, respectively) as on more complex tasks.

Alcohol effects on typing are of particular interest in the current review since typing is a task frequently done in the business environment. Jellinek and McFarland (1940) reported that small alcohol doses (0.3 to 0.6 g/kg; estimated BACs of 0.031 and 0.076%, respectively) caused a slight (1.5 to 5%) decrease in speed but a great (40 to 121%) decrease in accuracy.

Alcohol also significantly impairs subjects' ability to track or control a moving object. Bahnsen and Vedel-Peterson (1934) found that moderate alcohol doses increased (by 60%) the number of deviations of a stylus from a target in a task resembling the pursuit rotor. Drew, Colquhoun, and Long (1958) found that increased BACs resulted in increased tracking errors in a test in which subjects were required to keep a marker on a moving target by moving a steering wheel. This manipulation points to the obvious resemblance of tracking to automobile driving. Hence, other studies dealing with this issue will be discussed in a subsequent section.

Cognitive domain. As with the psychomotor domain, the material in this section is divided into a few major areas: (1) verbal performance; (2) problem solving; (3) learning and memory; and (4) attention and judgment.

Most research on the effects of alcohol on verbal performance has been concerned with verbal responses to words. Jellinek and McFarland (1940) indicated that, in this situation, alcohol increased superficial, egocentric, and inappropriate associations.

Verbal fluency, as measured by the number of words said, is also impaired by alcohol (Hartocollis and Johnson, 1965).

Verbal mastery, the ability of a subject to select an appropriate word, also is affected negatively by alcohol ingestion. Hartocollis and Johnson (1956) reported that alcohol impaired subjects' ability to identify a particular word when given its definition.

Studies concerned with the effect of alcohol on problem solving have focused on arithmetical calculations, digit symbol substitution, spatial/temporal relations, and complex intellectual functioning. The research dealing with arithmetic indicates a detrimental effect which primarily attacks accuracy over speed and which is enhanced by complex tasks (Wallgren and Barry, 1970). Davis, Gibbs, Davis, Jetter, and Trowbridge (1941) found that BACs of 0.09 to 0.13% caused a large increase in addition errors but no consistent change in the number of figures added. Ekman, Frankenhaeuser, Goldberg, Bjerver, Jarpe, and Myrsten (1963) found a similar effect in a task which required both addition and subtraction. They further found that the increasing error rate was a function of increasing BACs with a 15% increase at 0.035% BAC and a 31% increase at 0.07% BAC.

Zirkle, McAtee, King, and VanDyke (1960) found a larger decrement (15%) on a task involving division than on an addition task (7%) when subjects were given the same alcohol dosages, thus supporting Wallgren and Barry's (1970) claim of a greater effect of alcohol on complex tasks. In addition, Forney and Hughes (1961) reported that detrimental effects are enhanced by distracting conditions which may be seen as contributing to increased task complexity.

Many of the same researchers who investigated arithmetical calculation investigated the digit symbol test. This test, which requires the person to substitute symbols for letters, is considered a simpler mental task than is arithmetic, but it is less familiar and requires greater sensory-motor capability since the subject must consult the list of symbols while making the substitution (Wallgren and Barry, 1970). Zirkle et al. (1960) found that ethanol impaired performance on the digit symbol test by 9%. Lawton and Cahn (1963) also found a small decrement (3%) in digit symbol performance under alcohol conditions in a study in which no effect was found on arithmetical calculations. Although the decrement found by Lawton and Cahn is quite a bit smaller than that found by other researchers, the research is noteworthy for the indication that digit symbol performance, which has a heavy sensory-motor orientation, is more degraded than is a more purely cognitive task.

In regard to spatial/temporal relationships, Wallgren and Barry (1970) reported that manipulation of spatial relationships is severely impaired by alcohol. Temporal relationships are also affected. Hartocollis (1962) indicated that time seems to pass more quickly for a subject who is under the influence of alcohol. Rutschmann and Rubinstein (1966) found that alcohol impaired the ability of subjects to press a lever at 1- and 10 s intervals with subjects pressing more slowly at the 1 s interval and more quickly at the 10 s interval.

Several studies on the effect of alcohol on complex reasoning have been conducted. Hutchison, Tuchtie, Gray, and Steinberg (1964), using a measure of abstract reasoning (the similarities section of the Wechsler Adult Intelligence Scale (WAIS)) found an 11% decrement in subjects with BACs of 0.10%. Frankenhauser, Myersten, and Tarpe (1962) found a small decrement on an inductive reasoning test in subjects under the influence of alcohol. Carpenter, Moore, Snyder, and Lisansky (1961) looked at the effects of three alcohol dosages on algebraic manipulation. While the highest dose (0.8 g/kg; estimated BAC = 0.099%) caused a substantial decrease in problem solving ability, the two lower dosages (0.27 and 0.54 g/kg; estimated BACs = 0.027 and 0.068%, respectively) seemed to enhance performance slightly.

Before leaving the topic of problem solving, it is worthwhile to note that many of the tasks used in this research are taken from adult intelligence tests (i.e., arithmetic, digit symbol, and similarities). As Jellinek and McFarland (1940) commented, it seems, then, that alcohol may impair the manifestation of intelligence.

Research on the effects of ethanol on learning and memory can be divided into three areas: those concerned with classical conditioning, short-term memory (STM), and long-term memory (LTM). In the classical conditioning paradigm, Hobson (1966a, 1966b) found that the percentage of conditioned eyeblink responses to a stimulus paired with an air puff decreased under alcohol conditions. The extent of this decrease was dependent on BAC, with higher BACs producing fewer conditioned responses.

Studies of ethanol effects on STM have typically used either the digit span test from the WAIS or verbal learning tasks. In both cases, alcohol has a detrimental effect on the ability to recall material immediately after presentation. On the digit span test, the effects of alcohol are particularly striking if the participant must reorganize the presented material by reciting the digits backward. Hutchison et al. (1964) reported that subjects with BACs of 0.10% did not differ significantly from controls in the number of digits that could be repeated forward but did differ in the number that could be repeated backward.

Nash (1962) studied the effect of alcohol on recall of verbal material. He found that high dosages (0.065% BAC) impaired subjects' memory only for relatively difficult words. Further, both 0.035 and 0.065% BACs produced impaired recall of a story but not of a sentence, thus indicating that alcohol is only detrimental to recall of complex verbal material.

Studies of LTM have led to the conclusion that alcohol leads to memory deficits regarding events that took place while the subject was intoxicated. Diethelm and Barr (1962) reported that the conversations of subjects under the influence of alcohol were typically forgotten by those subjects tested the next day when they were sober. Kalin (1964), in a study in which subjects were given the Thematic Apperception Test while intoxicated and then asked to recall their response while sober, indicated that the extent of forgetting was related to the degree of intoxication. As Wallgren and Barry (1970) noted, these deficits may have been the result of change from intoxicated to sober conditions rather than due to any impairment of storage or retention.

One attempt to test such an idea was made in the research by Goodwin, Powell, Bremer, Hoine, and Stein (1969) in which 48 subjects were tested in four groups: learn sober/recall sober, sober/intoxicated, intoxicated/sober, and intoxicated/intoxicated. The greatest disruption occurred in the group switched from intoxicated to sober conditions. Both the sober/intoxicated and intoxicated/intoxicated conditions were inferior to the sober/sober condition. These results lead to several conclusions: (1) learning is state dependent; (2) recall is most impaired when material is learned in one state and recalled in another; this is especially true if the material is learned when intoxicated, indicating that intoxication impairs storage; and (3) the best state situation is sober/sober. About 0.7 to 1.2 g/kg (estimated BACs = 0.089 and 0.190%, respectively) of alcohol is needed to produce these results (Eich, 1977).

Although Goodwin et al. (1969) give some indication that alcohol affects the storage processes, none of the research discussed thus far has systematically attempted to determine whether alcohol affects storage or retrieval (or both) in short-term and long-term memory tasks. Here, however, there is a methodological problem associated with separating the storage process (formation of a memory trace) and the retrieval process (searching for and finding the trace). Work such as that by Goodwin et al. has been criticized as inadequate for assessing storage versus retrieval deficits because the tasks used required both acquisition and recall (Birnbaum and Parker, 1977). In investigating the storage process, then, Birnbaum and Parker used tasks which they believed minimized the necessity for retrieval, namely recognition tasks, which do not require memory search. Two different tasks were used. In the first task, subjects learned a paired-associates list with consonants as stimuli and the months of the year as responses. The authors assumed that, since the months of the year are well known, incorrect responses would not be due to retrieval impairment. In the second task, subjects were shown photographs and then asked to identify them in a forced-choice recognition task. In both tasks, three alcohol levels (placebo, medium, and high) were used. On the paired-associates tests, only the high dosage caused a deficit. On the picture recognition test, however, there was a dose dependent decrement. These results indicate that alcohol does affect information storage and that this effect is greater on tasks which require more information to be stored (in this case, the picture recognition task).

In studying the retrieval process, Birnbaum and Parker (1977) used both free-recall and paired-associates (a consonant paired with an adjective) tests. At the initial session, sober subjects were asked to learn the two lists to a criterion of perfect recitation. At the second session a week later, half the subjects were given alcohol and the other half were not. Subjects were then asked to recall the lists, first without then with cues. (The uncued test required retrieval while the cued test did not.) On both the cued and the uncued tests, sober and intoxicated subjects performed equally well. For both groups, cueing increased the amount of material subjects were able to recall. These results indicate that alcohol primarily affects storage rather than retrieval of information.

Another study by Birnbaum and Parker (1977) confirms this notion. Here, subjects learned and recalled a categorized free-recall list either while sober or while intoxicated. Two recall situations, uncued and cued, were used. In the uncued situation, intoxicated subjects recalled fewer words, fewer words per category, and fewer categories than sober subjects. In the cued situation, however, intoxicated subjects showed great improvement in recall while sober subjects were not greatly affected. While this result initially seems to point to differences in retrieval between the two groups, the authors explain that the ability of sober subjects to "empty the contents" of storage more thoroughly than intoxicated subjects in the noncued conditions may have been due to a stronger trace in the memories of these subjects. Cueing may have served to reinforce the weaker trace of the intoxicated subjects, allowing retrieval gains.

Several other studies concerned with the effect of alcohol on memory are worth mentioning. Jones and Jones (1977) were concerned with whether there would be differential memory effects on a free recall test for subjects tested on the ascending versus the descending limb of BAC. They found that, in a test of immediate recall, descending limb performance was significantly better than ascending limb performance. In a test of STM, however, there were no significant differences between the two limbs.

Jones and Jones (1977) also wanted to determine whether alcohol affects the memory of females differently than the memory of males. Again using a free recall task with immediate memory and STM tests, they found no significant differences in baseline or immediate tests, but females were more affected than males on the STM test.

In addition, Moskowitz and Murray (1974) indicated that the rate at which information is processed is slowed under alcohol conditions. Finally, Rundell and Williams (1977) noted that the most significant effect of alcohol is on the ability to reorganize information "stored in" LTM. This ability is particularly impaired at BACs greater than 0.09%.

Like the work on the effects of alcohol on tracking, the research concerned with attention and judgment has primarily focused on driving tasks. Hence, it will be treated subsequently. Only a few general points will be mentioned here. With regard to attention, alcohol seems to have no significant effect on simple auditory or visual vigilance tasks (Talland, Mendelson, and Ryack, 1964). Erwin, Wiener, Linnoila, and Truscott (1978) reported that visual vigilance of a somewhat more complicated nature (i.e., like that used in driving) can be impaired by alcohol-induced drowsiness and its resultant eye droop. Moskowitz and DePry (1968) indicated that, when a vigilance task requires divided attention, alcohol impairs performance at moderately high dosages.

Impairment of judgment under alcohol is also widely demonstrated in the literature. Newman and Fletcher (1941) reported that intoxicated subjects engaged in a sensory-motor task believed their performance to be improved when it was really impaired. Nash (1962) indicated that subjects under the influence of alcohol underestimated the degree of their performance impairment. In addition to impairing the ability to estimate self-performance, alcohol impairs the ability to judge the performance of others (Lubin, 1979).

The willingness to take risks is also increased under ethanol conditions. Price and Barbre (1985) studied risk taking on a touch entry task under alcohol conditions. They found that risk taking behavior was affected by the presence of alcohol in the blood. Further, criticality was operative in risk taking behavior. Alcohol affected risk taking more on low criticality trials than on high criticality trials. However, as BACs increased, the care taken on high criticality trials decreased. When performance at a BAC of 0.20% was extrapolated from the observed data, no difference was found between the low and the high criticality conditions. Willingness to take risks appears to interact with drinking experiences: inexperienced drinkers are more likely to take risks when intoxicated than are experienced drinkers (Goodwin, Powell, and Stein, 1973).

Finally, Verhaegen, VanKeer, and Gambert (1974) indicated that, independent of the quality of judgment, subjects under the influence of alcohol became slower in making a decision in situations which required swift action.

Comments. A major problem arises for anyone reading a review, such as the one just presented, of the literature on the psychological effects of alcohol. Namely, how can this material be integrated so that generalizations can be made? Fortunately, this issue was addressed by Levine, Greenbaum, and Notkin (1973) and by Levine, Kramer, and Levine (1975). Using a subset of the studies reviewed here, these authors classified the research according to the abilities required for task performance. Three classes of abilities -- cognitive, perceptual-sensory, and psychomotor -- were used. The aim was to determine whether there was a differential effect of alcohol on the different types of tasks.

Levine et al. (1973; 1975) developed curves which indicated performance decrements at various alcohol dosages (in g/kg). Performance decrements were expressed as the percent difference between control and experimental scores, divided by the control scores, and then multiplied by 100%. Positive scores indicate better performance on the part of the experimental group. Negative scores have the opposite interpretation. Price (1985) adapted these curves to reflect decrements at various BACs (Figure 1 and Figure 2) and to define a "zone of impaired performance" (p. 12) as shown in Figure 2.

Comparison of these curves suggests that performance effects due to alcohol differ as a function of task requirements. Psychomotor performance was least impaired by alcohol, cognitive performance was impaired at an intermediate level, and perceptual-sensory performance was most impaired. Levine et al. (1973) explained the relative

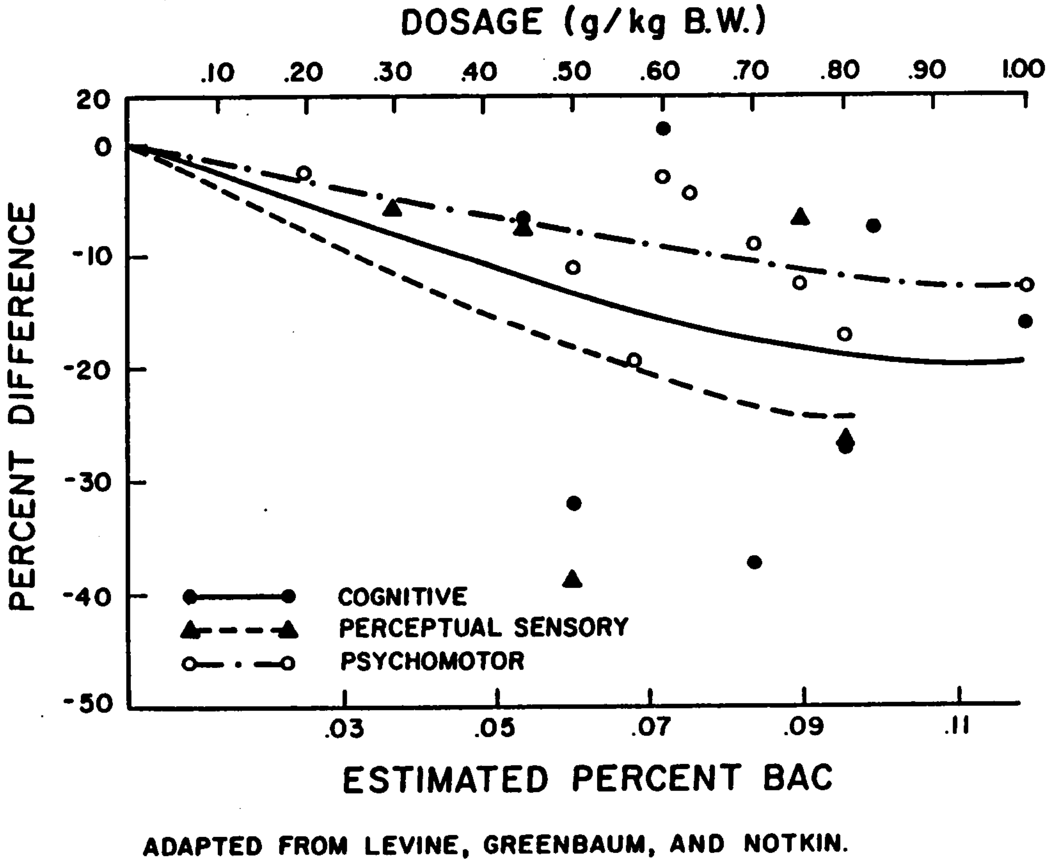


Figure 1: Performance decrements as a function of BAC.

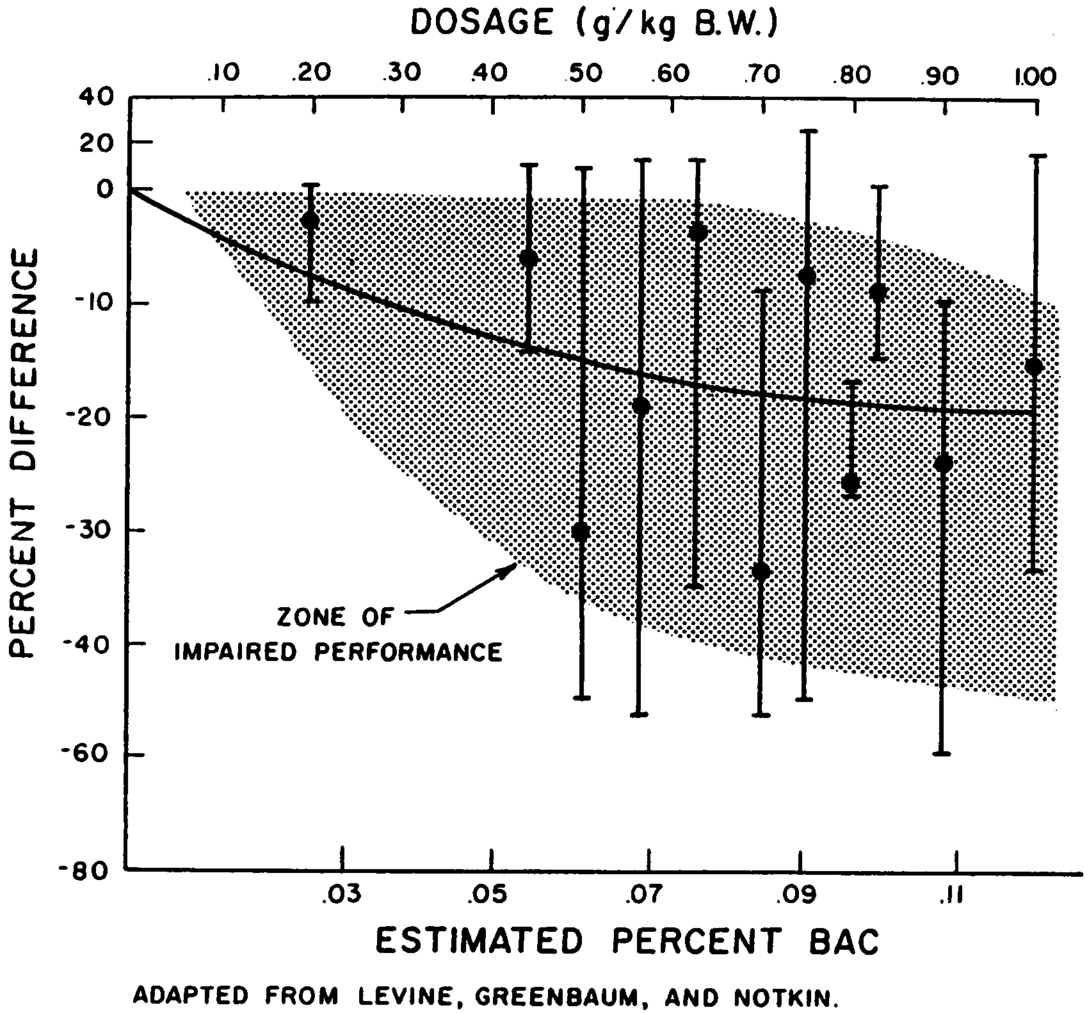


Figure 2: Zone of impaired performance as a function of BAC.

resistance of psychomotor tasks to alcohol impairment as a manifestation of overlearning: psychomotor tasks, unlike cognitive and perceptual tasks, tend to be highly learned; hence, they are resistant to the "stress" of the alcohol. Regardless of the degree of impairment, however, all three of the task classes studied by Levine et al. showed decrements due to alcohol.

Effects on Automobile Driving

The literature on the effects of alcohol on driving is primarily concerned with sensory-motor and cognitive performance. The eye movement of drinking drivers has been one area of study. Kobayaski (1974) reported that, for drivers under the influence of alcohol, horizontal saccadic eye movements were decreased, the road area on which they fixated was also decreased, and the area of fixation shifted to the bottom of the visual field. This prolonged fixation and shrinking of the visual field results in the driver receiving less information. Further, the use of the bottom of the visual field under alcohol conditions suggests that the driver is collecting information at shorter distances than he or she would under sober conditions. The results of Biedeman and Stern's study (1977) also indicated that the intoxicated driver receives less information than the sober driver. They found that under 0.07% BACs subjects experienced up to 35% more eye closures of 50-150 ms durations.

Attwood (1978) was concerned with drunk drivers' ability to detect and interpret information commonly encountered while driving, namely, rear brake and turn signals. Response errors and latencies showed impairment with blood alcohol levels as low as 0.05% when the standard signal configuration (brake and turn signals combined under the same lens) was employed.

A large body of literature regarding vehicle control has been amassed. Bjerver and Goldberg (1950), in a study which measured speed to complete six driving maneuvers at BACs of 0.05%, found decrements ranging from 3% on a steering test to 72% on a parallel parking test. Wallgren and Barry (1970) reported that even low dosages (0.03% BAC) caused steering impairments and that at higher dosages deviation from a set track increased as much as 100%. A study by Mortimer and Sturgis (1974) also revealed a steering decrement under low and moderate alcohol dosages. This research, further, examined the effect of alcohol on the various components of steering and indicated that subjects under the influence of alcohol used fewer of the available cues (i.e., they decreased their use of rate and heading angle cues and focused on lateral position cues) reducing their level of competence. In addition to steering deficits, Laurell (1977) found braking deficits (i.e., slowed reactions, measured as longer stopping distances) in subjects with BACs of 0.04%. Steering deficits were manifested by an increase in the number of obstacles (pylons) collided with on a test track; 50% of subjects under the influence of alcohol experienced collisions while only 10% of subjects in the no-alcohol condition had collisions. Huntley and Perrine (1971, reported in Ryder, Malin, and Kinsley, 1981), however, noted that this impairment was conditional on driving instructions such that, if intoxicated subjects were directed to drive accurately, the effect was not observed.

The effects of alcohol on driving speed are unclear. Coldwell, Penner, Smith, Lucas, Rodgers, and Darroch (1958) reported that low dosages of alcohol decreased driving speed. Jellinek and McFarland (1940) found increases in driving speed under low alcohol dosages. In the study reported by Jellinek and McFarland, however, subjects were unable to judge their driving speed and indicated that they had been driving more slowly than their actual speed.

Alcohol also seems to impair drivers' judgment. Cohen, Dearnaley, and Hansel (1958) found that intoxicated drivers would try to drive their vehicles through a narrower gap than would sober drivers. Light and Keiper (1971) reported impairment of passing judgment in intoxicated drivers.

Effects on Performance of Industrial Tasks

Very little research has been reported on the effects of alcohol on performance of specific industrial tasks. Of that reported, most has been concerned with motor processes. Price and Hicks (1979) sought to determine the effects of alcohol on a water tap assembly task using quality of work, number of units produced, and assembly time as indices. Four blood alcohol levels (placebo, 0.05, 0.07, and 0.09%) were administered to six male subjects. The results indicated an increase in the number of errors made as dosage increased as well as an increase in assembly time of up to 19% with increasing alcohol consumption. The authors concluded that there was a considerable degradation of performance for relatively low levels of alcohol consumption (less than the 0.10% BAC often used as the legal criterion for intoxication).

Price, Radwan, and Tergou (1986) studied an assembly task. Eight male and eight female subjects assembled and checked a circuit board (by properly placing coded resistors and adjusting a volt meter) under the same BACs used by

Price and Hicks (1979). Four pacing conditions, unpaced and paced at 50%, 75%, and 100% capacity, were employed. In the unpaced trials, there were also two incentive conditions in which speed and accuracy, respectively, were stressed. The dependent variables included the numbers of correctly completed circuit boards, orientation errors in resistor placement (one of two pins misplaced), position errors (both pins misplaced), improper resistors selected, errors in volt meter adjustment, and incomplete units. Completed units served as the productivity-related dependent variable. All error measures were summed to produce a total error score which was the score used for quality-dependent analysis. Scoring was adjusted for differential opportunity to err in the paced conditions. The general results of the study are as follows: (1) productivity decreased up to 50% at 0.09% BAC as compared to placebo; (2) in both the paced and the unpaced conditions, females worked faster but with more errors than males; (3) females were more responsive to incentive instructions than were males; (4) a gender by alcohol interaction was found for both accuracy and productivity, with females showing greater impairment with increasing BAC than males; (5) paces which employed a less than maximum workload increased productivity but decreased quality; (6) the effect of alcohol was more pronounced at faster paces; and (7) workers operating under a speed incentive showed greater impairment due to alcohol than those working under an accuracy incentive.

Barbre and Price (1982) were also concerned with a primarily motor task, namely, the operation of a simulated punch press. The subjects, eight males, were required to operate a punch press simulator under the four BAC levels used in the previously cited research. Duration of intoxication and task complexity were manipulated. Performance measures involved percent of parts completed correctly and number of parts attempted. The results indicated that: (1) the percentage of parts completed correctly was significantly affected by BAC with increased BAC yielding lower percentages; (2) the percentage of correctly completed parts was significantly higher during the longer intoxication period; (3) the number of parts attempted was significantly lower for higher BAC levels; and (4) the number of parts attempted was significantly higher during the longer intoxication period. The authors concluded that "blood alcohol concentration probably cannot be accurately used as the sole predictor of ethanol-impaired work performance decrements. Duration of BAC and task complexity should also be considered" (p. 919).

Flax and Price (1982) and Price and Flax (1982) investigated the effects of alcohol and task difficulty on drill press operation. They used eight male subjects at four dosage levels (BACs of 0.00, 0.03, 0.06, and 0.09%) and eight levels of task difficulty (which was manipulated by changing the size and distance of two holes into which the participant was required to consecutively place a drill probe). Speed and accuracy were the dependent variables of interest and two sets of instructions, each stressing one of these variables, were used. Accuracy was determined by the number of hits (probe insertion without touching the hole surround) and misses (touching the hole surround with the probe). The results showed that increasing BACs resulted in a decrease in the number of hits. There was also a significant alcohol by task difficulty interaction; however, the authors offered no interpretation of this result.

Price and Liddle (1982) looked at the effect of alcohol on an arc welding task. Three BAC levels (placebo, 0.06, and 0.09%) were used. Twelve experienced welders served as subjects. Welding speed, electrode angle, and current variations were the measures of interest. The results showed a significant effect of alcohol on current reversals, with greater variations taking place at the higher BACs. These current reversals resulted in a degraded weld; hence, one could conclude that the welding operation was adversely affected by ethanol consumption.

Finally, Barbre (1983) and Barbre and Price (1983) were concerned with ethanol effects on a target acquisition task, specifically on the mediational processes involved with visual search under various conditions of perceived error criticality. Eight male subjects were asked to touch a pre-screened target using a touch entry video display terminal and their search time, touch accuracy, search perseverance, and hand travel time were measured. Four BAC levels (0.00, 0.05, 0.07, and 0.09%) were used and criticality was manipulated using monetary incentives. The authors reported that search time decreased with increasing ethanol level. This time decrease was due to the decreasing willingness of subjects to search. Other results indicated decreased touch accuracy, fewer trials completed, and increased travel time with increased BACs. Further, although there were generally more "give-ups" under low criticality conditions both these effects were significantly less under the higher BACs, suggesting that relatively low levels of intoxication may alter one's perception of criticality.

<u>Comments</u>. As was the case with the general literature, an integration of this research aids the readers' understanding.

Following the procedure used by Levine et al. (1973), Price (1985) summarized the losses of productivity in the studies cited above as shown in Figure 3.

By comparing this figure to Figure 2, one can see that there is a great deal of similarity in the zones of impaired performance obtained on industrial tasks and on the psychophysical tasks reviewed by Levine et al. (1973). In both cases, "productivity" losses are quite large.

As Price (1985) noted, this similarity supports the concept that "the elemental studies have a relationship to the industrial tasks because these tasks include the cognitive, sensory-perceptual, and motor elements explored in the laboratory" (p. 14). Given the strong similarity in the zones fitted to the psychophysical and the industrial tasks, this relationship appears to be quite robust.

Rationale for the Research

The current study is part of an ongoing project of the Safety Projects Office at the Virginia Polytechnic Institute and State University; the aim is to evaluate the effects of ethanol intoxication on industrial productivity by studying a wide range of industrial tasks. This line of research is thought to be worthwhile in light of the astronomical losses to the American economy due to alcohol misuse.

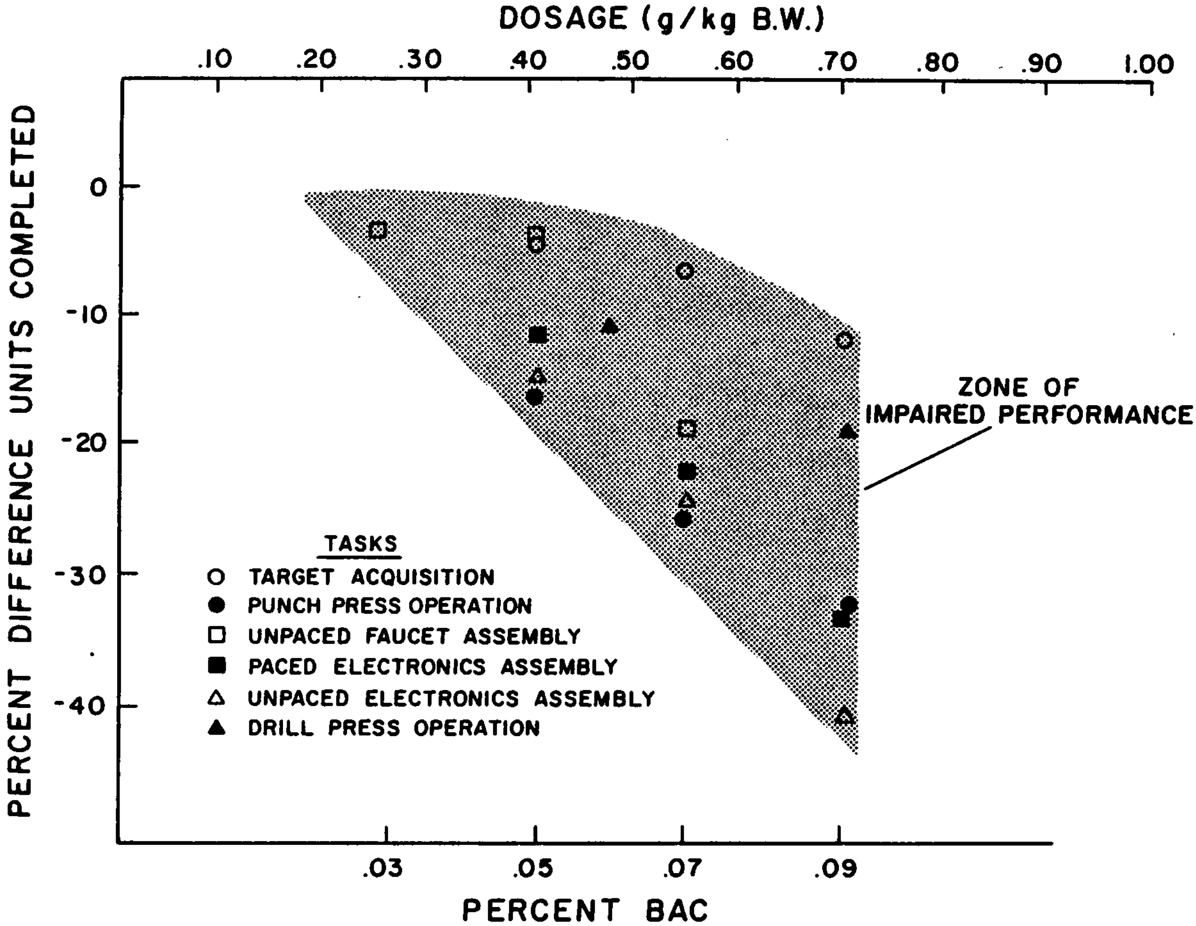


Figure 3: Zones of impaired performance for simulated industrial tasks.

It is often impossible to collect alcohol-impairment information directly in the workplace. Thus, productivity losses due to alcohol use while on the job have only generally been estimated using laboratory simulations (to determine impairment levels) and projected frequencies of on-the-job alcohol use. So far, the visual search (Barbre, 1983; Barbre and Price, 1985), punch press operation (Flax and Price, 1982; Price and Flax, 1982), assembly (Price and Hicks, 1979; Price, Radwan, and Tergou, 1985), and welding (Price and Liddle, 1982) tasks discussed above have been simulated and variables such as task complexity, workload levels, pacing, and incentives have been manipulated. In all cases, alcohol impairment has been observed.

This approach is limited in that it only provides information on a specific job (i.e., the one being simulated). Research which facilitates the ability to evaluate <u>any</u> job for potential alcohol effects is needed. To accomplish this end, it is necessary to move away from job-specific research and toward research which examines the effects of alcohol on entire classes of behavior. Here, a consideration of behavioral taxonomies can be of use.

<u>Incorporation of a behavioral taxonomy</u>. A classification system can be viewed as a tool the function of which is to enhance the ability to interpret or predict

human performance (Fleishman, 1975). The development of such structural systems is important to enable efficient organization and generalization of behavioral data.

In the late 1960s and early 1970s a great deal of taxonomic work was done, primarily under the auspices of the American Institutes for Research. Three major approaches (as described by Farina and Wheaton, 1971, and Fleishman, 1975) were used. In the first major approach, called the "task characteristic approach," the concern is primarily on the task per se. Here, the task is considered to be a set of antecedent conditions which elicit performance and it is these conditions rather than operator behaviors that are of interest. Thus, tasks are described according to task-intrinsic properties such as goals, responses, procedures, stimuli, and stimulus-response relations.

Farina and Wheaton (1971) conducted the majority of the research which used this method. For each of the five task components listed above, several (from three to five) task characteristics were derived. For each task characteristic, a rating scale was developed. Each rating scale presented a definition of the task characteristic to which the rater could refer along with a seven-point scale with defined anchor- and mid-points for which examples were provided. In all, 19 rating scales were used to rate each task.

While these scales were generally found to have adequate reliability in the developmental studies, the ability to use them reliably as a real-world tool is questionable since the authors recommended that raters have a background in human factors or psychology or training regarding stimulus-response conceptualizations. The willingness of the "common man" found in the industrial setting to think in these terms is suspect. In addition, the inclusion of such a large number of scale items makes this a rather unwieldy device for industrial application. Further, for each task evaluated the original 19 items must be screened, using multiple regression techniques, to determine which contribute most to performance.

In the second major approach, called the "behavior or ability requirement approach," the focus is on the resources or abilities of the operator required for task performance. Here, tasks are described with regard to the abilities required of the operator, the assumption being that certain tasks require certain enduring abilities.

Fleishman and his colleagues (Fleishman, 1967a; Fleishman, 1967b; Theologus and Fleishman, 1971) have conducted the bulk of the research on this taxonomic approach. Four major categories of ability, in the physical, cognitive, psychomotor, and perceptual-sensory domains, were determined via a series of experimental, factor-analytic studies which describe performance in a wide variety of tasks. Thirty-seven factors have been defined in these four categories.

As in the task characteristic approach, each ability requirement has an associated rating scale. These scales are similar in format to those used by Farina and Wheaton (1971). Hence, in rating a particular task, a rater would be expected to evaluate the activity on 37 seven-point scales. As was the case with the Farina and Wheaton scales, then, this might be rather cumbersome in practical circumstances. Nonetheless, adequate reliability has been demonstrated both with regard to descriptions of laboratory experiments and descriptions of jobs. Thus, the same ability concepts can be used to "bridge the gap in describing laboratory and real-world tasks within the same conceptual framework" (Fleishman, 1975, p. 1137). However, in all cases expert raters were used in the reliability studies. Again, then, the ability of non-technical raters to comprehend adequately the rather complicated operational definitions presented for each scale item is questionable.

In the third approach, called the "behavior descriptive approach," the focus is on the specific activities in which an operator engages while performing a task. The conditions under which performance takes place are tangential.

The taxonomy developed by Berliner, Angell, and Shearer (1964) (shown in Table 1) exemplifies this approach. In this system, behaviors are classified at three levels -- the process level, the activity level, and the specific behavior level. Behaviors were purposely represented by action verbs, which do not necessitate complex operational definitions, to enhance comprehensibility. The workability of the system was assessed empirically by having raters from various backgrounds sort a large group of verbs (representing specific behaviors) into the categories of behavioral processes -- only those verbs agreed upon by 75% of the raters were included in the taxonomy.

One advantage of this taxonomic approach over those discussed previously, then, is that "judges with rather diverse backgrounds and interests can agree quite well on whether or not a specific activity possesses characteristics which put it in a class of behaviors whose general nature is described by some broad behavioral-process designation" (Berliner et al., 1964, p. 285). Indeed, one restriction imposed by the authors while developing the taxonomy was that "the categories have meaning for non-psychologist users of the system" (p. 294). Thus, the emphasis on comprehensibility shown in the development of this taxonomy may render it most amenable for use by the "common man."

TABLE 1

Classification of Behaviors by Berliner et al. (1964)

Processes	Activities	Specific Behaviors
Perceptual	Searching for and Receiving Information	Detects Inspects Observes Reads Receives Scans Surveys
	Identifying Objects, Actions, Events	Discriminates Identifies Locates
Mediational	Information Processing	Categorizes Calculates Codes Computes Interpolates Itemizes Tabulates Translates
	Problem Solving and Decision Making	Analyzes Calculates Chooses Compares Computes Estimates Plans
Communication		Advises Answers Communicates Directs Indicates Informs Instructs Requests Transmits

TABLE 1 (continued)

Processes	Activities	Specific Behaviors
Motor	Simple/Discrete	Activates Closes Connects Disconnects Joins Moves Presses Sets
	Complex/Continuous	Adjusts Aligns Regulates Synchronizes Tracks

Unlike Fleishman (1967a; 1967b; 1975) and Farina and Wheaton (1971), Berliner et al. (1964) do not provide a rating scale for use with their taxonomy. Rather, they suggest that jobs be described in action verb terms using task-analytic type procedures. Then, importance ratings of these behaviors can be obtained using either critical incidents or expert ratings (where an expert is defined as a person who is experienced in the job rather than a psychologist or human factors specialist). These importances can be used to weight job components, even as high up as the process level. Hence, if several jobs are similarly rated with regard to the higher-category headings one could infer that the processes are unitary enough to possess some common implications for human performance.

A further advantage of this approach is that only three mensural indices -- time, accuracy, and frequency -- are required to adequately evaluate performance of the specific behaviors (Berliner et al., 1964).

Time measures consist primarily of reaction time or task completion time. Accuracy measures include: (1) whether a correct choice is made given several alternatives; (2) whether the sequence of responses is correct; (3) error frequency; and (4) error amplitude, that is, degree of discrepancy. Frequency of non-error events can also be measured. In general, these measures can be directly obtained and perhaps even automatically recorded. In any case, they can usually be obtained with a minimally disruptive effect on the subject's performance.

Christensen and Mills (1967) used the Berliner et al. (1964) taxonomy in a paper the aim of which was to describe, in psychological terms, the actual activities of operators in complex systems. They chose the Berliner et al. approach from among several alternatives because it was easy to use as well as comprehensive (p. 331).

Activities for 31 operators were classified according to the Berliner et al. (1964) scheme with a median reliability of +0.78. Although the authors felt that this reliability was acceptable, they gave several suggestions whereby reliability might be significantly increased. Among these were the recommendations that the classifiers be very familiar with the jobs being rated and that the classifiers be given practice at rating (although it was felt that relatively little practice would suffice). Additionally, classification at a more gross level (i.e., process rather than activity) could be expected to increase reliability.

Christensen and Mills (1967) offered a critique of the Berliner et al. (1964) taxonomy. They found the list of specific behaviors to be generally adequate; however, they noted, as a drawback, that central-processing type activities must be inferred. Further, the authors stated that their task would have been made easier if a list of standard descriptors for operational activities was available to enhance the ability to relate such operations to the appropriate taxonomic structure -- the use of nonpsychological terms is, however, still advocated.

Levine et al. (1973; 1975) used the abilities requirement approach in their classifications of the effects of alcohol consumption on performance. The purpose of these studies was to categorize the existing research literature on alcohol effects according to the type of tasks used and to determine whether alcohol effects differ as a function of type of task. It was hoped that these findings would allow generalization of alcohol effects across tasks within each category and prediction of alcohol effects on other tasks in the same category.

Despite the fact that there exists a large body of literature dealing with the effects of alcohol on physical abilities (i.e., the work on equilibrium discussed above) this category was not used by Levine et al. (1973; 1975); these authors cited lack of data as the reason for its omission. In all, 41 studies, which examined 165 tasks, were classified as falling into the cognitive, perceptual-sensory, and psychomotor domains. For each task, the rating scales discussed previously were used to determine the extent to which an ability was required for task performance. The ability ratings were ranked to allow determination of importance. The three most frequently occurring abilities (selective attention in the cognitive domain, perceptual speed in the perceptual-sensory domain, and control precision in the psychomotor domain) were used as the basis for classification.

Three independent variables -- dosage, time elapsed between alcohol administration and task performance and time in task -- were analyzed with the dependent variable being percent difference between experimental and control groups. Negative values indicated inferior performance of the alcohol-treated group.

Curves (like those shown in Figure 1 but without the BAC estimates) were fitted by eye for the three ability domains, the three specific abilities, and each of three testing time categories. Percent difference was represented on the ordinate; dosage in g/kg on the abscissa. For time in task, curves were drawn for each ability domain and time in task replaced dosage in the abscissa.

Of primary interest is the effect of alcohol on the ability domains. These curves suggest that, while all abilities are affected by alcohol to some extent, psychomotor abilities are most resistant to alcohol effects and perceptual-sensory abilities are least resistant. The authors suggest that this result might be due to an overlearning of psychomotor tasks.

These results provide evidence that the use of a taxonomic approach may be helpful in organizing data on the effects of alcohol on human performance. Although it has not yet been accomplished in the literature, it also seems feasible that such a taxonomic approach could be used to predict the effects of alcohol on performance given that the task at hand could be adequately categorized within the confines of a taxonomic system.

This type of prediction is one of the aims of the current study. The idea here is that, if a task with known behavioral components could be studied under known blood alcohol levels, predictive regression equations could be derived which would allow estimation of impairment on any job for which behavioral process ratings and weightings could be obtained. The Berliner et al. (1964) taxonomic system seems to be the most promising alternative for this endeavor since it appears to be the simplest to use in a real-world setting.

In all previous studies conducted by the Safety Projects Office, an industrial task was simulated. In each case, one process in the Berliner et al. (1964) taxonomy was dominant; however, the tasks were not designed to be pure. Thus, a particular study did not focus on a single process. Hence, despite the fact that the same dosing procedures were used in most of the prior experiments, it is impossible to combine the previously collected data to develop prediction equations. For prediction equations to be developed a task which includes behaviors which tap each of the processes such that the relative effect of alcohol on each of the processes can be studied in a single experiment is needed. Thus, a fabricated task, rather than a high-fidelity industrial simulation, was used.

The activity in which subjects engaged involved "solving" a series of slide-based, square, nine-compartment mazes, each of which required him/her to employ a different behavioral process. (See Appendix A for examples of the mazes.) The subject was first asked to identify the location of a pre-screened target in the maze; identification is a perceptual process. Then, he or she planned a way to move the target through the maze to the home location; planning is a mediational process. Next, the subject was asked to describe the route through the maze to the experimenter verbally, using lane markings and direction of movements; verbalization is a communication process. Fianlly, the subject guided an X-Y cursor through the previously planned pathway; movement constitutes a motor process. (A more detailed explanation of this sequence can be found in the Method section.)

This task, then, is analogous to a situation in which an operator must guide a mechanical device to move a desired object; the only "artificial" aspect is the experimental requirement of verbalization of the planned route. (Even this is not farfetched, though, since it is sometimes necessary for one worker to verbally direct the control inputs of another.) In the "heavy industries" such a scenario is commonplace: large, heavy, or hazardous items may be moved using various types of cranes. The operator's job is one of properly locating the target object, planning a route to the desired destination that is free of obstacles, and moving the object using manual controls. Additionally, with the advent of robots as replacements for human workers in hazardous environments, robots are being used as retrieving mechanisms. Here, the robot must be trained to engage in fine movements (for example, a pick and place operation). Among the options for the design of such a training package is having the human operator use a manually controlled programming unit, such as a joystick, to lead the robot through the task. This procedure avoids many of the potential risks involved in leading the actual robot arm. This application, then, is another (and perhaps closer) parallel of the design employed in the current research.

By determining a priori weightings (as provided by "expert" judges) for each process in each slide set used, regression equations can be developed to predict impairment levels on a particular (measured) variable given known alcohol levels. These formulae, then, could be used in an industrial setting by having workers or supervisors rate a job of interest on each behavioral process. These ratings, along with hypothesized alcohol levels could be "plugged into" the equations to estimate the increase in job completion time at a given BAC as compared to the completion time under no-alcohol conditions. This would be useful in evaluating the impact of alcohol use on industry without the need to conduct actual on-site experiments.

Incorporation of gender as a research variable. There is evidence that a substantial number of working women are alcohol misusers. Further, there is every reason to believe that females under the influence of alcohol will exhibit impaired productivity in the industrial setting.

Landauer and Howat (1983) studied the psychomotor performance of males and females under low and moderate alcohol doses. While both groups experienced degraded performance due to alcohol, no performance differences were found between the sexes. Further, the authors stated that they had found no gender-based performance differences in any of their previous research. They noted that "sex differences in psychomotor skills tends to be rare and the psychopharmacological literature on the effects of drugs (and alcohol) on performance does not seem to report any investigation of sex differences" (pp. 652-654).

In the one study conducted in this laboratory which was concerned with gender effects (Price et al., 1986), however, both gender-based performance differences and gender-alcohol interactions were found on a motor task.

Generally speaking, though, there has been little experimentation in this area and few, if any, conclusive results can be drawn from that which has been conducted. Hence, there exists a large gap in the knowledge base in the field of alcohol research.

In addition to a lack of specific information regarding the effect of alcohol on the productivity of female subjects, there is also the more general problem of the lack of comparative studies of the performance of males and females in human factors research. Hudgens and Billingsley (1978) argue that, with ever-increasing numbers of women entering the work force, it is important for the field to evaluate their comparative performance in all research with pertinence to the work environment so as to begin to build a base for the development of standards and guidelines that are applicable to women.

Most of the gender-based differences found in the literature which relate to the work world are based in the physical domain rather than in the task performance domain (Hahn, 1984).

Several studies in which direct performance differences were reported exist, however. Two experiments (Bell, Loomis, and Cervone, 1982; Testin and Dewar, 1981) showed that males had shorter reaction times than females. Wojtczak-Jaroszawa, Makowska, Rzepecki, Banaszkiewicz, and Romejko (1978) found that males performed better than females on a visual-motor coordination task. More recently, Riley and Cochran (1984) found that females performed better on four tasks which tapped fine manual dexterity but that males were more proficient on a task which required gross motor activity using a hand tool. The authors explained these results as being due to a cultural advantage regarding knowledge of tool use on the part of the men.

With these two issues (gaps in both gender-based research in general and gender-based research concerned specifically with alcohol) in mind, both male and female subjects were included in the current research. The use of female subjects, however, required consideration of factors that would not be of concern had the sample contained only males. These include the (1) differential intoxication levels for males and females given the same doses of alcohol, (2) effect of oral contraceptives on ethanol metabolism, and (3) interaction of alcohol with phases of the menstrual cycle.

Different dosages were administered to males and females. (See Appendix B for dosage formulae.) The BACs of subjects were monitored and subjects participated in the experiment when they reached or neared the target BAC. Hence, the BACs obtained for the men and women during the period of experimentation were quite similar.

Additionally, female subjects were screened for use of oral contraceptives and eliminated from the experiment if they indicated that they used this birth control method on the screening questionnaire.

Finally, in order to minimize effects of the menstrual cycle, while at the same time maximizing the interval during which a particular female could be tested, subjects were scheduled for testing during the intermenstrual phase.

Incorporation of instruction as a research variable. Jennings, Wood, and Lawrence (1976) found a trade-off between speed and accuracy in a choice reaction time task. They showed that increased reaction speeds resulted in lower accuracy, but that this relationship was unaffected by alcohol; decreased reaction speeds produced higher accuracy; however, this accuracy was detrimentally affected by alcohol.

It should be noted, however, that Jennings et al. (1976) were not studying the effect of speed versus accuracy instructions. Rather, they were examining the subjects' inherent biases toward one or the other of these dimensions as the task characteristics related to time were changed. Subjects were rewarded for the number of correct responses which occurred before a "deadline" on each trial and were punished for incorrect responses. The length of the deadline was systematically varied. Nonetheless, their results indicate that speed can be increased by sacrificing accuracy and vice versa. This finding implies that if a subject were given instructions to complete a task as quickly as possible, time to completion would be quick but accuracy would be poor. Further, alcohol may affect this relationship.

In the manual assembly task studied by Price et al. (1986), specific instructions telling the subject to stress either speed or accuracy in a particular run were given. A gender-by-instruction interaction was obtained. For females only, the number of units produced and assembly errors increased under the speed criterion and decreased under the accuracy criterion. An alcohol-by-instruction interaction was also found such that performance under the speed criterion was more degraded by increased BAC than was performance under the accuracy criterion.

Baker, Holding, and Loeb (1984) found a sex difference in speed-accuracy strategies on a mathematics task. As in the Jennings et al. (1976) study, specific instructions were not given to subjects; only the time available to complete the task was altered. Response time and number of correctly solved problems were measured. The results showed that as men practiced the task they maintained a stable level of accuracy while gaining in speed of response; women showed little change in response time but their accuracy improved. The fact that sex introduces a bias toward one criterion over the other may indicate that gender may influence susceptibility to instructions with the instruction condition to which a bias exists being more salient than the instruction condition stressing the nonpreferred criterion.

In light of these results, it seems worthwhile to pursue an examination of instruction as an independent variable. Knowledge of this relationship is important if research is to be generalized to real-world settings where accuracy may be stressed over speed of production (or vice versa). In such settings, prediction of performance may be enhanced by inclusion of this variable.

Overview of the Research

The current study examines the effects of alcohol on performance on a task designed to tap each of the four behavioral process enumerated by Berliner et al. (1964), namely, perception, mediation, communication, and motor activity. Four levels of difficulty were presented for each process. Before engaging in the task, the male and female subjects ingested a mixture of 80 proof vodka and orange juice. This mixture yielded one of four target BAC levels (0.00, 0.05, 0.07, and 0.09%). Each subject experienced a different "mix" of behavioral processes with each new dosage. Further, at each dosage level subjects underwent testing under two different sets of instructions, one of which emphasized speed, the other of which emphasized accuracy. Equally difficult task stimuli were used for each instruction condition.

Measurements were made of the time taken to locate targets and number of attempts needed to correctly identify target position in the perception stage, of the time needed to plan a path from the target to a home position, number of false paths travelled, and false distance travelled in the mediation stage, of the time required to verbalize the path, number of words and pauses produced, proportion of pauses to spoken words, and number or verbalization errors in the communication phase, and of the time to trace the pathway, number of times the cursor touched the maze wall, and the time spent touching the maze wall in the motor activity phase. Hence, both quality and productivity were studied. A total time to completion measure was obtained by summing the times to locate the target, to plan the path, to verbalize the path, and to trace the path. Since a time-dependent measure was used for each of the behavioral processes, the relative effect of alcohol on each of the processes can be measured.

While the task used constitutes a psychophysiological, rather than an industrial simulation approach, there are industrial analogies to the task. More importantly, Price (1983) demonstrated that there is a link between laboratory data and the industrial situation. It is hoped, then, that the findings of this research can be generalized to a wide variety of industrial situations.

Several tactics for exploring the data were used. First, the effects of alcohol on the dependent measures were assessed using an analysis of variance approach. This type of analysis, then, constitutes a traditional hypothesis testing approach to data exploration.

In addition, it would be desirable to use the results of this research as a model for determining the extent to which productivity decrements could be expected at these dosage levels in other settings. Here, total time to task completion was the dependent measure of interest. Using regression analysis, a model using gender, BAC, instruction conditions, and mean importance rankings on each of the four behavioral processes (which were determined from ratings given by expert judges prior to experimentation) for the maze used on a particular trial were evaluated for their ability to predict total time to task completion.

It is hoped that such models could be used in other settings by having expert judges develop importance ratings on the tasks of interest. These ratings could then be ranked and the ranks used in the appropriate regression formula. In practice, it is desirable to know expected performance decrements under alcohol. This information could be obtained by predicting task completion times both under suspected alcohol levels and no-alcohol conditions.

Hence, an assessment of the effect of alcohol on productivity in a given task setting can be made given knowledge of the importance of the four behavioral processes of Berliner et al. (1964).

It would also be desirable to look at the degree of agreement between the the predictions generated in the current research and the literature. Total task completion time was predicted for the full factorial combination using the regression equations developed previously. These predicted times were then used to calculate percent mean differences (as discussed by Levine et al. 1973, 1975) which were plotted in the figures showing percent mean differences and zones of impaired performance given previously (Figures 1 and 2).

It was hoped that this approach also applied to the prediction of subtask completion times with regression equations using gender, BAC, instruction, and the ranking variable of interest being developed for each subtask then used to formulate percent mean differences. Problems arose in this endeavor, however, which made its application impractical. These problems are discussed in more detail in the Results section.

HYPOTHESES

The results of this study were expected to support the following hypotheses.

1. Alcohol level will affect the time taken to visually locate targets in the maze.

This hypothesis is supported Barbre's (1983) work in which visual search time increased with increasing BACs.

2. The number of attempts necessary to identify the target correctly will be affected by BAC.

This hypothesis is suggested by the Price et al. (1986) study in which increasing alcohol levels resulted in increasing errors in a resistor selection task. One possible reason for this result would be impairment of the ability to identify the correct target, or resistor, under alcohol conditions. If target identification is adversely affected by alcohol, this effect would be expected to be manifested in the current study.

3. There will be an effect of BAC on the time required to plan a path from the target position to the "home" position.

4. There will be an effect of BAC on the number of false paths travelled in planning the path.

5. BAC will affect the distance travelled in false paths during the mediation stage.

Hypotheses 3, 4, and 5 are supported by studies which document the adverse effects of alcohol on complex problem solving ability (i.e., Hutchison et al., 1964; Wallgren and Barry, 1970). Wallgren and Barry also indicated that speed in complex tasks is compromised under alcohol conditions. Hence, if the planning task in the current research is considered within the domain of the cognitive tasks reviewed, alcohol effects should be expected.

6. Ingestion of alcohol will affect the time required to verbalize the previously planned pathway from the target position to the "home" position.

7. The number of incorrect verbalizations, that is, verbalization of an incorrect path label, will be affected by BAC.

Hartocollis and Johnson (1956) indicated that alcohol impaired verbal mastery (defined as the ability of a subject to select an appropriate word).

8. The number of words produced in the communication phase will be affected by alcohol dosage.

Two rationales can be used to support this hypothesis; however, they differ in their predictions as to the direction of the effect. First, there is the argument that inhibitions are released under alcohol; hence, one would predict that speech production should increase. On the other hand, the experimental results of Hartocollis and Johnson (1956) and Nash (1962) both indicate decreased verbal fluency, as indicated by number of words produced, under alcohol.

9. Ingestion of alcohol will affect the number of pauses exhibited in the communication phase.

10. Ingestion of alcohol will affect the proportion of pauses to spoken words in the communication phase.

While there is no direct evidence in the alcohol literature to support hypotheses 9 and 10, a rationale for them can be found by synthesizing the alcohol and speech pathology literatures. Perkins (1978) noted that the time to produce a spoken message will increase if hesitations in speech due to thinking are introduced. Since alcohol ingestion has an adverse effect on the thought processes, such hesitations can be expected to occur more frequently under alcohol conditions; hence, both the number of pauses and the time needed for production should be affected.

11. Alcohol level will affect the time to trace a previously planned pathway from the target position to the "home" position.

12. The number of steering reversals exhibited during pathway tracing will be affected by BAC.

13. The distance travelled in steering reversals will be affected by alcohol ingestion.

14. The number of times a subject allows the cursor to touch the maze wall will be affected by BAC.

15. The time spent out of the pathway (i.e., touching or across the maze wall) will be affected by alcohol.

Hypotheses 11 through 15 follow from work indicating that alcohol has detrimental effects on both speed and accuracy of motor tasks (i.e., Flax and Price, 1982; Price and Flax, 1982).

16. Instructions stressing speed over accuracy or vice versa will affect both the time to complete a task and the error rate on that task in all task phases.

This hypothesis is suggested by the work of Price et al. (1986) in which decreased accuracy and increased speed were found under speed-stressed conditions and the opposite found under accuracy-stressed conditions in a motor task.

17. The performance of men and women will be differentially affected by alcohol.

Hypothesis 17 is suggested by the research of Price et al. (1986) which showed that females were affected more by alcohol than males.

METHOD

General Methodology

This section contains a description of the typical scenario encountered by a subject in the current study. It is meant only to be a general overview to aid the reader in understanding the experiment -- technical details are presented in subsequent sections.

Students who responded to a campus-wide flyer advertising campaign were contacted by the experimenter for initial screening. At this screening session, basic information regarding the experiment (i.e., times of required participation, the fact that alcohol would be ingested, and that subjects would be driven home by the experimenter, etc.) was given. Potential subjects were then asked to fill out a survey dealing with (1) demographic information, (2) alcohol and drug use habits, and (3) a release form allowing University Health Service personnel to review their medical records for contra-indications of alcohol use. These forms are presented in Appendix C. Students were also tested for acceptable near visual acuity and were weighed.

On the basis of the information collected during the screening interview, subjects were selected for the experiment. These subjects were contacted and each came into the laboratory for a 1 hr individual training session.

At the training session, subjects were first asked to read and sign the informed consent form given in Appendix D. Then, the events which were to occur during the practice session were explained and enacted.

First, subjects were asked to practice pacing their drinking rate to the pace required by the experiment. Each subject was given a container of water the volume of which was the same as the volume of the vodka and orange juice mixture to be used in the study along with a timer set for 15 min. They were told to drink the water evenly over the 15 min period.

Next, the procedure for collecting breath specimens was explained and subjects practiced giving breath specimens in the proper manner. Prior to this, the Breathalyzer had been disabled by removing the vial of test solution so that actual readings were not obtainable.

Finally, subjects practiced the experimental task. First, they "worked through" the task by following a set of tape-recorded instructions. A transcript of these instructions is given in Appendix E. Then, the actual experiment was simulated; all experimental equipment was operative. Subjects completed two maze sets using only verbal cues from the experimenter. As the mazes were presented, the experimenter made all notations regarding data values that would be made during the experimental session. These data were not used in any fashion; they were collected only so that the timing of the maze sequence would be accurate during training. Further, no speed or accuracy instructions were given during the practice session. The point at which these instructions would be given during the experiment was, however, indicated.

Following practice, the scheduling of the study was reviewed with the subjects.

Each subject participated in four experimental sessions. These occurred over a minimum of a two-week period. Typically, four subjects, usually two males and two females, participated each evening. Due to scheduling problems, however, group size actually ranged from one to five. The experimental protocol was the same on each evening. Upon arrival at the laboratory, subjects were asked to rinse their mouths with water and to give a breath specimen to ensure that they had no alcohol present in their systems. (Note: breath specimens were always preceded by mouth rinsing[2].) Each subject was then given a cup containing the appropriate alcohol/orange juice mixture. The amount of alcohol drunk each evening varied such that BACs of 0.00, 0.05, 0.07, and 0.09% were obtained. The BAC to be attained on a given night was unknown to the subjects. Participants were also given a timer set for 15 min and were instructed to drink the beverage steadily over this period. After the beverage had been drunk, subjects were told to set the timer for another 15 min to allow the ethanol to be absorbed. Subjects were then asked to provide another breath specimen. If the desired BAC had been reached, the experiment was begun. Otherwise, breath specimens were collected periodically until the appropriate level was attained.

Subjects engaged in the experimental task, "solving" a sequence of mazes, twice in each session. One time, they were asked to complete the task as quickly as possible; the other time, as accurately as possible. Instructions regarding these conditions were given immediately prior to maze presentation. The order of instructions was random. At each session, different sets of mazes, which varied in difficulty, were presented. Thus, four difficulty levels of mazes were employed, one on each of the four different evenings. The two maze sequences encountered in a particular session, however, while not exact duplicates of one another, were designed to be equally difficult.

After completing the experimental task, subjects were asked to supply another breath specimen. They then waited in the laboratory until their BACs had reached 0.03% or less. The waiting period ranged from one to three hours depending on arrival time. BACs were verified by collecting a final breath specimen. Once all subjects' BACs had declined, they were taken home by a driver who had ingested no alcohol.

After the second and fourth sessions, subjects were paid for their participation. After the fourth session, a short debriefing was also conducted.

Subjects

Sixteen male and 16 female university students served as subjects. All were at least 21 years of age (males: mean = 21.6 yr; females: mean = 21.9 yr). All had corrected near vision of 20/25 or better (mean = 20/19), measured by an Orthorater. Further, for no subject was there a contra-indication of alcohol ingestion present on university medical records. The screening questionnaire was used to eliminate students taking drugs which might interact with alcohol (i.e., oral contraceptives, decongestants). Abstainers and heavy and/or morning drinkers were also eliminated such that only moderate drinkers served as subjects.

All subjects received monetary remuneration for their participation.

<u>Stimulus Materials</u>

The stimulus materials used in the current study consisted of 10 sets of maze sequences such as the set shown in Appendix A. Two of these sets were used only for practice and will not be discussed further. Each stimulus was presented in the form of a slide which was projected to be 38.1 cm square and viewed from a distance of 92.5 cm.

The eight maze sequences used in the experiment were all developed in a similar fashion. Each set consisted of four sections, one for target identification, one for mediation, one for verbalization, and one for motor control.

For each maze sequence, it was desirable to develop four difficulty levels so that each alcohol level could be paired with a unique maze difficulty level.

The first two drawings in Appendix A are concerned with the perceptual processes. The first slide presented the subject with a target to study. The word "target" appeared in bold letters. Under it was the actual target, a small drawn disc with a design containing a series of four dots (.), dashes (-,|), and/or slashes (/,\) inside. Difficulty was manipulated by altering the complexity of the pattern drawn inside the disc.

The second slide presented the target imbedded in a maze which was divided into nine equally sized compartments delineated by boundary lines. Eight of these compartments contained drawn discs, and the ninth was a centrally located home space. This space contained a moveable dot which acted as a cursor in subsequent phases. The position of the target stimulus was random with the constraint that a target could not appear in the same position twice to reduce learning effects. The difficulty of the target identification phase was further manipulated via the distractors such that the target was more or less similar to the distractors across mazes. One manipulation was concerned with the shape of the outer border of the distractors. In some cases, both the target and all the distractors had the same circular shape. In other cases, only some distractors had a circular border, while others had a hexagonal outer boundary. Further, the distractors could contain either the same symbols as were contained in the target or symbols that were not present in the target. A summary of the maze characteristics is given in Appendix F.

The next three slides were used to present the mediation phase of the experiment. The first slide presented in this phase contained only the outlines of the maze compartments. The interior maze walls were removed to eliminate potential practice with the maze prior to the recording of the data. The cursor and the target were located in their appropriate positions. As this slide served only a positioning function, difficulty was not manipulated.

The second slide shown in this phase also contained only the target stimulus and the cursor. Further, the detail of all the now extraneous compartments used in the targeting phase were removed, leaving only their boundaries and the detail of the pertinent compartment, so as to reduce possible distracting effects. Each maze was constructed such that the optimal path from the target position to the home location was the same length. The use of a constant length represents an attempt to control for differential path difficulty due solely to target position. The complexity of the path varied across mazes. Specifically, the number of turns necessary to "solve" the maze correctly varied from one to four as did the total number of incorrect turns (false paths) that could be taken at the decision points throughout the maze, not including turns subsequent to making an incorrect decision.

The mediation phase ended with a slide containing only the cursor and the outline of the home box with a circle drawn in the center. Since positioning was the object of this slide, difficulty was not manipulated.

In the verbalization phase, the maze presented was the same as had been presented previously except that each pathway was labelled with a letter to facilitate path description. Difficulty of communication was manipulated by altering the minimum number of commands needed to describe the path adequately. Subjects were required to say the starting point as well as the direction moved and through which alley movement occurred. The number of commands necessary to accomplish this varied from two to five. Because the number of possible false paths does not affect communication, the difficulty of the communication phase is largely independent of the mediation phase.

In the final (motor) phase, the three slides used were the same as had been used in the mediation phase. During the measured segment (the middle, nonpositioning slide), difficulty was manipulated by altering the size of the alley between the maze walls to increase or decrease the relative difficulty of moving the cursor without touching the walls. The projected alley width could be narrow (1.5 cm) or wide (3.0 cm) or a combination thereof.

Since each maze was to be solved under two instruction conditions, two parallel mazes were required at each difficulty level to eliminate practice effects. Thus, once a maze had been drawn, another maze having the same characteristics but a different solution was developed.

After all eight mazes were designed to incorporate the difficulty manipulations described above, difficulty was assessed by a group of independent raters. The point of this was not only to confirm that the mazes were actually different in difficulty but also to determine the importance of each of the Berliner et al. (1964) processes to successful task completion for use in subsequent model building. Berliner et al. suggested that a group of experts on the task make such a determination. Since the current task was a fabricated one, there were no task "experts". Hence, expert status was related to potential raters' ability to identify the specific behaviors listed by Berliner et al. as belonging to particular behavioral processes. Graduate students in the human factors curriculum voluntarily served as unpaid raters. The ratings of 10 students were obtained.

A Q-sort type of exercise, in which potential raters sorted 40 cards, each of which contained a phrase describing one of the Berliner et al. (1964) specific behaviors, was employed. As outlined by Anastasi (1976), these cards were sorted into four labelled piles of 10 cards each, with each pile representing one of the Berliner et al. processes. The categorization given by Berliner et al. and shown previously in Table 1 served as the Q-set against which the students' sorts were judged. This procedure of matching student sorts to a uniform Q-set assures comparability of the ratings later obtained from different raters. Only those students who accurately placed 90% of the cards were used as expert raters. A total of 14 potential raters was given the Q-sort before 10 who met this requirement were found. For those who were actually used as raters, the mean score on the Q-sort was 96% correctly placed.

Following tabulation of the Q-sort, raters judged to be experts were given training on the experimental task. Like the actual subjects in the experiment, they worked through the maze while listening to the tape-recorded instructions given in Appendix E. The range of possible maze characteristics for each behavioral process was also described to them. To facilitate the giving of ratings, raters engaged in the experimental task for each pair of parallel maze sequences. The order of presentation of the sequences was random. After completing the maze sequence, raters were asked to assess the importance of each behavioral process represented to successful task completion on the seven-point scale (1 = not at all important; 7 = very important) shown in Appendix G. It was explained to the raters that "successful task completion" meant that the overall task would be completed as quickly and accurately as possible. The more difficult the task component, the more important it would be to overall successful task completion. All eight mazes were rated in a single session.

The data collected from these raters were used for three purposes: (1) to estimate the reliability of the ratings; (2) to determine that maze sets designed to be parallel were parallel with respect to the difficulty ratings assigned; and (3) to determine that maze sets designed to be different were assigned different difficulty ratings. Since the rating scales were ordinal and discrete in nature, nonparametric statistics were used in all analyses. The ratings were transformed to ranks before analysis.

The nonparametric equivalent of intraclass correlation, the coefficient of concordance, as discussed by Guilford and Fruchter (1973), was employed to assess the reliability of the ratings for each behavioral process. The coefficients of concordance, and their associated chi-squares and significance levels are reported in Table 2. For each behavioral process, significant concordance of ratings was obtained.

TABLE 2

Results of Reliability Analysis on Rating Data for each Behavioral Process

Behavioral Process	Coefficient of Concordance (W)	Chi-square	p
Perception	0.53	37.12	0.001
Mediation	0.55	38.55	0.001
Communication	0.39	27.41	0.001
Motor	0.50	34.62	0.001

Since overall maze difficulty, defined as the sum of the ratings across the behavioral processes, was used as the independent variable in assigning subjects to maze difficulty - alcohol combinations, a reliability study was also conducted on the overall maze difficulty ratings. In this analysis, the value of the coefficient of concordance was found to be 0.71. This value indicates significant agreement among the raters (chi-square = 49.7, p = 0.001).

Since a particular maze was assigned as its difficulty rating the mean of the ratings, it was of interest to estimate the reliability of the mean values. This estimate can be calculated from the coefficient of concordance (Guilford and Fruchter, 1973). This procedure yields the expected correlation of the obtained rankings with a hypothetical comparable set. Reliabilities were computed for ratings on each behavioral process as well as for the overall difficulty ratings. The obtained reliabilities were as follows: 0.90 for ratings on the perceptual process, 0.91 on mediation, 0.83 on communication, 0.80 on motor control, and 0.96 on overall difficulty.

Once satisfactory agreement among the raters was assured, the ratings were used to ensure that the mazes had been designed as was desired. First, the Wilcoxon rank sum test, as discussed by Hollander and Wolfe (1973), was used to test the parallelism of the pairs of maze sequences which had been designed to be equal in difficulty. In the terms specified in Appendix F, then, one would expect there to be no significant differences in the ratings on each behavioral process obtained for Mazes 1 and 2, 3 and 4, 5 and 6, or 7 and 8. As Table 3 shows, in no instance was there a significant ($p < .05$) difference in the difficulty ratings obtained for two mazes which had been designed to be equivalent in difficulty on a particular behavioral process.

This type of analysis was also conducted on the overall difficulty ratings. The same results as were found for the individual behavioral processes, that there were no differences in the ratings on "parallel" forms of the maze sequences, were found for the overall difficulty ratings. These results are summarized in Table 4. Hence, the ratings on each maze pair were combined and all subsequent analyses were conducted on the resulting four sets of ratings. For clarity, these will be labelled Mazes I, II, III, and IV.

The final analyses conducted on the rating data aimed to ensure that different difficulty levels of mazes had been obtained. This was a two-phase operation. First, it was determined, using the Kruskall-Wallis test (Hollander and Wolfe, 1973), that a difference existed among all means. Since this difference was significant, differences between

TABLE 3

Results of Wilcoxon Rank Sum Tests on "Parallel" Mazes for each Behavioral Process

Behavioral Process	Test statistic (Zw)	p
Perception		
Maze 1 versus Maze 2	0.16	0.434
3 4	0.97	0.166
5 6	0.63	0.264
7 8	0.34	0.367
Mediation		
Maze 1 versus Maze 2	0.12	0.452
3 4	1.48	0.069
5 6	0.08	0.468
7 8	0.12	0.452
Communication		
Maze 1 versus Maze 2	0.60	0.274
3 4	0.08	0.468
5 6	0.04	0.484
7 8	1.34	0.090
Motor		
Maze 1 versus Maze 2	0.81	0.209
3 4	1.18	0.119
5 6	0.52	0.302
7 8	1.51	0.066

TABLE 4

Results of Wilcoxon Rank Sum Tests on Overall Difficulty Ratings on "Parallel" Mazes

Comparison		Test statistic (Zw)	p
Maze 1 versus Maze	2	0.42	0.337
3	4	0.27	0.394
5	6	0.34	0.367
7	8	1.50	0.067

pairs of these means were examined using the Wilcoxon rank sum test. The ratings on the individual behavioral processes were examined first. Kruskall-Wallis tests were conducted on the ratings obtained on all mazes for each behavioral process. The results are shown in Table 5 and indicate that there were significant differences among the mean ratings obtained for each behavioral process.

Wilcoxon rank sum tests were conducted for all possible pair-wise comparisons for each behavioral process. The results of these tests are summarized in Table 6. For each behavioral process, significant differences in the ratings were obtained for all but one pair-wise comparison. No differences were found between Mazes III and IV on perception, Mazes I and III on mediation or motor control, or Mazes I and II on communication. This is of little consequence, however, since the independent variable "maze difficulty" was defined as the sum of ratings across the behavioral processes such that each complete maze sequence was assigned a single difficulty rating.

There were significant differences among all pair-wise comparisons on overall maze difficulty, as shown by a Kruskall-Wallis test conducted on the overall difficulty ratings for each maze ($H' = 31.63$, $p = 0.001$).

TABLE 5

Results of Kruskall-Wallis Tests on Mean Ratings across Mazes for each Behavioral Process

Behavioral Process	Test statistic (H')	p
Perception	20.35	0.001
Mediation	22.09	0.001
Communication	19.46	0.001
Motor	21.90	0.001

TABLE 6

Results of Wilcoxon Rank Sum Tests on All Possible Pair-wise Comparisons by Behavioral Process

Behavioral Process	Test statistic (W or Zw)*	p
<u>Perception</u>		
Maze I versus Maze II	W = 154	0.0001
III	W = 145	0.002
IV	W = 155	0.001
Maze II versus Maze III	Zw = 2.21	0.011
IV	Zw = 2.21	0.014
Maze III versus Maze IV	W = 119	0.314
<u>Mediation</u>		
Maze I versus Maze II	W = 140.5	0.006
III	W = 114.5	0.528
IV	W = 145	0.002
Maze II versus Maze III	Zw = 2.97	0.002
IV	Zw = 2.40	0.008
Maze III versus Maze IV	W = 150	0.001
<u>Communication</u>		
Maze I versus Maze II	W = 118	0.352
III	Zw = 2.32	0.010
IV	W = 136	0.018
Maze II versus Maze III	Zw = 1.64	0.050
IV	W = 148	0.001
Maze III versus Maze IV	W = 153.5	0.001

TABLE 6 (continued)

Behavioral Process	Test statistic (W or Zw)*	p
Motor		
Maze I versus Maze II	Zw = 3.08	0.001
III	W = 114	0.528
IV	W = 152	0.001
Maze II versus Maze III	Zw = 2.43	0.008
IV	Zw = 2.39	0.008
Maze III versus Maze IV	W = 148	0.001

* Which test statistic was used depended upon the number of tied ranks, with Zw being used as the correction for a large number of ties.

Wilcoxon rank sum tests were made for all pair-wise comparisons among the overall difficulty ratings. The results, presented in Table 7, show significant differences between all pairs.

Apparatus

The same equipment was employed at all practice and experimental sessions. Breath samples were taken using a Smith and Wesson Breathalyzer (Model 900A). Prior to experimentation, the Breathalyzer actually used in this experiment was calibrated with a Smith and Wesson Mark II Simulator, and found to be accurate. The results of this calibration can be found in Appendix H. In general the specifications on the instrument require that it be accurate within an interval of plus or minus 5% around any "true" measurement (W. Styles [3], personal communication, November 19, 1986)

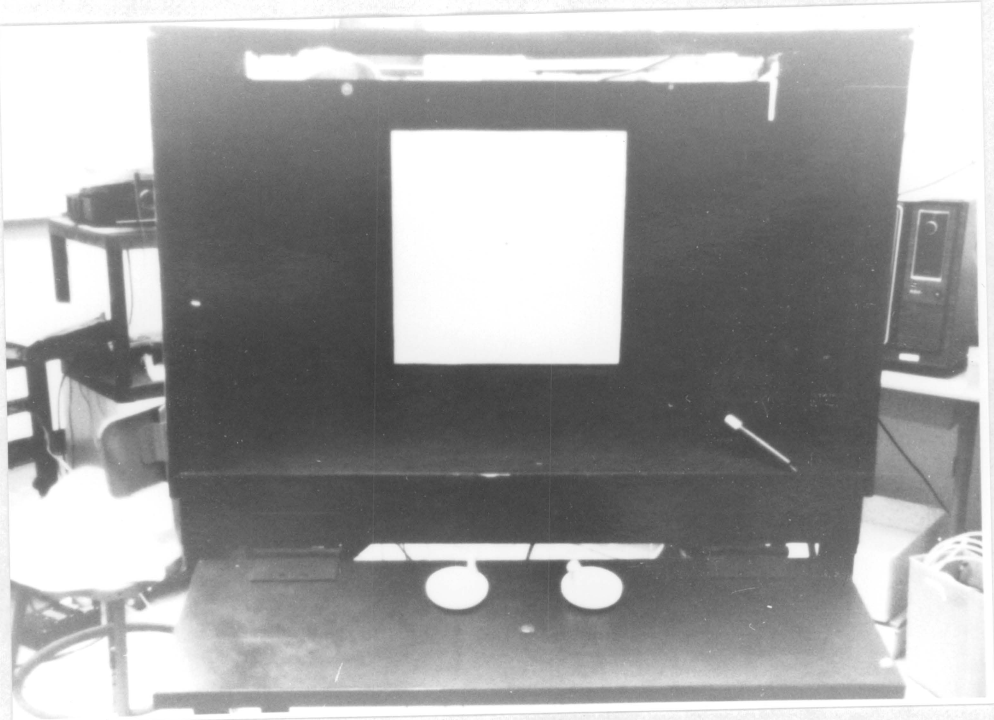
Subjects sat in front of the experimental apparatus, on the opposite edge of which was mounted a double-frosted mylar screen, shown in Figure 4. The screen was enclosed in a housing which protected it from overhead illumination to reduce glare (since glare effects are enhanced under alcohol). A five-volt push-button switch was used to control slide presentation. This switch was centrally

TABLE 7

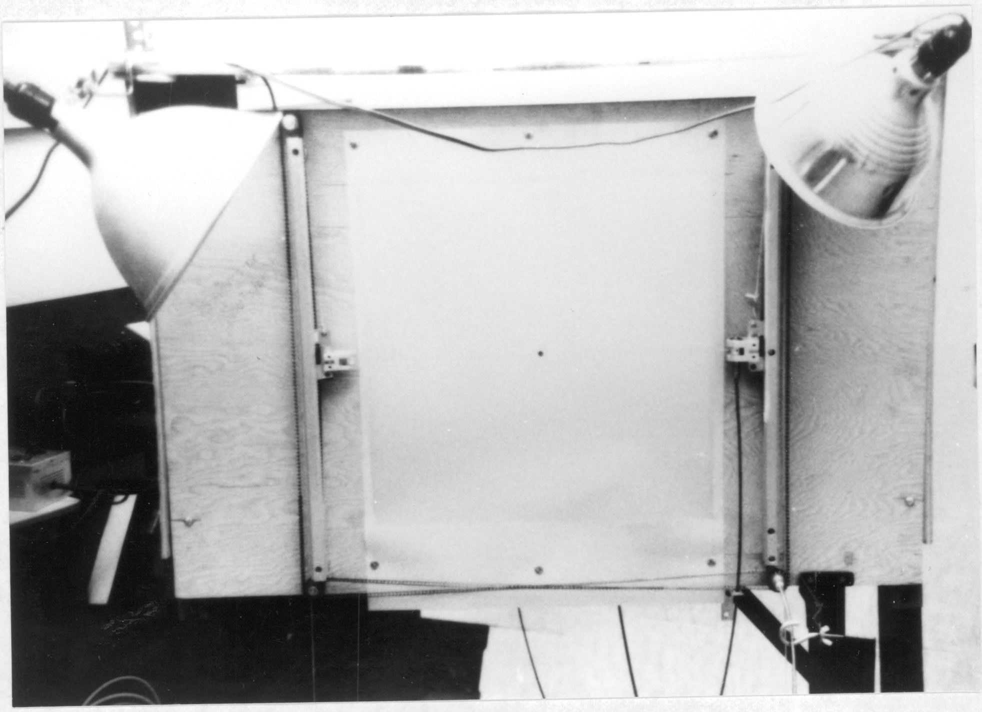
Results of Wilcoxon Rank Sum Tests on All Possible Pair-wise Comparisons on Overall Difficulty

Comparison	Test statistic (W or Zw)*	p
Maze I versus Maze II	W = 151	0.001
III	Zw = 1.90	0.029
IV	Zw = 3.81	0.0002
Maze II versus Maze III	Zw = 2.53	0.006
IV	Zw = 3.37	0.0004
Maze III versus Maze IV	Zw = 3.68	0.0002

* Which test statistic was used depended upon the number of tied ranks, with Zw being used as the correction for a large number of ties.



Front View (Subject's side)



Back View (Experimenter's side)

Figure 4: Photographs of experimental apparatus.

mounted to accommodate subject handedness. Two rotary knobs controlled cursor movement via a pulley system mounted on the back of the apparatus. The right-most knob controlled movement in the vertical direction while the left-most knob controlled movement in the horizontal direction.

Two lamps mounted on the back of the apparatus provided screen illumination between projections to maintain constant visual adaptation. The same switch which turned the slides on and off controlled these lamps such that while a slide was being projected the lamps were off.

The seat height of the subject's chair was adjusted to keep the eye height of all subjects at the level of the cursor in its resting position.

The stimulus materials were presented using an ennaMat side-fed projector. The use of a side-fed rather than a gravity-fed mechanism ensured proper alignment of the slides on the screen. The projector was positioned such that the projected image was 38.1 cm square. A Gerbrands tachistoscopic shutter was mounted in front of the lens of the projector. This shutter opened and closed in response to the switch at the subject's station and a similar switch at the experimenter's station. Pressing this switch also activated a Lafayette stop clock, located at the experimenter's station, to allow time measurements to be taken.

A microphone mounted at the subject's station was connected to a Sanyo cassette recorder-player at the experimenter's location. This system was used to collect and analyze data in the communication phase.

A boom-mounted ITC camera "looked over" the subject's shoulder so that the screen could be filmed. Along with this camera, a Mitsubishi video cassette recorder and a Setchell-Carlson video monitor were employed to collect and analyze data in the mediation and motor phases.

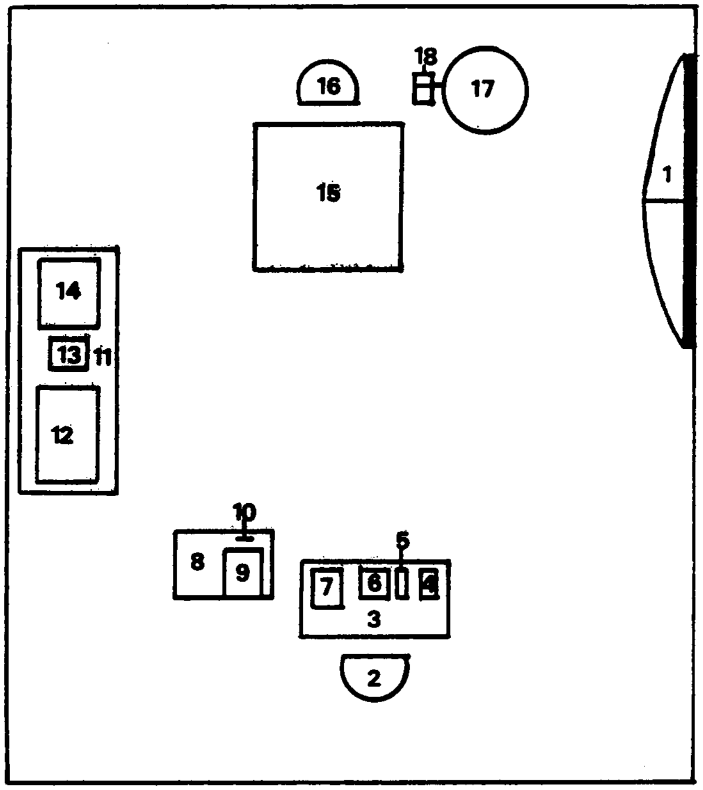
A frequency generator, operated by a five-volt push-button switch under the experimenter's control, was used to produce a tone to indicate subject errors. The sound emanated from a buzzer which was mounted on the top of the rear projection apparatus.

The layout of the laboratory is diagrammed in Figure 5.

Experimental Task

In this section, the four-phase maze-based task encountered by the subject is described. The procedure employed was the same regardless of the difficulty of the maze or the alcohol level at a particular session.

Upon beginning the session, the subject was seated in front of the apparatus described previously. Prior to beginning the slide sequence, the subject was informed as to



Legend:
(1) double doors
(2) experimenter's chair
(3) experimenter's desk
(4) desk lamp
(5) control panel
(6) stop clock
(7) tape recorder
(8) utility cart
(9) projector
(10) tachistoscopic shutter
(11) utility tables
(12) video monitor
(13) Breathalyzer
(14) VCR
(15) subject's station
(16) subject's chair
(17) camera boom
(18) camera

Scale: 1/4 in = 1 ft

Note: Equipment irrelevant to current study omitted.

Figure 5: Diagram of laboratory layout.

whether speed or accuracy should be stressed. Then, the subject was permitted to study a slide of the target for 15 s. This presentation was under the experimenter's control.

When the subject was ready to begin the target identification phase, he or she pressed the switch which opened the shutter, revealing the slide. Once the slide was available, the subject began to search for the specific target. When the target was located, the subject pressed the switch again, closing the shutter. (This activation-occlusion process occurred for every slide in the sequence and will not be repeated.) He or she then stated the number of the compartment in which the target was found. The experimenter verified the response and sounded a tone if the response was incorrect. If the position stated was correct, the phase ended. If the position stated was incorrect, the process was repeated, beginning with a review of the target, until a correct response was obtained.

Once target identification had been accomplished, the mediation phase began. When confronted with the first (positioning) slide, the subject was required to move the cursor from the home position to the target position using the rotary controls.

The second slide required the subject to plan a path from the target to the home position. The subject was instructed to "think through" the maze while moving the cursor to coincide with the thought processes. One restriction was that the path taken could not cross the maze walls but could employ only the drawn alleys.

Another positioning task was presented so that the cursor could be returned to the neutral position. Here, the subject moved the cursor to be inside the drawn target. This completed the mediation phase.

In the next phase, the subject was required to verbalize the pathway he or she had planned by stating the initial target position, the direction of each movement made, and the letter designation of each alley travelled. The experimenter monitored the subject's verbalizations for two types of errors: (1) an incorrect verbalization, in which the subject said a letter that designated a path other than the correct one or an incorrect direction; if this occurred, a single tone was sounded immediately after the verbalization to inform the subject of his/her error; and (2) an unintelligible verbalization (e.g., mumbling, slurring, or soft speech) in which the experimenter could not understand what the subject had said; if this occurred, the tone was sounded twice to indicate that the subject should repeat what had just been said.

Prior to beginning the final phase of moving the cursor through the maze to trace the planned path, the subject again moved the cursor from the home position to the target position using the same procedure as had been used in the mediation phase.

The subject then engaged in tracing the previously planned path, guiding the cursor through the maze to the home position while trying to prevent the cursor from touching the maze walls.

The final activity in the motor process phase was repositioning the cursor in the center of the home location.

Once the entire maze sequence had been completed, its parallel form was presented. Subjects were given instructions to stress speed or accuracy, whichever had not been used on the first run, then the process described above was repeated.

Experimental Design

Each subject engaged in four experimental sessions. A different blood alcohol concentration was used in each session and a maze of different difficulty was presented with each BAC. The order of BAC and maze difficulty was counter-balanced using a four-by-four orthogonal Latin Square as shown in Figure 6. Note that the traditional

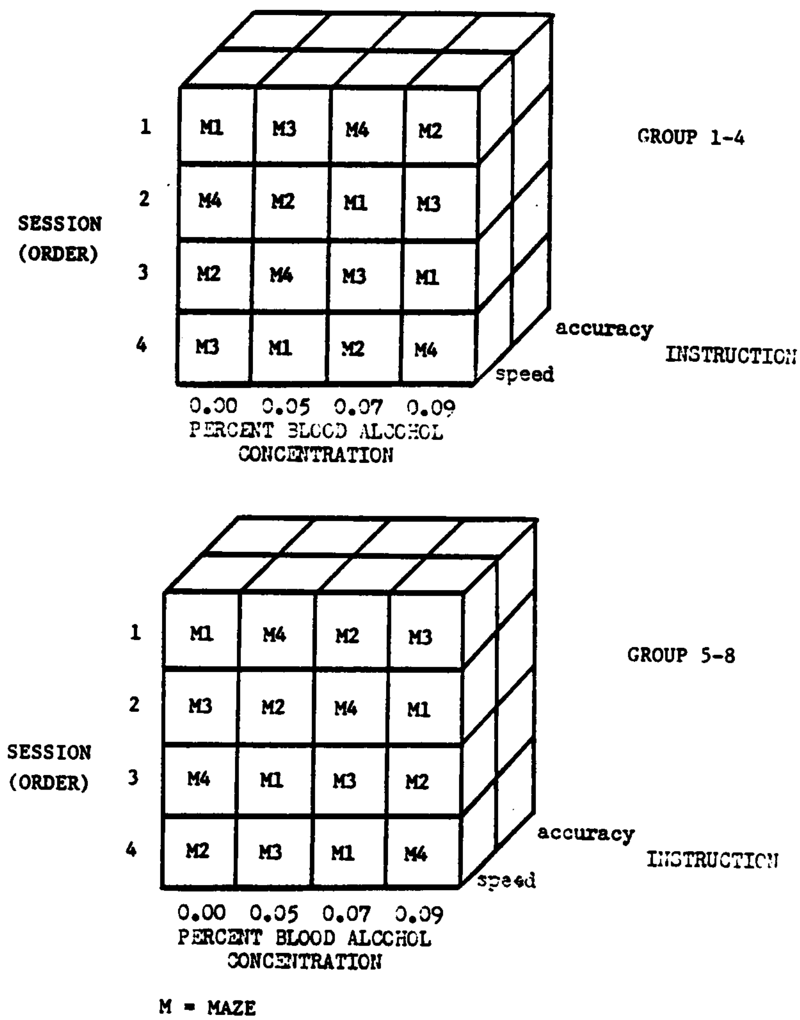


Figure 6: Diagram of experimental design.

Latin Square variable "order" is called "session" here. Order and session are the same in the current study, since a different BAC/Maze combination was presented at each session. Thus, session represents a sequence variable just as order typically does.

At each session, each subject underwent testing under both speed-stressed and accuracy-stressed conditions. Thus, the Latin Square was replicated across instruction conditions such that order effects are the same for both instruction conditions. The order of presentation of these instructions was random. Two equivalent maze sets were used as stimuli at each session. The order by which the parallel mazes were presented was also random.

A group variable was employed as a between-subjects factor. Eight groups of subjects were used. Since only four groups could be accommodated by the four-by-four Latin Square, an orthogonal square was used for the four remaining groups.

Each group consisted of two male and two female subjects. Hence, equal numbers of male and female subjects were present in each alcohol-maze difficulty combination.

Independent Variables

Blood alcohol concentration was manipulated to achieve four target BACs: placebo, 0.05, 0.07, and 0.09%. The drinks consisted of ethanol and orange juice with dosage determined by subjects' body weight and sex, and with total drink volume held constant with respect to body weight. A description of the dosing procedure can be found in Appendix B.

Four levels of overall maze difficulty were employed.

Since both male and female subjects participated in the study, two levels of gender were represented.

Each subject was assigned to one of eight groups.

Two types of instructions, speed and accuracy, were used. For the speed condition, subjects were told that it was important to complete the task as quickly as possible. They were told that the best way to be productive was to minimize the time spent on each of the component tasks. For the accuracy condition, subjects were told that it was most important to be as accurate as possible in completing the task. They were told that the best way to be accurate was to minimize the possible errors that could be made on each component task (i.e., targeting errors). In both conditions subjects were told to be both as quick and as accurate as possible but to stress the instructed condition.

Finally, each subject participated in four sessions.

Dependent Variables

In the targeting task, search time was defined as the time, in seconds, between the initial switch operation which revealed the maze and the switch operation which occluded the maze. (All subsequent timing measures were also defined in this fashion.) The number of attempts necessary to correctly identify the target was also counted.

In the path-finding task, time to plan the path was recorded. The number of turns into incorrect paths was recorded and the distance travelled in these paths was measured (in cm) from the monitor screen. A conversion factor was applied to translate this measurement into the actual distance the cursor had moved on the projected image. (A summary of these conversions can be found in Appendix I.)

In the verbalization task, time to verbalize the planned pathway was recorded. The number of spoken words was counted as was the number of pauses. A pause was defined as a break in speech of duration 0.2 s or greater. (This definition comes from the literature concerned with speech recognition devices (see McCauley, 1984) where pauses in speech are necessary if the machine is to "understand" the communication.) The proportion of pauses to spoken words was also computed. Finally, the numbers of incorrect and unintelligible verbalizations were recorded.

In the motor task, time to trace the path was recorded. The number of times the subject allowed the cursor to touch the maze walls was counted and the total time spent touching the maze walls, in seconds, was recorded from a review of the videotape. The number of tracking reversals was counted and the cumulative distance travelled in reversals was measured (in cm) using the same procedure employed in collecting the distance data in the mediation phase.

Total time to complete the task was defined as the sum of the times to locate the target, to plan the path, to verbalize the path, and to trace the path.

RESULTS

Analyses of Variance

Each dependent variable was examined using analysis of variance (ANOVA) techniques. Where significant *F* ratios were found in the main effects, post-hoc multiple comparisons were conducted using the Newman-Keuls procedure. Significant interaction effects were examined visually via plots of the means, which are given in Appendix K. Simple-effect F-tests were applied to significant interactions. These F-tests were followed by the Newman-Keuls procedure where appropriate.

Perceptual phase variables: (1) *Target identification time*. The results of the ANOVA for the time to visually locate targets in the maze are given in Table 8. There are significant main effects for session, BAC, and maze.

For the session effect, the Newman-Keuls test (Table J1; see Appendix J for the results of all Newman-Keuls tests) indicates that subjects took significantly longer to identify the target during the first session than during subsequent sessions. Target identification time did not vary significantly among the last three sessions.

TABLE 8

ANOVA for Target Identification Time

Source	df	MS	F	p
<u>Between Subjects</u>				
Group	7	23.772	0.53	0.801
Sex	1	28.329	0.63	0.439
Group*Sex	7	37.970	0.84	0.568
Subj/Sex/Group	16	45.024	----	-----
<u>Within Subjects</u>				
Instruc	1	1.425	0.31	0.587
Group*Instruc	7	3.252	0.70	0.672
Sex*Instruc	1	2.608	0.56	0.465
Group*Sex*Instruc	7	6.036	1.30	0.312
Instruc*Subj/Sex/Group	16	4.646	----	-----
Session	3	52.182	4.40	0.005
BAC	3	35.044	2.96	0.034
Maze	3	261.980	22.10	0.0001
Sex*Session	3	2.058	0.17	0.914
Sex*BAC	3	6.454	0.54	0.653
Sex*Maze	3	4.806	0.41	0.749
Instruc*Session	3	3.979	0.34	0.800
Instruc*BAC	3	1.124	0.09	0.963
Instruc*Maze	3	7.816	0.66	0.578
Sex*Instruc*Session	3	9.155	0.77	0.511
Sex*Instruc*BAC	3	7.202	0.61	0.611
Sex*Instruc*Maze	3	5.070	0.43	0.733
Residual	156	11.854	----	-----
Total	255			

Legend: Subj = Subject
BAC = Blood Alcohol Concentration
Instruc = Instruction

As Table J2 shows, the Newman-Keuls procedure indicates that there was an increase in target identification time at the highest BAC level as compared to the two lowest levels. There was a 24% increase in performance time between the 0.09% BAC and the placebo conditions.

The Newman-Keuls test for the maze variable (Table J3) shows that target identification times were shorter for the easiest maze than for the harder mazes, as would be expected.

Perceptual phase variables: (2) Number of attempts for target identification. Table 9 shows the results of the ANOVA for the number of attempts necessary to identify correctly the pre-screened target. There is no BAC effect.

The main effect for the maze variable is significant. Here, the greatest number of errors was made on the two moderate difficulty mazes as shown by the Newman-Keuls procedure (Table J4). This may represent a speed-accuracy trade-off. Since more time was used to identify the target in the most difficult maze (as seen previously), accuracy was not compromised. Where less time was taken (at the intermediate difficulties), accuracy was impaired as demonstrated by an increase in the number of attempts necessary to identify the target.

TABLE 9

ANOVA for Number of Attempts for Target Identification

Source	df	MS	F	p
<u>Between Subjects</u>				
Group	7	0.373	2.39	0.071
Sex	1	0.250	1.60	0.224
Group*Sex	7	0.161	1.03	0.449
Subj/Sex/Group	16	0.156	----	-----
<u>Within Subjects</u>				
Instruc	1	0.391	8.33	0.011
Group*Instruc	7	0.087	1.86	0.145
Sex*Instruc	1	0.563	12.00	0.003
Group*Sex*Instruc	7	0.170	3.62	0.016
Instruc*Subj/Sex/Group	16	0.047	----	-----
Session	3	0.182	1.28	0.282
BAC	3	0.057	0.40	0.751
Maze	3	0.776	5.46	0.001
Sex*Session	3	0.021	0.15	0.932
Sex*BAC	3	0.188	1.32	0.270
Sex*Maze	3	0.115	0.81	0.492
Instruc*Session	3	0.990	0.70	0.555
Instruc*BAC	3	0.990	0.70	0.555
Instruc*Maze	3	0.088	0.62	0.601
Sex*Instruc*Session	3	0.420	0.29	0.830
Sex*Instruc*BAC	3	0.420	0.29	0.830
Sex*Instruc*Maze	3	0.073	0.51	0.674
Residual	156	0.142	----	-----
Total	255			

Legend: Subj = Subject
BAC = Blood Alcohol Concentration
Instruc = Instruction

There is also a main effect of instruction with the speed condition producing more attempts (mean = 1.17) than the accuracy condition (mean = 1.09).

Instruction is also involved in two significant interactions, Sex x Instruction and Group x Sex x Instruction. Simple-effects F-tests were conducted for each sex. The results of these tests are given in Table 10.

Females were not influenced by the instruction condition; males were. For the women, the mean number of attempts under the speed instruction is 1.09; under the accuracy instruction, the mean number is 1.11. For the men, the mean numbers of attempts are 1.25 and 1.08 under speed and accuracy manipulations, respectively. The results for males are in the expected direction, that is, with an increase in error rate under speed-stressed conditions.

The simple-effect F-tests shown in Table 11 indicated that only Groups 6, 7, and 8 were involved in the Sex x Instruction interaction. The Newman-Keuls test given in Table J5 showed that, for Group 6, both males and females were affected by the instructions; however, males responded in the expected direction (with fewer errors under the accuracy condition) while females responded in a manner opposite to expectation. For both Groups 7 and 8, only the males were affected by the instructions. Interactions

TABLE 10

Simple-effect F-tests for the Sex x Instruction Interaction on Number of Attempts for Target Identification

Source	df	MS	F	p
Females				
Instruction	1	0.008	0.17	< 0.25
Males				
Instruction	1	0.945	20.11	> 0.01

Note: Although F with 1 df is the same as a t-test, F-tests have been used to maintain consistency between the post-hoc tests of interactions. The appropriate ANOVA residual was used as the error term for all simple-effect F-tests.

TABLE 11

Simple-effect F-tests for the Group x Sex x Instruction Interaction on Number of Attempts to Identify the Target

Source	df	MS	F	p
Group 1				
Sex*Instruction	1	0.031	0.67	< 0.25
Group 2				
Sex*Instruction	1	0.000	0.00	1.00
Group 3				
Sex*Instruction	1	0.031	0.67	< 0.25
Group 4				
Sex*Instruction	1	0.125	2.67	< 0.10
Group 5				
Sex*Instruction	1	0.000	0.00	1.00
Group 6				
Sex*Instruction	1	0.781	16.67	> 0.01
Group 7				
Sex*Instruction	1	0.500	10.67	> 0.01
Group 8				
Sex*Instruction	1	0.281	6.00	> 0.05

involving groups are of little practical importance since it is very difficult to diagnose why differences exist among groups.

Mediation phase variables: (1) Pathway planning time. The results of the ANOVA for the time to plan a pathway from the target position to the home location are given in Table 12. Significant main effects exist for all independent variables except sex and group.

For the session effect, the Newman-Keuls procedure (Table J6) shows the same pattern for pathway planning time as was indicated for target identification time; namely, longer response times were obtained during the first session than during other sessions, and no difference exists among later sessions.

Performance under alcohol conditions was worse (i.e., more time was taken) than under the no-alcohol condition (Table J7). However, there was no difference in performance among the alcohol dosage levels. Averaging the means for the conditions in which alcohol was ingested yields a time of 11.46 s for pathway planning. Under alcohol conditions, then, there was a 12% increase over the placebo condition time of 9.94 s.

There is also a significant effect of maze. The Newman-Keuls test (Table J8) shows that the two easiest

TABLE 12

ANOVA for Time to Plan the Pathway through the Maze

Source	df	MS	F	p
Between Subjects				
Group	7	30.950	0.73	0.654
Sex	1	4.962	0.12	0.738
Group*Sex	7	37.527	0.88	0.544
Subj/Sex/Group	16	42.689	----	-----
Within Subjects				
Instruc	1	110.670	19.16	0.0005
Group*Instruc	7	11.198	1.94	0.129
Sex*Instruc	1	0.578	0.10	0.756
Group*Sex*Instruc	7	15.749	2.73	0.046
Instruc*Subj/Sex/Group	16	5.776	----	-----
Session	3	141.529	15.63	0.0001
BAC	3	36.325	4.01	0.009
Maze	3	204.543	22.59	0.0001
Sex*Session	3	4.849	0.54	0.659
Sex*BAC	3	7.666	0.85	0.470
Sex*Maze	3	0.883	0.09	0.964
Instruc*Session	3	2.221	0.25	0.865
Instruc*BAC	3	0.474	0.05	0.984
Instruc*Maze	3	7.136	0.79	0.502
Sex*Instruc*Session	3	0.744	0.08	0.970
Sex*Instruc*BAC	3	10.455	1.15	0.329
Sex*Instruc*Maze	3	9.994	1.10	0.350
Residual	156	9.055	----	-----
Total	255			

Legend: Subj = Subject
BAC = Blood Alcohol Concentration
Instruc = Instruction

mazes were "solved" significantly faster than were the two most difficult mazes. This effect is in the expected direction.

The effect of instruction condition is also significant with the speed-stressed instruction producing significantly faster pathway planning (mean = 10.42 s) than the accuracy-stressed instruction (mean 11.74 s). This effect is in the expected direction.

Instruction is also involved in a three-way interaction with group and sex. The simple-effect F-tests presented in Table 13 shows that a Sex x Instruction interaction was present in Groups 3 and 4. From the Newman-Keuls test in Table J9, it can be seen that only the females in Group 3 were responsive to the instruction conditions while only the males in Group 4 were responsive.

Mediation phase variables: (2) Number of false paths followed. The ANOVA summary table for the number of false paths travelled during pathway planning is given in Table 14. Only the maze variable is significant. According to the Newman-Keuls test (Table J10), the maze that had been rated moderate-low in difficulty produced fewer errors than the two most difficult mazes.

Mediation phase variables: (3) Distance travelled in false paths. Table 15 gives the ANOVA results for the

TABLE 13

Simple-effect F-tests for the Group x Sex x Instruction Interaction on Pathway Planning Time

Source	df	MS	F	p
Group 1				
Sex*Instruction	1	17.479	2.51	< 0.10
Group 2				
Sex*Instruction	1	0.575	0.10	< 0.25
Group 3				
Sex*Instruction	1	57.192	9.90	> 0.01
Group 4				
Sex*Instruction	1	25.956	4.49	0.05
Group 5				
Sex*Instruction	1	2.703	0.47	< 0.25
Group 6				
Sex*Instruction	1	6.799	1.18	< 0.25
Group 7				
Sex*Instruction	1	0.113	0.02	< 0.25
Group 8				
Sex*Instruction	1	0.001	0.00	1.00

TABLE 14

ANOVA for Number of False Paths Followed During Pathway Planning

Source	df	MS	F	p
<u>Between Subjects</u>				
Group	7	1.825	1.08	0.417
Sex	1	0.035	0.02	0.887
Group*Sex	7	2.491	1.48	0.243
Subj/Sex/Group	16	1.684	----	-----
<u>Within Subjects</u>				
Instruc	1	0.098	0.08	0.786
Group*Instruc	7	0.124	0.10	0.998
Sex*Instruc	1	0.473	0.37	0.552
Group*Sex*Instruc	7	0.357	0.28	0.953
Instruc*Subj/Sex/Group	16	1.277	----	-----
Session	3	2.104	2.62	0.053
BAC	3	1.941	2.52	0.060
Maze	3	4.410	5.73	0.001
Sex*Session	3	0.046	0.06	0.981
Sex*BAC	3	0.327	0.42	0.736
Sex*Maze	3	0.108	0.14	0.936
Instruc*Session	3	0.879	1.14	0.334
Instruc*BAC	3	0.285	0.37	0.774
Instruc*Maze	3	0.671	0.87	0.458
Sex*Instruc*Session	3	0.150	0.19	0.900
Sex*Instruc*BAC	3	0.369	0.48	0.698
Sex*Instruc*Maze	3	0.858	1.11	0.345
Residual	156	0.770	----	-----
Total	255			

Legend: Subj = Subject
BAC = Blood Alcohol Concentration
Instruc = Instruction

TABLE 15

ANOVA for Distance Travelled in False Paths During Pathway Planning

Source	df	MS	F	p
<u>Between Subjects</u>				
Group	7	26.924	1.52	0.230
Sex	1	2.178	0.12	0.730
Group*Sex	7	31.767	1.79	0.158
Subj/Sex/Group	16	17.709	----	-----
<u>Within Subjects</u>				
Instruc	1	0.885	0.13	0.726
Group*Instruc	7	3.601	0.52	0.809
Sex*Instruc	1	0.709	0.10	0.754
Group*Sex*Instruc	7	2.759	0.40	0.891
Instruc*Subj/Sex/Group	16	6.973	----	-----
Session	3	20.667	2.69	0.048
BAC	3	21.496	2.80	0.042
Maze	3	29.718	3.87	0.011
Sex*Session	3	3.691	0.48	0.697
Sex*BAC	3	2.686	0.35	0.790
Sex*Maze	3	0.167	0.02	0.996
Instruc*Session	3	4.026	0.52	0.667
Instruc*BAC	3	2.197	0.29	0.836
Instruc*Maze	3	4.791	0.62	0.601
Sex*Instruc*Session	3	2.456	0.32	0.811
Sex*Instruc*BAC	3	7.704	1.00	0.393
Sex*Instruc*Maze	3	7.721	1.00	0.393
Residual	156	7.688	----	-----
Total	255			

Legend: Subj = Subject
BAC = Blood Alcohol Concentration
Instruc = Instruction

distance travelled in false paths during the pathway planning exercise. Main effects exist for the session, BAC, and maze variables. For the session effect, the Newman-Keuls test (Table J11) shows a trend toward performance improvement with each new session; however, only the first and fourth sessions were significantly different from each other with respect to the distance travelled in false paths during pathway planning.

For BAC, the Newman-Keuls test (Table J12) indicates that the 0.09% BAC condition was associated with longer travel distances than was the placebo condition.

For maze, the Newman-Keuls test (Table J13) shows that only the moderate-low difficulty maze produced fewer errors than the most difficult maze.

Communication phase variables: (1) Time to verbalize the pathway. The ANOVA results for pathway verbalization time are given in Table 16. No main effect exists for BAC. The session effect is not easily interpretable. From the Newman-Keuls procedure (Table J14), it can be seen that only at the third session was verbalization time significantly less than at the first or fourth sessions. Performance at the second and third sessions was not significantly different, nor was performance at the first, second, and fourth sessions. A graph of the means for each session (see

TABLE 16

ANOVA for Time to Verbalize the Pathway through the Maze

Source	df	MS	F	p
Between Subjects				
Group	7	125.532	0.94	0.506
Sex	1	117.519	0.88	0.363
Group*Sex	7	52.270	0.39	0.895
Subj/Sex/Group	16	134.023	----	-----
Within Subjects				
Instruc	1	48.956	5.35	0.034
Group*Instruc	7	8.283	0.90	0.527
Sex*Instruc	1	51.060	5.58	0.031
Group*Sex*Instruc	7	2.657	0.29	0.948
Instruc*Subj/Sex/Group	16	9.153	----	-----
Session	3	68.081	6.92	0.0002
BAC	3	0.834	0.08	0.968
Maze	3	455.988	46.33	0.0001
Sex*Session	3	4.125	0.42	0.740
Sex*BAC	3	15.159	1.54	0.206
Sex*Maze	3	14.189	1.44	0.233
Instruc*Session	3	34.842	3.54	0.016
Instruc*BAC	3	29.731	3.02	0.032
Instruc*Maze	3	1.256	0.13	0.944
Sex*Instruc*Session	3	2.426	0.25	0.864
Sex*Instruc*BAC	3	1.833	0.19	0.906
Sex*Instruc*Maze	3	3.275	0.33	0.802
Residual	156	9.842	----	-----
Total	255			

Legend: Subj = Subject
BAC = Blood Alcohol Concentration
Instruc = Instruction

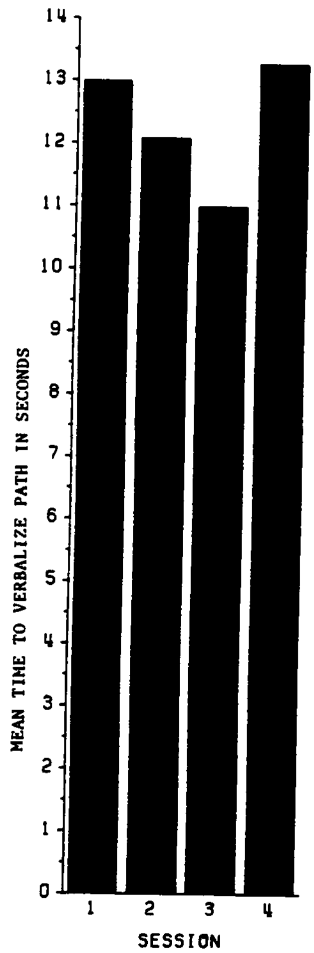


Figure 7: Mean times to verbalize the path at each session.

Figure 7) helps in understanding this effect. There is a trend (subject to the significant comparisons discussed above) toward decreasing verbalization times for each of the first three sessions and an increase in verbalization time at the final session.

The maze effect is straightforward, and in the expected direction. The Newman-Keuls test (Table J15) shows increasing verbalization times with increasing maze difficulty.

A main effect of instruction exists. Subjects took significantly longer to verbalize the path in the accuracy instruction condition (mean = 12.77 s) than they did in the speed instruction condition (mean = 11.89 s). This effect, then, was as expected.

Instruction is also involved in several interactions (with sex, session, and BAC). The simple-effect F-tests for the Sex x Instruction interaction shown in Table 17 indicated that only females were sensitive to the instruction conditions, with mean verbalization times of 10.77 s under the speed condition and 12.53 s under the accuracy condition. Males showed no difference in performance due to instruction with mean verbalization times of 13.01 and 13.00 s under speed and accuracy instructions, respectively.

TABLE 17

Simple-effect F-tests for the Sex x Instruction Interaction on Verbalization Time

Source	df	MS	F	p
Females				
Instruction	1	100.005	10.93	< 0.01
Males				
Instruction	1	0.011	0.00	1.00

For the Session x Instruction interaction, the simple-effect F-tests presented in Table 18 show that the instructions were effective only at the first and last sessions. From the Newman-Keuls test given in Table J16, it can be seen that, in both cases, the instructions had the expected effects.

Finally, the simple-effect F-tests for the BAC x Instruction interaction are found in Table 19. Instruction conditions were effective only when subjects were given the 0.05% BAC dose. At this dose, shorter verbalization times were exhibited under the speed instruction (mean = 10.94 s) than under the accuracy instruction (mean = 13.54 s).

Communication phase variables: (2) Number of incorrect verbalizations. Results of the analysis of variance for this variable are given in Table 20. A significant effect exists for BAC. The Newman-Keuls test (Table J17) showed that fewer errors were made in the no-alcohol condition than in the alcohol conditions, but that the mean number of errors was not significantly different regardless how much alcohol was administered.

Blood alcohol concentration is also involved in significant interactions with sex and session. Table 21 shows the simple-effect F-tests for both interactions. There was an effect of sex only at the 0.09% BAC dosage with

TABLE 18

Simple-effect F-tests for the Session x Instruction Interaction on Verbalization Time

Source	df	MS	F	p
Session 1				
Instruction	1	51.855	5.88	< 0.05
Session 2				
Instruction	1	7.819	0.79	> 0.25
Session 3				
Instruction	1	20.999	2.13	> 0.10
Session 4				
Instruction	1	66.810	6.79	< 0.05

TABLE 19

Simple-effect F-tests for the BAC x Instruction Interaction on Verbalization Time

Source	df	MS	F	p
0.00% BAC				
Instruction	1	25.251	2.57	> 0.10
0.05% BAC				
Instruction	1	107.874	10.96	< 0.01
0.07% BAC				
Instruction	1	4.521	0.46	> 0.25
0.09% BAC				
Instruction	1	0.502	0.05	> 0.25

Legend: BAC = Blood Alcohol Concentration

TABLE 20

ANOVA for Number of Incorrect Verbalizations

Source	df	MS	F	p
<u>Between Subjects</u>				
Group	7	2.096	1.27	0.327
Sex	1	1.563	0.94	0.346
Group*Sex	7	1.304	0.79	0.608
Subj/Sex/Group	16	1.656	----	-----
<u>Within Subjects</u>				
Instruc	1	0.250	2.29	0.150
Group*Instruc	7	0.205	1.88	0.141
Sex*Instruc	1	0.016	0.14	0.710
Group*Sex*Instruc	7	0.150	1.37	0.284
Instruc*Subj/Sex/Group	16	0.109	----	-----
Session	3	0.401	1.95	0.123
BAC	3	1.932	9.41	0.0001
Maze	3	1.547	7.53	0.0001
Sex*Session	3	0.281	1.37	0.254
Sex*BAC	3	0.563	2.74	0.045
Sex*Maze	3	0.073	0.36	0.786
Instruc*Session	3	0.344	1.67	0.175
Instruc*BAC	3	0.625	3.04	0.031
Instruc*Maze	3	0.073	0.36	0.786
Sex*Instruc*Session	3	0.151	0.74	0.532
Sex*Instruc*BAC	3	0.182	0.89	0.446
Sex*Instruc*Maze	3	0.318	1.55	0.205
Residual	156	0.205	----	-----
Total	255			

Legend: Subj = Subject
BAC = Blood Alcohol Concentration
Instruc = Instruction

TABLE 21

Simple-effect F-tests for the BAC x Sex and BAC x Instruction Interactions on Incorrect Verbalizations

Source	df	MS	F	p
<u>0.00% BAC</u>				
Sex	1	0.063	0.31	> 0.25
Instruction	1	0.000	0.00	1.00
<u>0.05% BAC</u>				
Sex	1	0.063	0.31	> 0.25
Instruction	1	1.000	4.87	< 0.05
<u>0.07% BAC</u>				
Sex	1	0.063	0.31	> 0.25
Instruction	1	0.563	2.74	> 0.10
<u>0.09% BAC</u>				
Sex	1	3.063	14.92	< 0.01
Instruction	1	0.563	2.74	> 0.10

Legend: BAC = Blood Alcohol Concentration

females making more incorrect verbalizations (mean = 0.81) than males (mean = 0.38).

The instruction effect was manifest only at the 0.05% BAC dosage; however, this effect is opposite to expectation: more incorrect verbalizations were recorded given the accuracy instruction (mean = 0.66) than given the speed instruction (mean = 0.41).

Maze is also significant. From the Newman-Keuls test, (Table J18) it can be seen that there were significantly more errors made on the two most difficult mazes than on the two easiest mazes.

Communication phase variables: (3) Number of unintelligible verbalizations. As Table 22 indicates, the analysis of variance uncovered no significant effects on this dependent variable.

Communication phase variables: (4) Number of words produced. The ANOVA summary is shown in Table 23. The session effect is significant. The Newman-Keuls test given in Table J19 shows that significantly more words were spoken at the second and fourth sessions than at the first and third sessions. The fewest words were spoken at the third session.

A significant effect of BAC exists. The Newman-Keuls test (Table J20) shows that the three alcohol conditions did

TABLE 22

ANOVA for Number of Unintelligible Verbalizations

Source	df	MS	F	p
<u>Between Subjects</u>				
Group	7	0.107	0.38	0.898
Sex	1	0.098	0.35	0.561
Group*Sex	7	0.428	1.54	0.223
Subj/Sex/Group	16	0.277	----	-----
<u>Within Subjects</u>				
Instruc	1	0.004	0.04	0.850
Group*Instruc	7	0.102	0.97	0.486
Sex*Instruc	1	0.191	1.81	0.197
Group*Sex*Instruc	7	0.075	0.71	0.662
Instruc*Subj/Sex/Group	16	0.106	----	-----
Session	3	0.129	0.87	0.460
BAC	3	0.056	0.38	0.771
Maze	3	0.108	0.73	0.538
Sex*Session	3	0.108	0.73	0.538
Sex*BAC	3	0.098	0.66	0.581
Sex*Maze	3	0.046	0.31	0.821
Instruc*Session	3	0.056	0.38	0.771
Instruc*BAC	3	0.171	1.15	0.333
Instruc*Maze	3	0.077	0.52	0.672
Sex*Instruc*Session	3	0.139	0.94	0.425
Sex*Instruc*BAC	3	0.066	0.45	0.721
Sex*Instruc*Maze	3	0.119	0.80	0.446
Residual	156	0.149	----	-----
Total	255			

Legend: Subj = Subject
BAC = Blood Alcohol Concentration
Instruc = Instruction

TABLE 23

ANOVA for Number of Words Produced

Source	df	MS	F	p
<u>Between Subjects</u>				
Group	7	627.941	1.74	0.170
Sex	1	46.410	0.13	0.725
Group*Sex	7	190.241	0.53	0.801
Subj/Sex/Group	16	360.848	----	-----
<u>Within Subjects</u>				
Instruc	1	10.160	0.40	0.538
Group*Instruc	7	10.526	0.41	0.880
Sex*Instruc	1	145.504	5.71	0.030
Group*Sex*Instruc	7	23.209	0.91	0.523
Instruc*Subj/Sex/Group	16	25.488	----	-----
Session	3	336.827	16.96	0.0001
BAC	3	75.077	3.78	0.012
Maze	3	1506.869	75.88	0.0001
Sex*Session	3	58.775	2.96	0.034
Sex*BAC	3	71.275	3.59	0.015
Sex*Maze	3	40.421	2.04	0.111
Instruc*Session	3	101.650	5.12	0.002
Instruc*BAC	3	96.296	4.85	0.003
Instruc*Maze	3	17.671	0.89	0.448
Sex*Instruc*Session	3	2.785	0.14	0.936
Sex*Instruc*BAC	3	41.848	2.11	0.102
Sex*Instruc*Maze	3	51.994	2.62	0.053
Residual	156	19.858	----	-----
Total	255			

Legend: Subj = Subject
BAC = Blood Alcohol Concentration
Instruc = Instruction

not differ with respect to word production; however, only the 0.05 and 0.09% BAC conditions are significantly different from the placebo.

The Maze variable is also significant. Word production increased as the difficulty of the mazes increased (Table J21). On the two most difficult mazes, a similar number of words was spoken.

While neither a sex nor an instruction effect exists, both of these independent variables are involved in a number of significant interactions. The Sex x Session interaction is significant. As the simple-effect F-tests in Table 24 shows, there was a sex effect only at the second session. Here, males spoke more words (mean = 26.84) than females (mean = 23.94).

The significant Instruction x Session interaction is also depicted in Table 24. Instructions were only effective at the first and third sessions. Performance under the speed instruction was similar at both sessions; however, subjects responded to the accuracy instruction with an increase in word production at the first session but with a decrease at the third session, as shown in Table J22.

The interaction of sex and BAC also attained significance. From the simple-effect F-tests in Table 25, it can be seen that there were sex-based performance

TABLE 24

Simple-effect F-tests for the Sex x Session and the Instruction x Session Interaction on Word Production

Source	df	MS	F	p
<u>Session 1</u>				
Sex	1	33.063	1.67	> 0.10
Instruction	1	105.063	5.29	< 0.05
<u>Session 2</u>				
Sex	1	135.141	6.81	< 0.05
Instruction	1	34.516	1.74	> 0.25
<u>Session 3</u>				
Sex	1	0.141	0.01	> 0.25
Instruction	1	165.766	8.35	< 0.01
<u>Session 4</u>				
Sex	1	54.391	2.74	> 0.10
Instruction	1	9.766	0.49	> 0.25

TABLE 25

Simple-effect F-tests for the BAC x Sex and BAC x Instruction Interactions on Word Production

Source	df	MS	F	p
0.00% BAC				
Sex	1	34.516	1.74	> 0.10
Instruction	1	0.141	0.01	> 0.25
0.05% BAC				
Sex	1	62.016	3.12	> 0.05
Instruction	1	228.766	11.52	< 0.01
0.07% BAC				
Sex	1	153.141	7.71	< 0.01
Instruction	1	70.141	3.53	> 0.05
0.09% BAC				
Sex	1	10.563	0.54	> 0.25
Instruction	1	0.000	0.00	1.00

Legend: BAC = Blood Alcohol Concentration

differences only when the 0.07% BAC dose was administered. Under this condition, males verbalized significantly more words (mean = 24.69) than females (mean = 21.59).

The BAC x Instruction interaction is also shown in Table 25. Instructions were effective only when the 0.05% BAC dose was given. Here, more words were spoken under the accuracy instruction (mean = 26.47) than under the speed instruction (mean = 22.69).

Finally, as shown in Table 26, sex and instruction interacted such that only females were responsive to instruction conditions with the speed instruction producing fewer words (mean = 22.06) than the accuracy instruction (mean = 23.97).

Communication phase variables: (5) Number of pauses produced. Results of the ANOVA are given in Table 27. While no main effect exists for BAC, the session, maze, and instruction effects are significant.

The Newman-Keuls test (Table J23) reveals a complex session effect with only the following pairs of sessions having significant differences with respect to the numbers of pauses produced: 1 and 3, 2 and 4, and 3 and 4. Graphing the means (see Figure 8) sheds some light on this effect: there is a trend toward a decrease in the number of pauses with each of the first three sessions, but the number

TABLE 26

Simple-effect F-tests for the Sex x Instruction Interaction on Word Production

Source	df	MS	F	p
Females				
Instruction	1	116.283	4.56	< 0.05
Males				
Instruction	1	39.383	1.55	> 0.10

TABLE 27

ANOVA for Number of Pauses Produced

Source	df	MS	F	p
Between Subjects				
Group	7	22.924	0.67	0.696
Sex	1	6.566	0.19	0.668
Group*Sex	7	15.200	0.44	0.861
Subj/Sex/Group	16	34.309	----	-----
Within Subjects				
Instruc	1	15.504	7.36	0.015
Group*Instruc	7	3.495	1.66	0.190
Sex*Instruc	1	2.066	0.98	0.337
Group*Sex*Instruc	7	1.022	0.49	0.832
Instruc*Subj/Sex/Group	16	2.106	----	-----
Session	3	20.441	7.36	0.0001
BAC	3	1.921	0.68	0.558
Maze	3	109.108	39.30	0.0001
Sex*Session	3	2.712	0.98	0.405
Sex*BAC	3	2.254	0.81	0.489
Sex*Maze	3	5.233	1.88	0.134
Instruc*Session	3	4.171	1.50	0.216
Instruc*BAC	3	2.566	0.92	0.431
Instruc*Maze	3	0.712	0.26	0.857
Sex*Instruc*Session	3	0.067	0.02	0.995
Sex*Instruc*BAC	3	0.316	0.11	0.952
Sex*Instruc*Maze	3	1.712	0.62	0.605
Residual	156	2.776	----	-----
Total	255			

Legend: Subj = Subject
BAC = Blood Alcohol Concentration
Instruc = Instruction

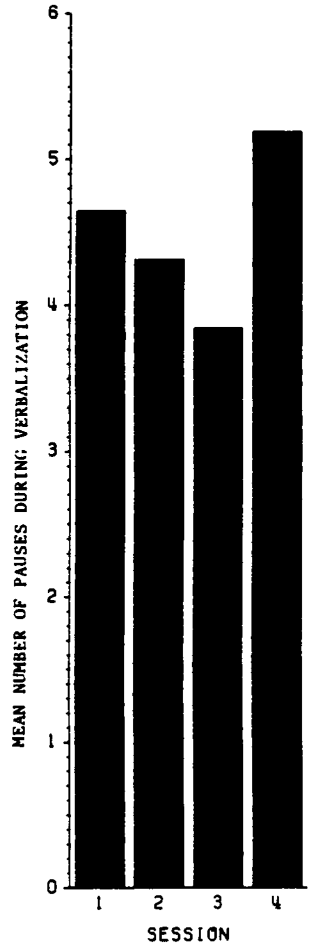


Figure 8: Mean number of pauses produced at each session.

of pauses increased at the last session. (This increase is significant only with respect to comparisons for the second and third sessions.)

On the maze variable, the number of pauses observed increased with increasing maze difficulty, although the two most difficult mazes are not different. This is shown by the Newman-Keuls test given in Table J24.

The significant instruction effect indicates that significantly more pauses occurred in the accuracy condition (mean = 4.74) than in the speed condition (mean = 4.25).

Communication phase variables: (6) Proportion of pauses to words. Results of the ANOVA are summarized in Table 28. Significant main effects exist for session, BAC, maze, and instruction. There are no significant interactions.

For the session variable, the Newman-Keuls test in Table J25 shows that performance was not significantly different between the first and fourth or the second and third sessions. As Figure 9 indicates, a similar trend as was seen for the number of pauses is repeated here.

The Newman-Keuls test for BAC (Table J26) shows that only the placebo and 0.09% BAC differed with respect to the proportion of pauses to words with a smaller proportion being exhibited under the alcohol condition.

TABLE 28

ANOVA for Proportion of Pauses to Words

Source	df	MS	F	p
__Between Subjects__				
Group	7	0.021	0.59	0.752
Sex	1	0.017	0.47	0.502
Group*Sex	7	0.036	1.04	0.444
Subj/Sex/Group	16	0.035	----	-----
__Within Subjects__				
Instruc	1	0.017	6.45	0.022
Group*Instruc	7	0.004	1.58	0.213
Sex*Instruc	1	0.000	0.02	0.885
Group*Sex*Instruc	7	0.002	0.81	0.593
Instruc*Subj/Sex/Group	16	0.003	----	-----
Session	3	0.019	6.48	0.0004
BAC	3	0.013	4.54	0.004
Maze	3	0.026	8.79	0.0001
Sex*Session	3	0.002	0.57	0.638
Sex*BAC	3	0.003	1.09	0.354
Sex*Maze	3	0.005	1.81	0.148
Instruc*Session	3	0.002	0.66	0.578
Instruc*BAC	3	0.001	0.20	0.898
Instruc*Maze	3	0.001	0.28	0.836
Sex*Instruc*Session	3	0.000	0.08	0.970
Sex*Instruc*BAC	3	0.001	0.36	0.785
Sex*Instruc*Maze	3	0.001	0.27	0.845
Residual	156	0.003	----	-----
Total	255			

Legend: Subj = Subject
BAC = Blood Alcohol Concentration
Instruc = Instruction

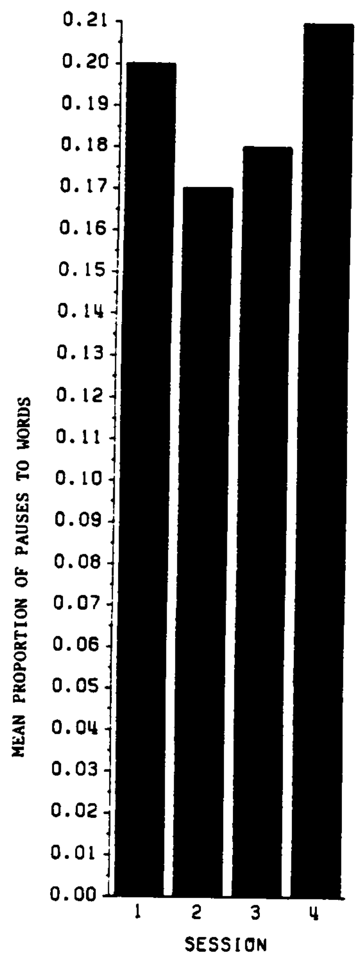


Figure 9: Mean proportion of pauses to words at each session.

For maze, the Newman-Keuls test (Table J27) shows that the two easiest mazes produced a significantly smaller proportion than the two hardest mazes.

Finally, the significant effect of instruction shows that the speed instruction resulted in a smaller proportion (mean = 0.18) than the accuracy instruction (mean = 0.20), as would be expected.

Motor phase variables: (1) Time to trace the path. The results of the ANOVA for this variable are given in Table 29. There is no reliable effect of BAC on tracing time.

There are, however, significant effects of session, maze, and instruction. As shown by the Newman-Keuls test in Table J28, tracing times were longer during the first and last sessions than during the two middle sessions. As Figure 10 shows, there was a trend toward decreasing tracing times with sessions subsequent to the first followed by a time increase at the last session (such that the first and last sessions were similar).

On the maze variable, the results are in the expected direction. The Newman-Keuls test (Table J29) generally reveals an increase in tracing time with increasing maze difficulty.

TABLE 29

ANOVA for Time to Trace the Path

Source	df	MS	F	p
<u>Between Subjects</u>				
Group	7	11.655	0.45	0.855
Sex	1	7.600	0.29	0.595
Group*Sex	7	15.068	0.58	0.760
Subj/Sex/Group	16	25.837	----	-----
<u>Within Subjects</u>				
Instruc	1	212.886	34.77	0.0001
Group*Instruc	7	11.657	1.90	0.136
Sex*Instruc	1	10.332	1.69	0.212
Group*Sex*Instruc	7	6.504	1.06	0.430
Instruc*Subj/Sex/Group	16	6.123	----	-----
Session	3	48.574	13.00	0.0001
BAC	3	1.482	0.40	0.756
Maze	3	112.135	30.01	0.0001
Sex*Session	3	2.521	0.67	0.569
Sex*BAC	3	1.374	0.37	0.776
Sex*Maze	3	2.695	0.72	0.541
Instruc*Session	3	5.149	1.38	0.252
Instruc*BAC	3	0.390	0.10	0.957
Instruc*Maze	3	3.876	1.04	0.378
Sex*Instruc*Session	3	1.392	0.37	0.773
Sex*Instruc*BAC	3	1.058	0.28	0.838
Sex*Instruc*Maze	3	1.052	0.28	0.838
Residual	156	3.736	----	-----
Total	255			

Legend: Subj = Subject
BAC = Blood Alcohol Concentration
Instruc = Instruction

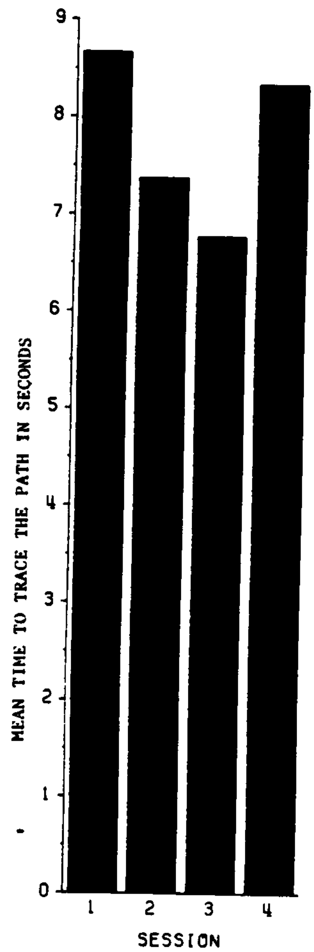


Figure 10: Mean times to trace the path at each session.

Finally, there was a significantly longer tracing time under the accuracy instruction (mean = 8.70 s) than under the speed instruction (mean = 6.87 s), as would be expected.

Motor phase variables: (2) Number of reversals in tracing the path. Table 30 shows the ANOVA for the number of reversals in pathway tracing. The only significant effect obtained is for BAC. From the Newman-Keuls test (Table J30), it can be seen that the number of reversals was not significantly different among the non-placebo dosage levels. At the same time, though, the 0.05 and 0.07% BACs did not produce results which were significantly different from the placebo.

Motor phase variables: (3) Distance travelled in reversals. The ANOVA summary table for this variable can be found in Table 31. The only significant effect is for BAC. The Newman-Keuls test in Table J31 showed that longer distances were travelled under alcohol conditions than under the no-alcohol condition. Within the alcohol doses, there is no significant difference with respect to the distance travelled.

Motor phase variables: (4) Number of wall touches during pathway tracing. The ANOVA summary table for number of wall touches is given in Table 32. Two significant main effects, BAC and maze, exist. For the BAC effect, the

TABLE 30

ANOVA for Number of Tracking Reversals

Source	df	MS	F	p
Between Subjects				
Group	7	2.718	0.53	0.796
Sex	1	6.566	1.29	0.273
Group*Sex	7	5.049	0.99	0.471
Subj/Sex/Group	16	5.090	----	-----
Within Subjects				
Instruc	1	0.035	0.03	0.862
Group*Instruc	7	1.946	1.74	0.171
Sex*Instruc	1	0.660	0.59	0.454
Group*Sex*Instruc	7	1.410	1.26	0.330
Instruc*Subj/Sex/Group	16	1.121	----	-----
Session	3	2.618	1.44	0.233
BAC	3	7.171	3.94	0.010
Maze	3	1.296	0.71	0.546
Sex*Session	3	3.410	1.88	0.136
Sex*BAC	3	1.066	0.59	0.625
Sex*Maze	3	1.441	0.79	0.500
Instruc*Session	3	0.483	0.27	0.850
Instruc*BAC	3	2.139	1.18	0.321
Instruc*Maze	3	1.077	0.59	0.621
Sex*Instruc*Session	3	0.754	0.41	0.743
Sex*Instruc*BAC	3	0.598	0.33	0.805
Sex*Instruc*Maze	3	1.327	0.73	0.536
Residual	156	1.818	----	-----
Total	255			

Legend: Subj = Subject
BAC = Blood Alcohol Concentration
Instruc = Instruction

TABLE 31

ANOVA for Distance Travelled in Tracking Reversals

Source	df	MS	F	p
<u>Between Subjects</u>				
Group	7	3.887	0.92	0.520
Sex	1	1.698	0.40	0.536
Group*Sex	7	8.157	1.92	0.133
Subj/Sex/Group	16	4.248	----	-----
<u>Within Subjects</u>				
Instruc	1	0.776	0.78	0.391
Group*Instruc	7	0.878	0.88	0.543
Sex*Instruc	1	0.187	0.19	0.671
Group*Sex*Instruc	7	0.586	0.59	0.757
Instruc*Subj/Sex/Group	16	0.996	----	-----
Session	3	2.355	1.72	0.165
BAC	3	7.722	5.65	0.001
Maze	3	0.812	0.59	0.620
Sex*Session	3	2.637	1.93	0.127
Sex*BAC	3	0.696	0.51	0.676
Sex*Maze	3	1.489	1.09	0.355
Instruc*Session	3	0.258	0.19	0.904
Instruc*BAC	3	0.957	0.70	0.553
Instruc*Maze	3	0.506	0.37	0.775
Sex*Instruc*Session	3	0.727	0.53	0.661
Sex*Instruc*BAC	3	0.264	0.19	0.901
Sex*Instruc*Maze	3	2.213	1.62	0.187
Residual	156	1.367	----	-----
Total	255			

Legend: Subj = Subject
BAC = Blood Alcohol Concentration
Instruc = Instruction

TABLE 32

ANOVA for Number of Wall Touches during Pathway Tracing

Source	df	MS	F	p
<u>Between Subjects</u>				
Group	7	1.962	1.38	0.279
Sex	1	1.891	1.33	0.266
Group*Sex	7	1.158	0.81	0.588
Subj/Sex/Group	16	1.422	----	-----
<u>Within Subjects</u>				
Instruc	1	1.891	2.47	0.136
Group*Instruc	7	1.444	1.89	0.139
Sex*Instruc	1	0.016	0.02	0.888
Group*Sex*Instruc	7	0.676	0.88	0.541
Instruc*Subj/Sex/Group	16	0.766	----	-----
Session	3	1.474	2.04	0.109
BAC	3	2.214	3.08	0.029
Maze	3	10.005	13.93	0.0001
Sex*Session	3	0.224	0.31	0.817
Sex*BAC	3	0.839	1.17	0.324
Sex*Maze	3	0.839	1.17	0.324
Instruc*Session	3	0.516	0.72	0.543
Instruc*BAC	3	1.005	1.40	0.245
Instruc*Maze	3	1.589	2.21	0.089
Sex*Instruc*Session	3	0.891	1.24	0.297
Sex*Instruc*BAC	3	0.005	0.01	0.999
Sex*Instruc*Maze	3	1.547	2.15	0.096
Residual	156	0.718	----	-----
Total	255			

Legend: Subj = Subject
BAC = Blood Alcohol Concentration
Instruc = Instruction

Newman-Keuls procedure (Table J32) shows that only the placebo and the 0.09% BAC conditions were significantly different.

There was also an increase in the number of wall touches with increasing maze difficulty, as can be seen from Table J33. Here, the results obtained on the two most difficult mazes are significantly different (with a greater number of touches) than those obtained on the two easiest mazes.

Motor phase variables: (5) Time spent touching maze walls. Table 33 shows the ANOVA summary table for the total time spent touching the maze walls while tracing the path. With the exception of sex and instruction, all the main effects are significant.

The Newman-Keuls test for the session effect (Table J34) shows that the time spent touching the maze walls did not differ significantly among the last three sessions, and that the second and fourth sessions led to less time than the first session.

For BAC, the Newman-Keuls procedure (Table J35) indicates that only the two highest alcohol doses produced significant impairment relative to the placebo condition. Among the non-placebo alcohol doses, however, there were no significant differences in performance.

TABLE 33

ANOVA for Time Spent Touching Walls during Pathway Tracing

Source	df	MS	F	p
<u>Between Subjects</u>				
Group	7	0.847	0.73	0.649
Sex	1	0.035	0.03	0.864
Group*Sex	7	0.454	0.39	0.893
Subj/Sex/Group	16	1.157	----	-----
<u>Within Subjects</u>				
Instruc	1	1.896	3.30	0.088
Group*Instruc	7	0.820	1.43	0.261
Sex*Instruc	1	0.129	0.23	0.642
Group*Sex*Instruc	7	0.426	0.74	0.641
Instruc*Subj/Sex/Group	16	0.574	----	-----
Session	3	1.518	3.32	0.022
BAC	3	1.460	3.19	0.025
Maze	3	6.942	15.17	0.0001
Sex*Session	3	0.033	0.07	0.975
Sex*BAC	3	0.168	0.37	0.776
Sex*Maze	3	0.975	2.13	0.099
Instruc*Session	3	0.449	0.98	0.403
Instruc*BAC	3	0.535	1.17	0.324
Instruc*Maze	3	1.187	2.59	0.055
Sex*Instruc*Session	3	0.502	1.10	0.353
Sex*Instruc*BAC	3	0.183	0.40	0.753
Sex*Instruc*Maze	3	1.679	3.67	0.014
Residual	156	0.458	----	-----
Total	255			

Legend: Subj = Subject
BAC = Blood Alcohol Concentration
Instruc = Instruction

The results for maze difficulty are the same as were obtained with respect to the number of wall touches. The Newman-Keuls test (Table J36) indicates that significantly more time was spent touching the walls on the two most difficult mazes than on the two easiest mazes.

A significant interaction among sex, maze, and instruction exists. As the simple-effect F-tests in Table 34 indicate, only females were involved in the Maze x Instruction interaction. For females, instruction effects are contrary to expectation on the easiest and most difficult mazes; only the moderate-low difficulty maze produced results consistent with expectation; and, there was no effect of instruction on the moderate-high difficulty maze. This interpretation is supported by the Newman-Keuls test found in Table J37.

Total time to complete the task. The ANOVA summary table for overall time for task completion is presented in Table 35. All main effects, with the exception of sex and group, are significant.

The Newman-Keuls test given in Table J38 shows that subjects took significantly longer to complete the task during the first session than in subsequent sessions. Graphing the means (see Figure 11) again indicates a trend toward decreasing completion times after the first session but with an increase at the last session.

TABLE 34

Simple-effect F-tests for the Sex x Instruction x Maze Interaction on Wall Touching Time

Source	df	MS	F	p
Females				
Instruction*Maze	3	2.144	4.69	< 0.01
Males				
Instruction*Maze	3	0.722	1.58	> 0.10

TABLE 35

ANOVA for Total Time to Complete the Task

Source	df	MS	F	p
Between Subjects				
Group	7	302.958	0.62	0.734
Sex	1	124.965	0.25	0.621
Group*Sex	7	233.972	0.48	0.837
Subj/Sex/Group	16	490.588	----	-----
Within Subjects				
Instruc	1	955.660	27.77	0.0001
Group*Instruc	7	54.929	1.60	0.207
Sex*Instruc	1	162.180	4.71	0.045
Group*Sex*Instruc	7	34.964	1.02	0.457
Instruc*Subj/Sex/Group	16	34.413	----	-----
Session	3	842.713	17.71	0.0001
BAC	3	141.236	2.97	0.034
Maze	3	2303.721	48.43	0.0001
Sex*Session	3	17.809	0.37	0.772
Sex*BAC	3	54.808	1.15	0.330
Sex*Maze	3	8.192	0.17	0.915
Instruc*Session	3	67.994	1.43	0.236
Instruc*BAC	3	26.071	0.55	0.650
Instruc*Maze	3	25.478	0.54	0.659
Sex*Instruc*Session	3	3.598	0.08	0.973
Sex*Instruc*BAC	3	27.385	0.58	0.632
Sex*Instruc*Maze	3	35.067	0.74	0.531
Residual	156	47.572	----	-----
Total	255			

Legend: Subj = Subject
BAC = Blood Alcohol Concentration
Instruc = Instruction

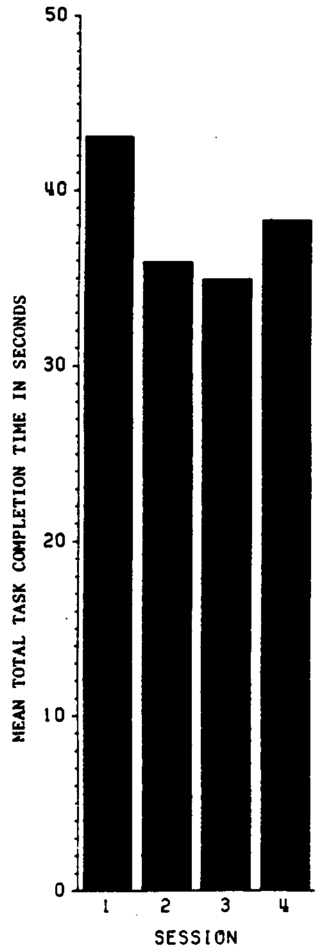


Figure 11: Mean total completion time at each session.

From the Newman-Keuls test (Table J39), it can be seen that time to complete the task increased relative to placebo only for the 0.09% BAC. The intermediate doses produced performance that did not differ significantly from either the 0.09 or the 0.00% BACs.

For the Maze effect the Newman-Keuls test given in Table J40 indicates a significant increase in total completion time with each increase in maze difficulty.

A significant instruction effect reveals a significantly longer total completion time under the accuracy instruction (mean = 39.96 s) than under the speed instruction (mean = 36.09 s).

Instruction also interacts with sex. As shown in Table 36, females and males performed differently under the speed instruction (with mean completion times of 34.60 and 37.59 s, respectively) but not under the accuracy instruction.

<u>Regression Analyses</u>

As was mentioned previously, one of the major aims of this research was to develop regression equations which could be used to estimate the productivity decrements on industrial tasks which are attributable to alcohol effects. Various models were developed and their ability to predict the total time to complete the current task was evaluated.

TABLE 36

Simple-effect F-tests for the Sex x Instruction Interaction on Total Completion Time

Source	df	MS	F	p
Speed				
Sex	1	285.934	8.31	< 0.05
Accuracy				
Sex	1	1.211	0.04	> 0.25

The independent measures included in these models varied somewhat from those which had been used in the analyses of variance. Sex, BAC, and instruction, as had been defined previously, were included in the regression equations. The maze variable, however, was not included per se. Recall that in the analyses of variance this variable was used to distinguish among four overall levels of task difficulty. Task difficulty, in turn, was a function of a composite of the importance of four behavioral domains -- perception, mediation, communication, and motor skills -- to overall task completion. In developing the regression equations, it was the influence of the individual behavioral components that was of interest. Thus, the variable previously called "Maze" was effectively broken down into four separate variables which were defined as the mean importance ranking (assigned from ratings given by a group of expert raters, as described previously) on perception, mediation, communication, and motor skills, respectively. Each of the four levels of maze, then, were characterized with respect to each of the four behavioral processes.

Several criteria were considered in examining the candidate models: (1) tests of hypotheses regarding the regression coefficients (b) where the null hypothesis states that b = 0 -- failure to reject the null hypothesis implies that the variable does not contribute to the regression in the presence of the other regressors; (2) R^2 -- ideally, the model chosen would be that with the highest R^2; however, one must also be aware that, while the most complicated model will always have the highest R^2, it will not always be the preferred model; (3) mean square error -- using only this criterion, the "best" model would be the one with the smallest value; this criterion has a built-in "punishment" for overfitting which R^2 lacks in that models which include extraneous variables may have larger mean square errors that those in which extraneous variables are omitted due to the division of the sums of squares residual by degrees of freedom; and (4) the PRESS statistic -- this statistic assesses the predictive capabilities of the model; the model with the smallest PRESS is the best predictive model. The PRESS statistic is a cross-validation criterion the effect of which is to take the candidate model, run it without the first observation, then use the regression equation from the run to predict the value of the dependent variable which was set aside (i.e., its value on the first observation). This is repeated for each successive observation to generate a set of PRESS residuals (prediction errors). The PRESS statistic is the sum of squares of these PRESS residuals[5] (Cook and Weisberg, 1982).

The development of the regression equations was an iterative process. In the first stage, a model containing all the independent variables of interest (sex, BAC, instruction, and the mean ranks on perception, mediation, verbalization, and motor skills at each observation) was subjected to regression analysis. This first analysis yielded an important piece of information, namely, that the use of all four ranking variables in the prediction equation is unnecessary as the fourth variable entered gives no new information and can be shown to be a complicated, but linear combination of the other three ranking variables and the intercept. (As an example, the Motor ranking variable was expressed as follows:

$$\text{Motor} = 9.88572 - 4.30781\ \text{Perception} - 2.84254\ \text{Mediation} + 6.03738\ \text{Verbalization.})$$

Hence, SAS assigned a parameter estimate of zero to the fourth ranking variable.

The impact of this development is to show that four different prediction equations, each of which omits one of the ranking variables, are required. How the implementation of the equations will be affected will be examined subsequently in the Discussion section.

Proceeding from this point, then, four models, each of which contained sex, BAC, instruction, and a unique three-way combination of the ranking variables, were examined. This iteration, too, yielded an important piece of information, namely, that the sex variable is superfluous in the presence of the other regressors. Based on the type of hypothesis testing discussed previously, one fails to reject the null hypothesis which states that the regression parameter associated with the sex variable is zero ($T = 1.145$, $p = 0.2533$ for all four models). This finding was not unexpected in light of the ANOVA results previously presented.

Summary tables illustrating this result are given in Table 37 for the model which included perception, mediation, and communication, in Table 38 for the model which included perception, mediation, and motor skills, in Table 39 for the model which included perception, communication, and motor skills, and in Table 40 for the model which included mediation, communication, and motor skills. It is also interesting to note that, for each of the four models, the same regression coefficients were assigned to BAC and instruction -- only the intercept and ranking variable coefficients varied across equations.

At this stage, it was known that one variable could be eliminated from each of the four basic models. Hence, the following four regression equations remained:

TABLE 37

Summary Table for Model which Included Sex, BAC, Instruction, Perception, Mediation, and Communication

Variable	Parameter Estimate	T	p
Intercept	158.871	7.969	0.0001
Sex	1.397	1.145	0.253
BAC	37.940	2.080	0.039
Instruction	3.864	3.167	0.002
Perception	-53.654	-6.060	0.0001
Mediation	-36.383	-6.267	0.0001
Communication	61.845	5.928	0.0001

For the model, df = 6, sum of squares = 8404.036, F = 14.697, the p-value is 0.0001, and R-square is 0.2615.

TABLE 38

Summary Table for Model which Included Sex, BAC, Instruction, Perception, Mediation, and Motor Skills

Variable	Parameter Estimate	T	p
Intercept	57.604	12.757	0.0001
Sex	1.397	1.145	0.253
BAC	37.940	2.080	0.039
Instruction	3.864	3.167	0.002
Perception	-9.526	-6.566	0.0001
Mediation	-7.265	-7.581	0.0001
Motor Skills	10.244	5.928	0.0001

For the model, df = 6, sum of squares = 8404.036, F = 14.697, the p-value is 0.0001, and R-square is 0.2615.

TABLE 39

Summary Table for Model which Included Sex, BAC, Instruction, Perception, Communication, and Motor Skills

Variable	Parameter Estimate	T	p
Intercept	32.338	9.571	0.0001
Sex	1.397	1.145	0.253
BAC	37.940	2.080	0.039
Instruction	3.864	3.167	0.002
Perception	1.484	2.240	0.026
Communication	-15.431	-7.581	0.0001
Motor Skills	12.800	6.267	0.0001

For the model, df = 6, sum of squares = 8404.036, F = 14.697, the p-value is 0.0001, and R-square is 0.2615.

TABLE 40

Summary Table for Model which Included Sex, BAC, Instruction, Mediation, Communication, and Motor Skills

Variable	Parameter Estimate	T	p
Intercept	35.744	10.193	0.0001
Sex	1.397	1.145	0.253
BAC	37.940	2.080	0.039
Instruction	3.864	3.167	0.002
Mediation	-0.979	-2.240	0.026
Communication	-13.351	-6.566	0.0001
Motor Skills	12.455	6.060	0.0001

For the model, df = 6, sum of squares = 8404.036, F = 14.697, the p-value is 0.0001, and R-square is 0.2615.

$$\text{SUMTIM} = 160.967 + 37.940\ \text{BAC} + 3.864\ \text{Instruction} - 53.654\ \text{Perception} - 36.384\ \text{Mediation} + 61.845\ \text{Verbal}, \quad (1)$$

$$\text{SUMTIM} = 59.700 + 37.940\ \text{BAC} + 3.864\ \text{Instruction} - 9.526\ \text{Perception} - 7.265\ \text{Mediation} + 10.244\ \text{Motor}, \quad (2)$$

$$\text{SUMTIM} = 34.434 + 37.940\ \text{BAC} + 3.864\ \text{Instruction} + 1.484\ \text{Perception} - 15.431\ \text{Verbal} + 12.800\ \text{Motor}, \quad (3)$$

$$\text{SUMTIM} = 37.840 + 37.940\ \text{BAC} + 3.864\ \text{Instruction} - 0.979\ \text{Mediate} - 13.351\ \text{Verbal} + 12.455\ \text{Motor}. \quad (4)$$

SUMTIM refers to the total time (in seconds) to complete the task.

All possible permutations of these models were examined with respect to R^2, mean square error, and PRESS. In each case, the models given above were superior on all three of these criteria to any of the candidate models which omitted one or more of the independent variables. For each of the models stated above, degrees of freedom is equal to five, sum of squares is equal to 8279.072, F is equal to 17.353, p is equal to 0.0001, R^2 is equal to 0.2576, mean square error is equal to 95.419, and PRESS is equal to 24984.6. The reason that the statistics associated with each of the models are identical stems from the relationship among the variables associated with the behavioral processes. Recall that the fourth of these variables is redundant, regardless of which variable is considered to be fourth. This indicates that any three of the variables, taken together, account for the same amount of variance as any other three. In essence, then, the models contain BAC, instruction, and one (combined) process variable. Since the parameter estimates for these models do not differ from those for the models which included sex except with respect to the values of the intercept, the summary tables will not be repeated.

One point of consideration regarding the models is that they evaluate only the additive effects of the process variables. Possible synergistic relationships are not considered, since they would be difficult for a user of the equation to determine. This omission may, however, have a negative impact on the theoretically attainable value of R^2.

Integration of Predictions with Previous Research

In order to assess the agreement between the predictions generated in the current study and previous research, the percent difference approach used by Levine et al. (1973; 1975) was employed. The regression equations given previously were used to generate expected completion times for each of the four sets of task characteristics across BACs.

For each of the four overall "tasks" (i.e., each constellation of the four behavioral domains) the equation employed was the one which omitted the task characteristic receiving the lowest ranking on importance. The obtained mean ranks on the three highest ranked task variables were substituted into the equation and estimated task completion times were predicted for each level of BAC at each level of instruction. Completion time was then averaged across instruction conditions. The predicted mean completion times are given in Table 41.

Finally, percent differences in completion times between the 0.00 and 0.05% BACs, the 0.00 and 0.07% BACs, and the 0.00 and 0.09% BACs were calculated and graphed as Figure 12.

It was hoped that a similar approach could be taken to predicting completion times for the segment of the overall

TABLE 41

Predicted Mean Completion Times in Seconds

BAC %	Time for Task 1	Time for Task 2	Time for Task 3	Time for Task 4
0.00	33.358	37.844	43.401	58.363
0.05	35.355	39.741	45.298	60.260
0.07	36.014	40.500	46.057	61.019
0.09	36.773	41.259	46.816	61.778

Note: Tasks 1 through 4 denote the four different constellations of task characteristics associated with each of the four mazes. Note that Task 1 does not necessarily imply Maze 1. The task designator was assigned based on the magnitude of completion time. Task 1 corresponds to the easiest maze for which the following average rankings were obtained: perception = 7.225, mediation = 3.675, communication = 5.25, and motor skills = 6.20. Since the lowest ranking was with respect to mediation, this variable was omitted, and total task completion time was computed using the ranks of perception, communication, and motor skills. The values for Tasks 2 and 4 were computed using the equation containing mediation, communication, and motor skills. In both cases, perception received the lowest ranking (4.25 and 3.475, respectively). For Task 2, the remaining rankings were: 6.20 for mediation, 5.25 for communication, and 5.65 for motor skills. For Task 4, these values were 5.875, 4.25, and 3.875. Finally, the values for Task 3 were computed using the equation containing perception, mediation, and motor skills since the lowest ranking (1.975) was obtained on communication. Rankings of 3.05, 2.25, and 2.275 were obtained on perception, mediation, and motor skills, respectively.

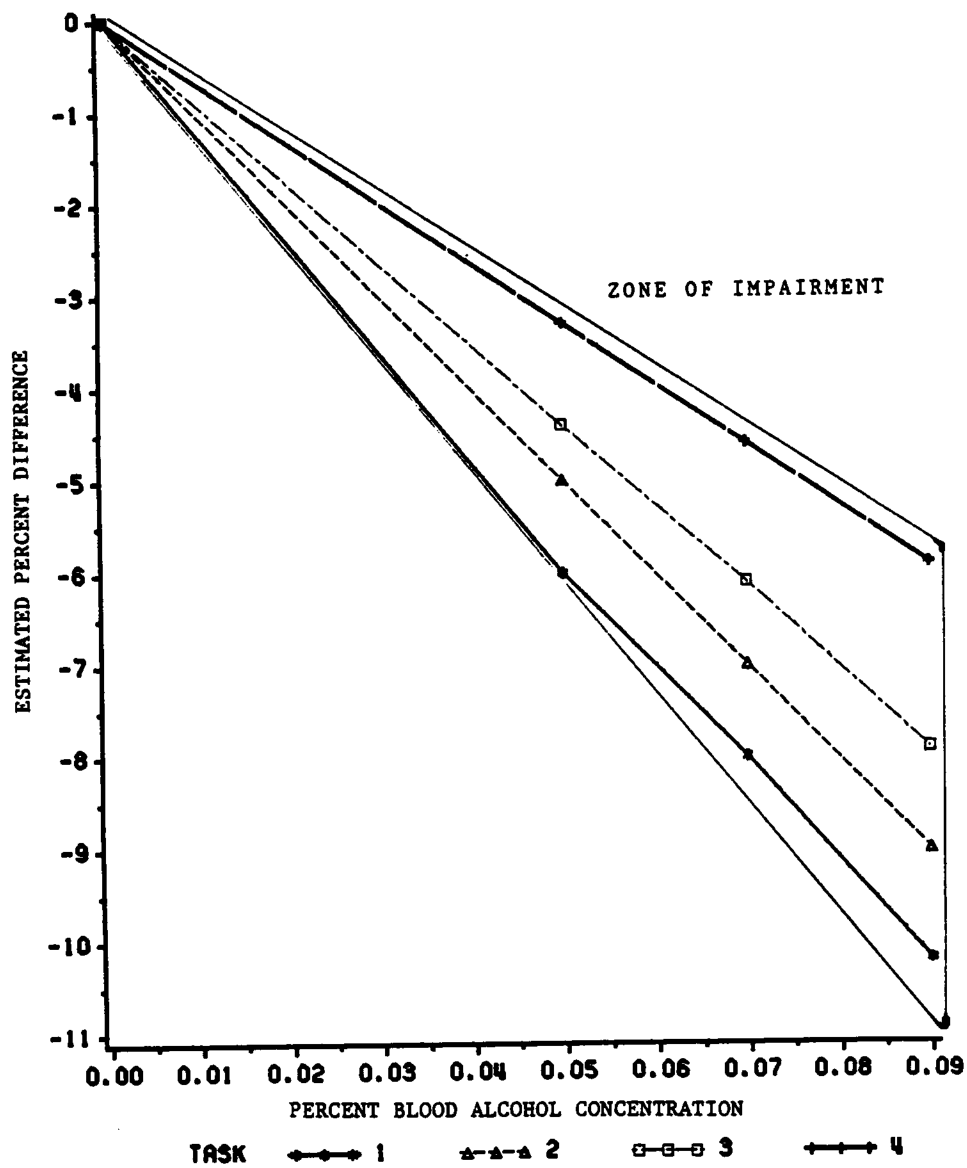


Figure 12: Performance decrements and zone of impaired performance for predicted completion time as a function of BAC.

task which dealt with each of the four behavioral processes independently, that is, time to identify the target, time to plan the path, time to verbalize the path, and time to trace the path. In this way the current research could have been compared more directly to previous studies which had been characterized with respect to their dominant behavioral domain as was shown in Figure 1.

To this end, four unique regression equations, each of which incorporated BAC, Instruction, and one behavioral domain variable, were generated. Unfortunately, the R^2 values obtained for these models -- .1612 for the model for target identification time as a high and .0228 for the verbalization model as a low -- were so small as to make their application impractical.

DISCUSSION AND CONCLUSIONS

Analyses of Variance

In examining the results of the ANOVAs given previously, one approach is to compare the obtained alcohol effects to the effects which were hypothesized for the various behavioral processes. Table 42 provides a summary of this comparison.

Examination of these effects leads to several conclusions. The first of these is that performance decrements were manifested on all of the behavioral processes as a result of alcohol ingestion. As can be seen from Table 42, for each behavioral dimension, some, if not all, of the dependent variables showed adverse effects with increasing alcohol doses. This result was expected in light of the vast amount of literature, reviewed previously, which indicates the deleterious impact alcohol has on many types of activities.

Second, the current results have implications for the relative effects of alcohol on the four behavioral processes studied herein. Using the approach discussed by Levine et al. (1973; 1975) mean percent differences were calculated

TABLE 42

Summary of Hypothesized vs Obtained Effects

Hypothesis	Obtained Result
Perception	
BAC will affect:	Hypothesis:
(1) target identification time	supported
(2) number of attempts to identify target	not supported
Mediation	
BAC will affect:	Hypothesis:
(3) pathway planning time	supported
(4) number of false paths taken in planning	not supported
(5) distance travelled in false paths	supported
Communication	
BAC will affect:	Hypothesis:
(6) time to verbalize path	not supported
(7) number of incorrect verbalizations	supported
(8) number of words produced	supported
(9) number of pauses produced	not supported
(10) proportion of pauses to words	supported

TABLE 42 (continued)

Hypothesis	Obtained Result
Motor Skills	
BAC will affect:	Hypothesis:
(11) time to trace path	not supported
(12) number of reversals during tracing	supported
(13) distance travelled in reversals	supported
(14) number of wall touches	supported
(15) time spent touching wall	supported

and plotted for each dependent variable which was significantly affected by BAC. A curve was also drawn to represent the median performance at each dosage for each behavioral process; these curves were superimposed on one another for comparison purposes and are shown subsequently. The plots for the perceptual, mediational, communications, and motor variables are given in Figures 13, 14, 15, and 16, respectively.

Of the two dependent measures concerned with perception, only one, time to identify the target, is significantly affected by alcohol. At the highest alcohol dose a statistically significant performance decrement relative to the placebo (shown as a 24% increase in completion time) was observed. Figure 13 also shows a mean percent difference increase of 2% at the 0.05% BAC and a mean percent difference decrease of 7% at the 0.07% BAC.

With the exception of number of false paths followed, all the mediational variables measured show impairment due to alcohol. For the pathway planning time measure, performance was impaired by the lowest alcohol dose but did not suffer significantly more degradation with an increase in BAC. At the 0.05% BAC, it took subjects 14.7% longer to plan the pathway than it had under the placebo condition. At the 0.09% BAC, this percentage increased only slightly to 17.7%.

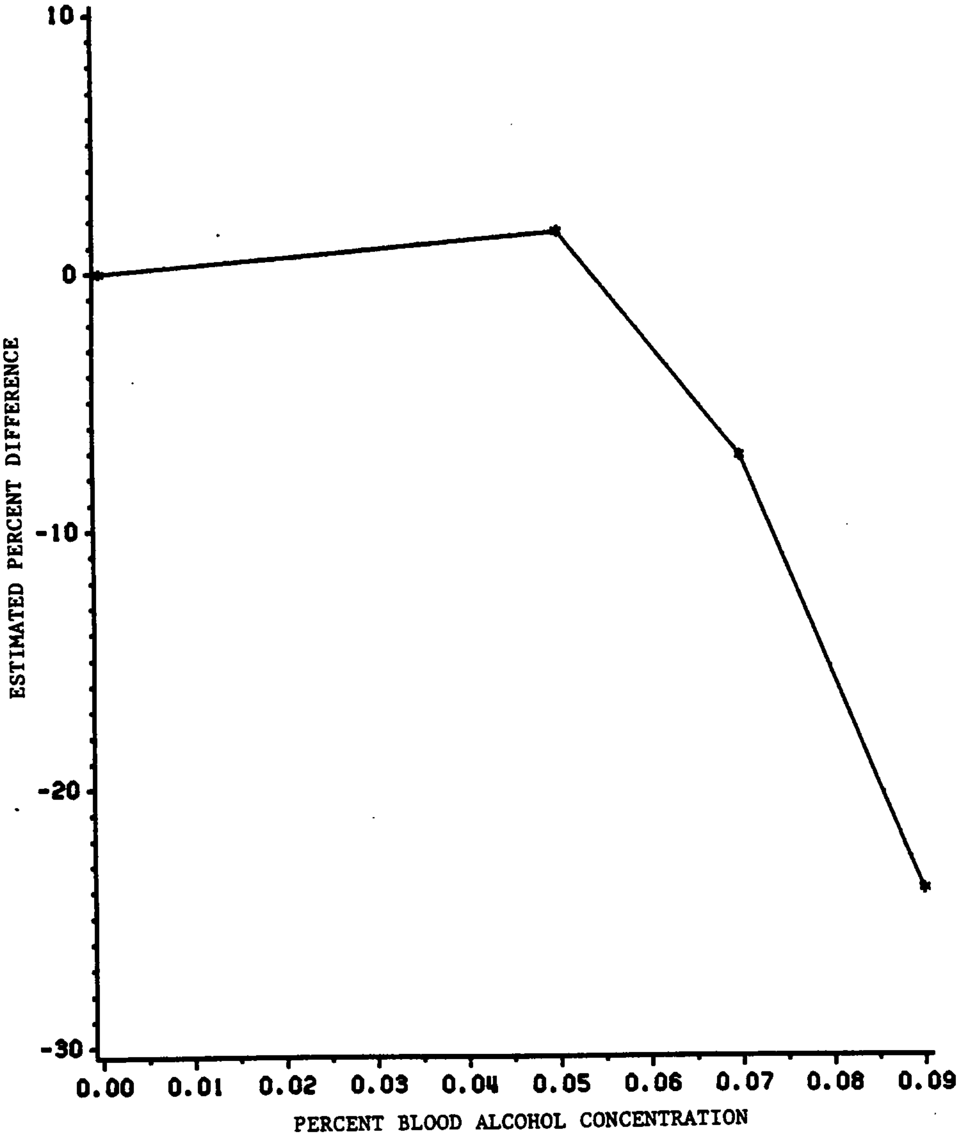
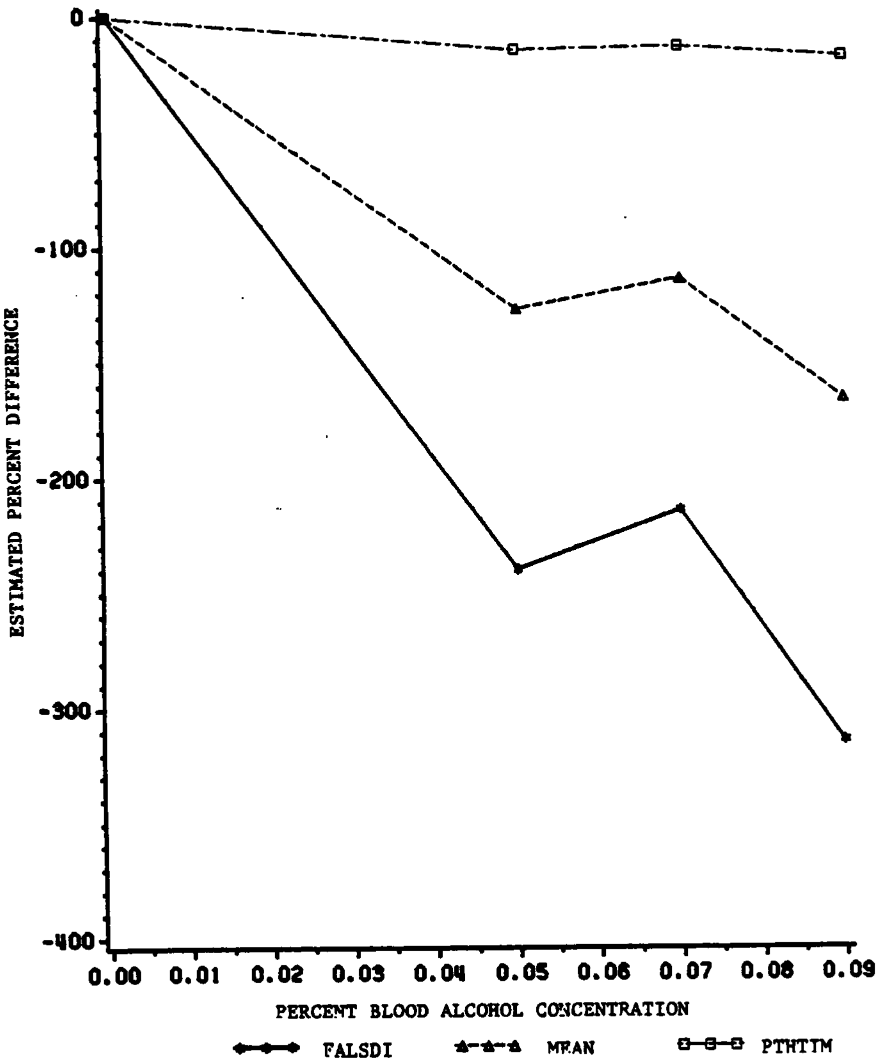
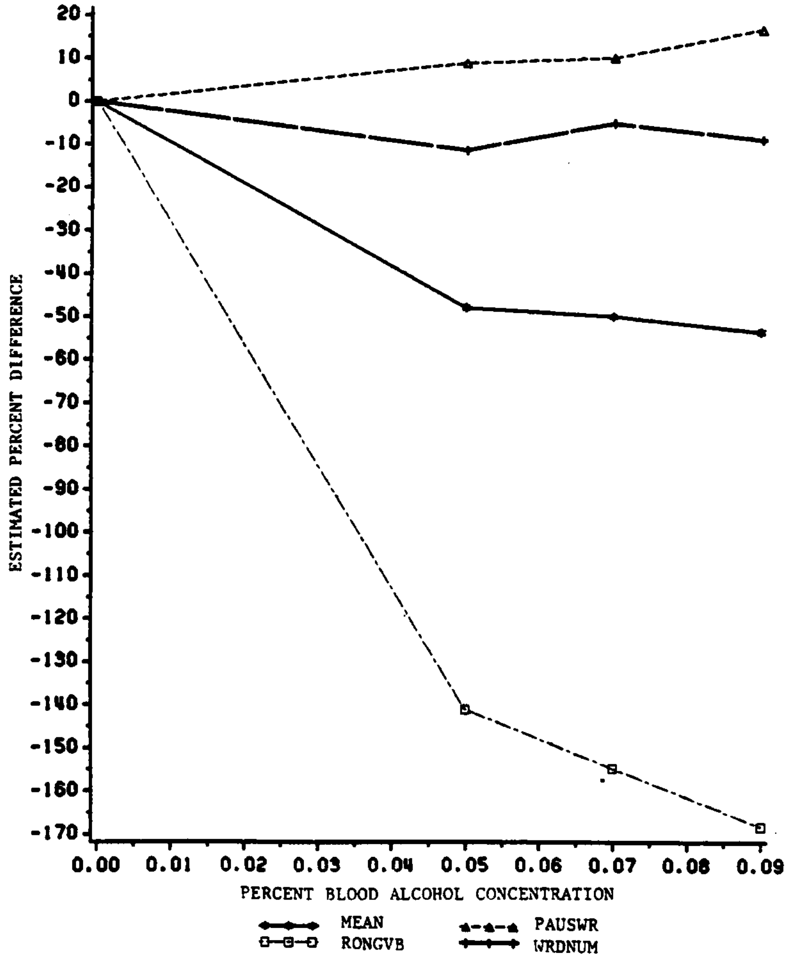


Figure 13: Mean percent difference curve for time to identify the target.



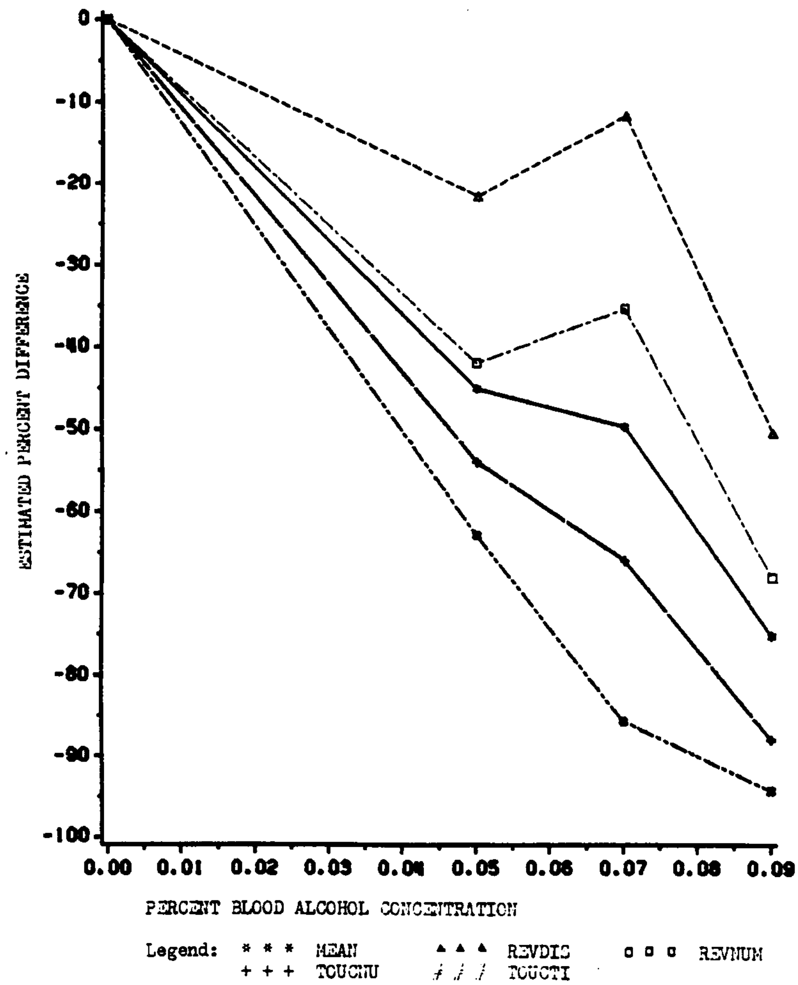
where: falsdi = mean distance travelled in false paths cm
pthtim = mean time to plan path sec
mean = mean of means.

Figure 14: Mean percent difference curve for mediational variables.



where: pauswr = mean proportion of pauses to words
rongvb = mean number of incorrect verbalizations
wrdnum = mean number of words spoken
mean = mean of means.

Figure 15: Mean percent difference curve for communication variables.



where: revdis = mean distance travelled in reversals cm
revnum = mean number of reversals
toucnu = mean number of wall touches
toucti = mean time touching walls sec
mean = mean of means.

Figure 16: Mean percent difference curve for motor variables.

For the variable concerned with the distance travelled in false paths, performance decrements were seen when alcohol was administered but there were no reliable performance differences among the alcohol conditions. Comparing mean distances within the alcohol conditions relative to the placebo, however, shows that subjects travelled twice as far in the false paths given the 0.05% BAC dose and three times farther given the 0.09% BAC dose.

As shown in Figure 14, on the average, across the mediational variables, a mean percent difference of approximately 127% was found at the 0.05% BAC, 114% at the 0.07% BAC, and 166% at the 0.09% BAC.

Three of the six communications variables, number of incorrect verbalizations, number of words produced, and proportion of pauses to words, exhibit BAC effects. For the proportion variable, increasing dosages resulted in fewer pauses in speech. This is contrary to the implications found in the literature (see the Hypotheses section) which suggest that speech hesitations would increase when subjects were given alcohol due to an increase in the time needed for thinking about what should be said. Perhaps, though, this result is an artifact of the task employed, since subjects were given the opportunity to "think through" the maze before verbalization was required. Thus, the need for new thought during the communication phase was minimized. Apparently, then, even the lowest alcohol dose served as a speech facilitator, supporting the argument that alcohol reduces inhibitions concerned with speech production.

With respect to the number of words produced, the 0.05% alcohol dose effected the greatest change in performance with 11.3% more words being spoken in that condition than in the placebo condition. More words were also spoken given the 0.07 and the 0.09% conditions than given the 0.00% condition.

The lowest alcohol dose also caused a significant performance impairment when compared to the placebo for the number of incorrect verbalizations. However, increasing BAC did not produce further degradation. Approximately one and one-half times more incorrect utterances were produced when subjects were given ethanol than when they were not.

Figure 15 shows that, overall, across the communication variables, mean percent differences of 48%, 50%, and 53% were obtained for the 0.05, 0.07, and 0.09% BAC conditions, respectively.

For the motor variables, only those concerned with accuracy of performance (number of reversals and distance travelled in reversals, and number of wall touches and time spent touching the maze wall) show impairment due to alcohol ingestion. When subjects were given the 0.09% BAC dosage, the mean number of tracking reversals increased by 68% over placebo.

For distance travelled in reversals, a significant difference in performance relative to 0.00% BAC was obtained when subjects' BACs were raised to 0.05%. This constitutes a 22% increase in distance over the distance travelled under the placebo condition. At the 0.09% BAC, this increase is 51% over the placebo.

With respect to the number of wall touches, performance significantly different from that exhibited at 0.00% BAC was first obtained with the 0.07% dose. Here, 66% more wall touches were observed under the 0.07% BAC condition than under the placebo condition. When BAC was increased to 0.09%, the number of wall touches increased by 88% relative to the placebo.

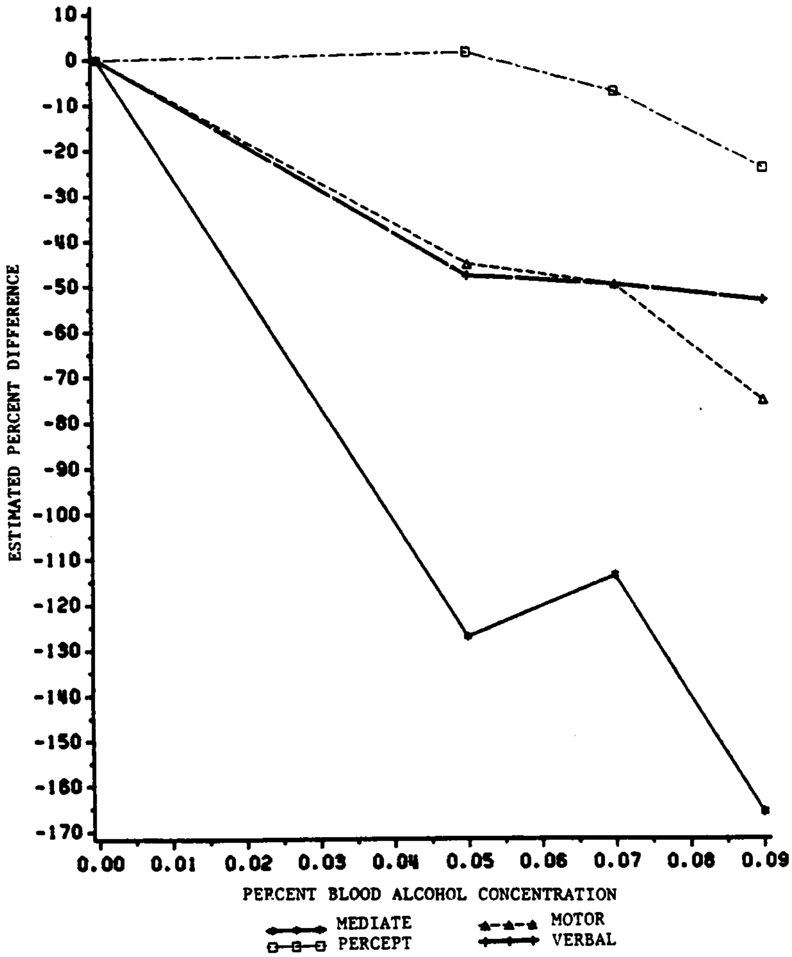
Similarly, for the time spent touching the maze wall, significant differences in performance from the placebo were not observed until the BAC of 0.07% had been administered. Subjects spent 86% longer touching the maze walls in this condition than at the placebo level. In the 0.09% BAC condition, they touched the maze walls 94% longer.

The average mean percent differences across the motor variables at each dosage level are given in Figure 16.

Approximately a 45% difference was found at the 0.05% BAC, a 50% difference at the 0.07% BAC, and a 75% difference at the 0.09% BAC.

These mean-value curves were then superimposed upon one another, as shown in Figure 17, so that the relative effects of alcohol on the four behavioral processes could be evaluated. The domains were compared with respect to three criteria: (1) the rate of performance change; (2) the magnitude of performance change; and (3) the percentage of dependent measures on which a change was effected. This author is cognizant, however, that the third of these criteria may be influenced by the fact that some processes had more associated dependent measures than others.

The curves plotted in Figure 17 suggest that, in the present study, the perceptual processes were least affected by alcohol, the verbal and motor processes moderately affected with the motor processes suffering more interruption than the verbal at the highest dosage level, and the mediational processes were greatly impaired by alcohol ingestion. These findings are in keeping with the traditional view that the "higher" behavioral processes should be more affected by alcohol than the "lower" ones; thus, intellectual functioning should be more impaired than sensory or motor functioning (Carpenter, 1962).



where: percept = perception
mediate = mediation
verbal = communication
motor = motor activity.

Figure 17: Mean percent difference curves for all behavioral processes.

When the above conclusions are compared to the general finding stated by Levine et al. (1973; 1975) concerning the differential effect of alcohol on different types of tasks, disparities are evident. Recall that, in the Levine et al. schema, psychomotor performance was found to be least impaired by alcohol, cognitive performance was said to be impaired at an intermediate level, and perceptual-sensory performance was shown to be most impaired. Note that Levine et al. did not consider performance concerned with communication. Hence, there is no basis for a comparison regarding that aspect of the current results. Eliminating the communication domain, then, the present study shows a descending hierarchy of impairment beginning with mediational processes as most impaired, followed by motor processes, then perceptual processes.

At least four differences between the two studies may be contributing to this discrepancy. In the Levine et al. (1973) paper, results of a large number of experiments were combined and overall conclusions were stated. These studies, however, differed with respect to how much time had passed between the administration of alcohol and the beginning of testing. Three conditions were present: (1) testing began within 30 min after dosing; (2) testing began from 31 to 59 min after dosing; and (3) testing began 60 min or more after dosing. When these conditions are examined independently, the relative effects of alcohol on the three behavioral processes can be shown to differ from the effects observed in the combined sample. When testing was begun within 30 min of alcohol administration, the cognitive processes were more impaired than either the psychomotor or perceptual-sensory domains; however, there was little differentiation among the processes. (This result may be due to the fact that a relatively small percentage of the reports examined used this dose-to-test interval; hence, there are few data in this condition.) Since, in the current study, testing was begun within 30 min of ingestion, it would seem more appropriate to compare the results of the present research to those stated immediately above than to those given for the complete sample.

In a similar vein, the studies categorized by Levine et al. (1973) also differed with respect to the duration of testing. Two testing periods, 59 min or less and 60 min or more, were discussed. For the shorter testing period, the greatest performance deterioration occurred on the cognitive tasks; psychomotor tasks were most resistant to impairment. Once again, when the present findings are compared to the Levine et al. condition which most closely matches the conditions of the current experiment, some of the original disparity disappears: both papers cite the greatest performance deterioration as occurring on the cognitive components.

Further, unequal numbers of studies represented each behavioral domain in the Levine et al. (1973) report. The psychomotor process was particularly underrepresented; only 16% of the research examined fell into this category. It is unclear whether this weighting difference actually had any effect on the results obtained. It is not unreasonable to speculate, though, that a more balanced sample would have revealed different relative effects of alcohol on the behavioral processes. In the present research, each of the domains was equally represented so problems which could have arisen due to weighting would not have been manifest.

Finally, in the Levine et al. (1973) study, the ability domains employed were not pure. For each experiment included in the analysis, the extent to which an ability was required for performance was determined using a seven-point scale. The dominant ability (ies) was (were) said to be that (those) on which a rating of five or more was obtained. Thus, more than one process could have been operative and the effect that this might have had on the results concerned with the comparative impairment associated with the domains is unknown. The current study was designed to maximize the purity of the behavioral components insofar as it was possible. Therefore, potential confounds such as that just described would be minimized.

In order to extract meaningful conclusions from the other independent variables, it might be most expedient to examine their effects across the dependent measures, looking for trends within the current data and for consistencies or the lack of consistencies with previous research. To facilitate this process, a summary of the main effects other than BAC and the directions of those effects is given in Table 43. Note that both sex and group have been omitted from the table since there were no main effects of either of these variables.

Sex. The lack of a significant effect on any of the dependent measures thus, contradicting the hypothesis that subject sex would affect performance (Hypothesis 17), was somewhat surprising. It had been presumed that such a main effect would be manifest, at least on the dependent variables concerned with motor processes, in light of the previous research conducted by Price et al. (1986) and Riley and Cochran (1984) where such an effect was found on manual assembly tasks. Perhaps the lack of significance on the motor phase variables stems from the nature of the task employed in the present research since, unlike the task

TABLE 43

Summary of ANOVA Main Effects

	INDEPENDENT VARIABLES		
DEPENDENT VARIABLES	Session	Instruction	Maze
Perception			
Target Ident. Time (s)	p = 0.005 longer time at first session	p = 0.587 NS	p = 0.0001 time inc. with inc. in maze difficulty
Number of Attempts to Identify Target	p = 0.282 NS	p = 0.011 more attempts under speed instruction	p = 0.001 most attempts at moderate doses
Mediation			
Pathway Planning Time (s)	p = 0.0001 longer time at first session	p = 0.001 less time under speed instruction	p = 0.0001 time inc. on 2 hardest mazes
Number of False Paths Followed	p = 0.053 NS	p = 0.786 NS	p = 0.001 highest number on 2 hardest mazes
Distance Travelled in False Paths (cm)	p = 0.048 longer time at first vs last session	p = 0.726 NS	p = 0.011 least distance in mod.-easy maze

TABLE 43 (continued)

DEPENDENT VARIABLES	INDEPENDENT VARIABLES: Session	Instruction	Maze
Communication			
Time to Verbalize Path (s)	p = 0.001 shortest time at 3rd session	p = 0.034 shorter time given speed instruction	p = 0.0001 time inc. with inc. in maze difficulty
Number of Incorrect Verbs.	p = 0.123 NS	p = 0.150 NS	p = 0.0001 highest number on 2 hardest mazes
Number of Unintelli-gible Verbs.	p = 0.460 NS	p = 0.850 NS	p = 0.538 NS
Number of Words Produced	p = 0.0001 most words at first and last sessions	p = 0.537 NS	p = 0.0001 increase with increasing difficulty
Number of Pauses Produced	p = 0.0001 least pauses at third session	p = 0.015 more pauses with accuracy instruction	p = 0.0001 increase with increasing difficulty

TABLE 43 (continued)

DEPENDENT VARIABLES	INDEPENDENT VARIABLES: Session	Instruction	Maze
Communication continued			
Proportion of Pauses to Words	p = 0.0004 larger at first and last sessions	p = 0.022 larger given accuracy instruction	p = 0.0001 larger given two hardest mazes
Motor			
Time to Trace Path (s)	p = 0.0001 longest at first and last sessions	p = 0.0001 longer time with accuracy instruction	p = 0.0001 increase with increasing difficulty
Number of Tracking Reversals	p = 0.233 NS	p = 0.862 NS	p = 0.546 NS
Distance in Reversals (cm)	p = 0.165 NS	p = 0.391 NS	p = 0.620 NS
Number of Wall Touches	p = 0.109 NS	p = 0.136 NS	p = 0.0001 more touches on 2 hardest mazes

TABLE 43 (continued)

DEPENDENT VARIABLES	INDEPENDENT VARIABLES		
	Session	Instruction	Maze
Motor continued			
Time Touching Walls (s)	p = 0.022 longest time at first session	p = 0.088 NS	p = 0.0001 more time for 2 hardest mazes
Total Time to Complete Task (s)	p = 0.0001 longest time at first session	p = 0.0001 longer time with accuracy instruction	p = 0.0001 increase with increasing difficulty

explored in the previous experiments, it did not require a great deal of fine manipulative control (especially finger dexterity) which would put those subjects with larger hands, who would usually be males, at a disadvantage. It could be argued, then, that the apparent performance differences found by previous authors were a function of a physical difference (dimension of the hand) which happens to correlate highly with sex rather than a true gender-based performance difference.

Further, even though Riley and Cochran (1984) found males to be superior to females in their performance on a task which involved gross motor activity (and, thus, would be more similar to the task presently being studied), this result was attributed to a cultural advantage in knowledge regarding tool use. As no tools were employed in the present experiment, perhaps the current results give veracity to this interpretation. If so, the fact that no gender differences were observed can be explained within this framework (i.e., that there are gender differences only in gross motor activities which involve the use of hand tools).

Perhaps, then, the lack of performance differences on the current motor task is not as unreasonable as it first appeared.

Finally, the results of the current study are in agreement with the findings reported by Shoptaugh and Whitaker (1984) in which there was no gender effect on the response time needed to find and verbally identify an embedded target stimulus. Note that this task was similar to the target identification task currently employed.

Previously, the lack of reports of performance differences between men and women was noted. It is unclear, however, why information regarding performance differences is not found in the literature (Hahn, 1984). Two reasons have been propounded: (1) lack of testing for gender-based differences such that true dissimilarities in performance between males and females are not detected, and (2) lack of reporting of results when sex-based differences in job-related performance fail to be supported. Since reasons why gender effects are not mentioned in a given piece of research are generally not stated by the investigators, a question remains as to whether gender-related performance differences exist. If the second of the arguments given above is the correct one, the results of the current study are not surprising at all. And, the answer to the question regarding performance differences would be an emphatic "No"!

In truth, though, this author suspects that there is a degree of veracity in each of the above statements. For this reason, it is important for future researchers to conduct sex analyses, if possible, and to report results regardless of outcome. If it is not possible to conduct sex analyses, their omission should be explained (Hahn, 1984). Only in this way will a conclusive body of literature regarding gender effects in alcohol and other research be accumulated.

Group. The lack of a significant main effect for this variable was expected since the group variable was employed only for assignment to experimental conditions with subjects placed in groups randomly.

Session. The presence of a session effect on more than half of the dependent measures was somewhat surprising since subjects had been given training prior to the experiment in order to reduce practice effects. The pattern of the obtained session effect does not, however, conform to that which would be expected if a practice effect was operative.

On some of the dependent measures, the session effect was manifested as performance impairment at only the first session, suggesting an adaptation to the actual experimental conditions.

On other measures, a trend that seemed to be consistent with a practice effect appeared at the first three sessions: performance improved (but not always by a statistically significant amount) with each subsequent session. At the fourth session, however, performance returned to the level exhibited at the first session. Obviously, this result is inconsistent with practice effects.

The fact that the session effect is not explainable as a learning effect may stem from the fact that session is confounded with the BAC x Maze interaction due to the use of the Latin Square design. Hence, the obtained main effect may, in fact, indicate that an interaction is occurring.

Maze. As discussed previously, the mazes had been designed such that each had a unique overall difficulty rating. The efficacy of this manipulation was demonstrated by the results obtained with respect to the total time to complete the task, the only global dependent measure employed. The time to complete the task increased with each increase in task difficulty, as would be expected. Thus, it was confirmed that four distinct levels of maze difficulty had been achieved.

Generally speaking, increasing maze difficulty also produced increasing completion times and errors on the dependent variables associated with the individual behavioral processes. In many cases, the results indicate significant differences for only some combination of the four mazes (i.e., the two mazes given the lowest difficulty ratings vs the two mazes given the highest difficulty ratings) rather than among all four mazes. Given that maze difficulty assignments were concerned with the task as a whole rather than with each behavioral process, this is not a matter of concern.

Instruction. Testing of this independent measure was originally viewed primarily as a manipulation check; however, contrary to the hypothesis that the two conditions would produce different performance (Hypothesis 16), statistically significant variations in performance were not found for all dependent measures. The pattern of significant results is quite interesting.

The instruction manipulation was most effective on those dependent measures which intrinsically stressed the time dimension. Obviously, pathway planning time, verbalization time, pathway tracing time, and the total task completion time are temporally oriented. In each case, longer times were recorded when subjects were given the accuracy instruction than when they were given the speed instruction, as would be expected.

Significance due to instruction conditions was also obtained on the two dependent measures which were concerned with pauses in speech. These variables are not clearly exclusively speed- or accuracy-oriented. However, the exhibition of fewer pauses under speed instructions than under accuracy instructions implies that subjects may have sensed a time stress with respect to the verbalization task.

Indeed, instruction was found to be significant with respect to all the temporally oriented dependent measures except one, namely, time to identify the target. Overtly, this variable seems to stress only the time dimension. It is plausible, though, that this measure actually has a strong, but covert, inherent accuracy stress since subjects had been told that they would not be permitted to continue with the experiment until this step had been completed successfully. The implication, then, was that the target identification task must be completed accurately and would be repeated, regardless of the time consumed, until this occurred.

The conclusion drawn from the above results is that whether an instruction is effective is based on the inherent characteristics of the task being performed. Specifically, the perception on the part of the subject that there is a time stress which is intrinsic to the job being performed serves to increase the salience of an instruction which emphasizes speed.

Further, it seems that this conclusion holds regardless of the behavioral dimension being tested. Of course, more research is needed with respect to the perceptual process since no purely time-oriented dependent measure was employed in the current study.

On the surface, these conclusions seem to be contradicted by the results found by Price et al. (1986) in which instructions for speed vs accuracy produced differential performance on some dependent variables which appear to be focused on accuracy (e.g., meter adjustment errors). The argument could be made, though, that there was a speed-stress inherent in the task since subjects were given trials of short duration (only two min). Viewed in this light, these results may be consistent with the conclusions stated above.

Interestingly, an examination of the data from the Jennings et al. (1976) study (see Wood and Jennings, 1976) also shows no contradiction to the above interpretation. Wood and Jennings noted that accuracy depended upon the speed-emphasis condition in which a given trial occurred. Accuracy was impaired in the short deadline (225 ms) or speed-stressed condition relative to the long deadline (275 ms) or accuracy-stressed condition even when the actual observed reaction times were the same across conditions. Thus, when actual response time was held constant such that effects of speed of performance were not present, accuracy was degraded by an inherent speed-stress within the task.

Relationship between BAC and temporal task characteristics. The apparent relationship between temporal task characteristics and instruction efficacy led to the question of whether a similar relationship might hold with respect to BAC and temporal aspects of the task. Thus, the percent mean difference approach was also applied in examining the relative effects of alcohol on the speed-stressed vs the accuracy-stressed dependent variables across behavioral domains.

Percent mean differences were plotted for those dependent measures for which a significant effect of BAC was obtained and for which a clear-cut speed or accuracy assignment could be made. The speed-stressed variables included were target identification time, pathway planning time, the total time to complete the task, and the mean of these three variables. Only 60% of the variables which emphasized speed of performance were significantly affected by alcohol ingestion. The accuracy-stressed variables included were number of distance travelled in false paths, number of incorrect verbalizations, number of tracking reversals, distance in reversals, number of wall touches, time touching the walls, and the mean of the accuracy variables. Significance due to BAC was found on 75% of the variables which emphasized accuracy.

The same three criteria employed in judging the relative impact of alcohol on the behavioral domains were used here.

Figure 18 shows that those measures which stressed accuracy of performance were more impaired by alcohol than were those measures which stressed speed of performance.

The bulk of the literature supports this observation. In their summary of the effects of alcohol on the sensory and motor processes, Wallgren and Barry (1970) stated that "alcohol appears to have a greater effect on accuracy and on variability than on average response speed" (p. 316). Rundell and Williams' (1977) results showed greater impairment of accuracy of response than speed of response on an auditory pitch discrimination task. Jellinek and McFarland (1940), reporting on alcohol effects on a typing task, noted that alcohol produced a large increase in typewriting errors and only a slight decrease in speed.

Both Levine et al. (1973) and Wallgren and Barry (1970) also noted that alcohol impairs accuracy more than speed with respect to complex intellectual functions. This result was demonstrated in several studies concerned with mathematical manipulations (see Wallgren and Barry for a complete review). Davis et al. (1941) found a large increase in addition errors under alcohol conditions but no

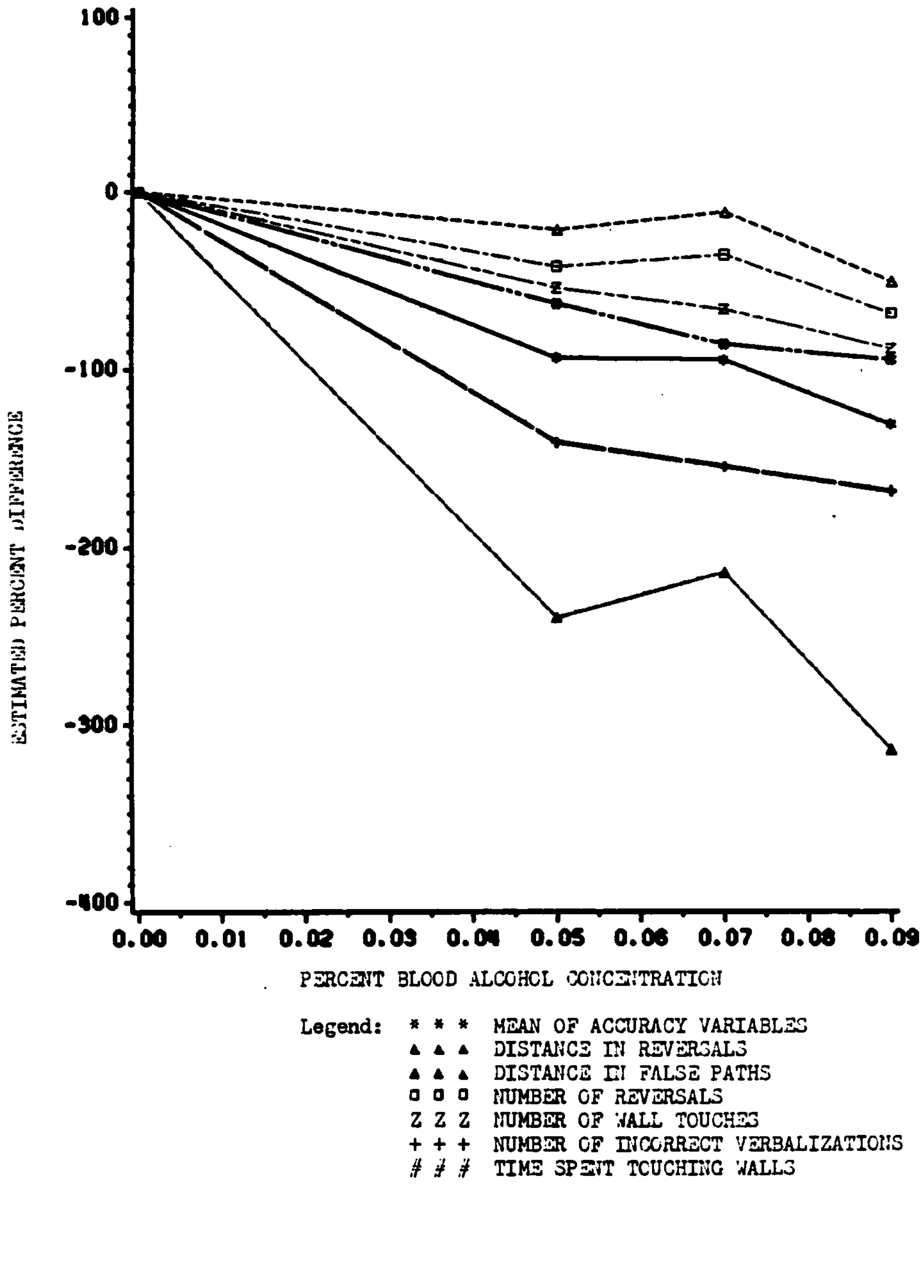


Figure 18: Mean percent difference curves for speed-stressed vs accuracy-stressed dependent measures: (A) speed.

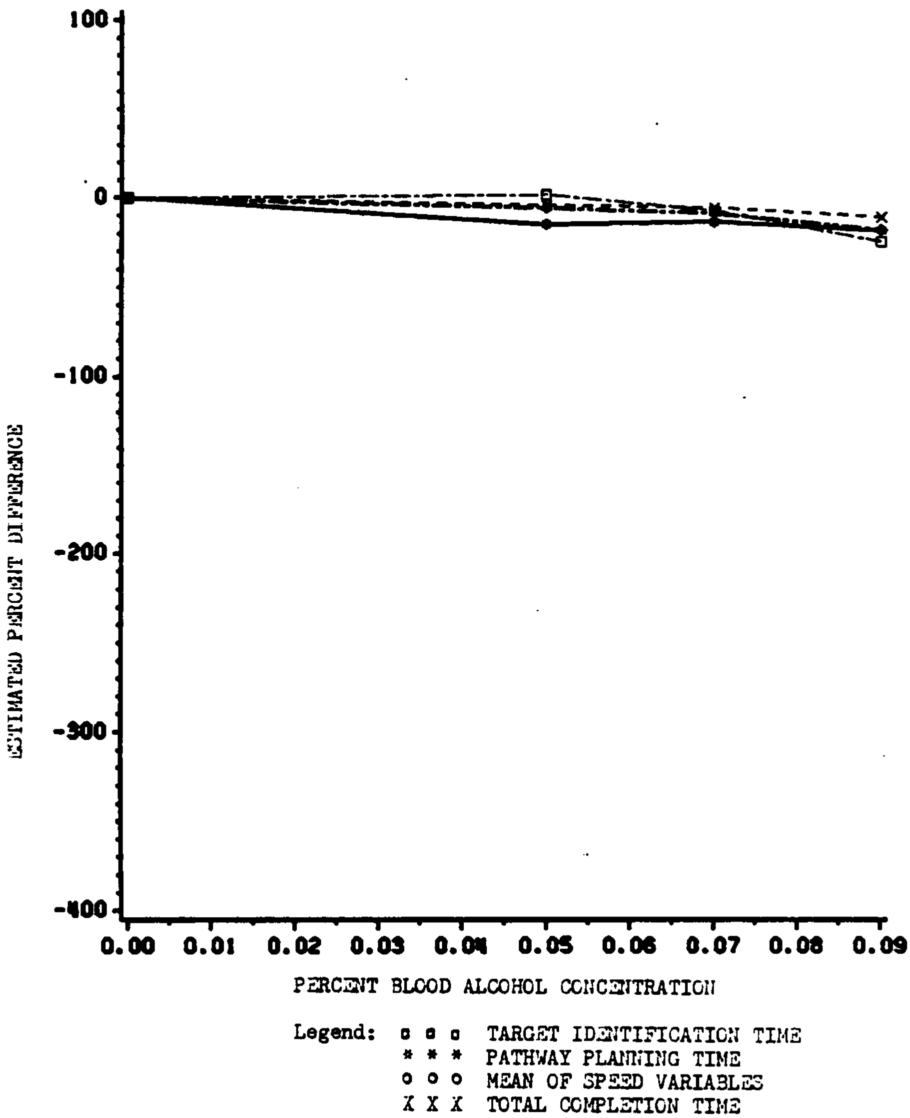


Figure 18 continued: (B) accuracy.

consistent change in the number of computations performed. Frankenhauser et al. (1962) also found that alcohol had a greater detrimental effect on accuracy than on speed in a multiplication task.

Price (1985) indicated that industrial losses due to employees working after ingesting alcohol "can be expected to be as much as 40% loss in productivity and six times more errors in quality of workmanship, at levels less than 0.09% BAC" (p. 20).

Several of the possible interactions were of interest. Since, in a previous experiment (Price et al., 1985), Sex x BAC, Sex x Instruction, and BAC x Instruction were all found to be significant, an examination of these three interaction terms was thought to be warranted.

Sex x BAC. The results of the Price et al. (1986) study led to the expectation that there would be a significant interaction of sex and BAC with females showing greater impairment due to alcohol than males on both the dependent variables concerned with speed (i.e., the timed variables) and those concerned with accuracy (i.e, the error measures) across the four behavioral processes. In general, this is not the case. No Sex x BAC interactions were found for any of the speed-oriented dependent measures and a Sex x BAC interaction was found on only one of the accuracy-oriented dependent measures, specifically on the number of incorrect verbalizations. In this case, the direction of the effect was consistent with the previous research -- females showed greater impairment, manifested in more verbalization errors at the highest alcohol dosage, than did males.

In drawing an overall conclusion, however, one would have to state that the performance of females was no more affected by alcohol than was the performance of males on the task at hand. The reasons for the contradiction between the current results and the findings of the earlier study might be simply explained. In the Price et al. (1986) study, performance of the males was poor relative to that of the females even under no-alcohol conditions for the reasons concerned with fine manipulation cited previously. Thus, the possible range over which degradation could occur under alcohol conditions was much wider for female subjects than for male subjects. Hence, the observation that female subjects showed greater impairment than male subjects may be partially or fully attributed to the fact that more impairment was possible for the females. In the current research, such is not the case since baseline performance between the two groups did not differ significantly.

Sex x Instruction. Price et al. (1986) also found a significant Gender x Instruction interaction, which was largely lacking in the present results. In the current study, this interaction was found to be significant for only 4 of the 17 dependent variables: number of attempts to identify the target, time to verbalize the pathway, number of words produced, and total time to complete the task.

On the perceptual variable, the interaction is in the direction opposite to the effect found by Price et al. (1986). In the present study males were more responsive to instruction conditions than were females. For the males, fewer attempts were required to correctly identify the target under the accuracy condition than under the speed condition, as would be expected. For the females, there was no difference in the requisite number of attempts due to the two instructions.

On the two communications variables, however, the interaction is consistent with that observed in the previous study (Price et al., 1986). Females verbalized the pathway in a shorter time under speed conditions than under accuracy conditions while male verbalization time was invariant across instruction conditions. With respect to the number of words produced, female performance is consistent with expectation with fewer words being produced when the subject experienced speed stress.

Again, though, the weight of evidence found in the present results does not lead to a summary conclusion that one gender group was more affected by instruction conditions than the other.

BAC x Instruction. Price et al. (1986) found a significant alcohol by instruction interaction such that subjects operating under a speed incentive showed greater impairment due to alcohol than those working under an accuracy incentive. In the present experiment, BAC x Instruction effects were found only in the communications phase where significance was obtained on two variables: number of incorrect verbalizations and number of words produced. Here, however, a different interpretation than that used by Price et al. must be applied. In each case, instructions were effective only when subjects were given the 0.05% BAC dosage.

BAC x Maze. A Latin Square design was used to assign treatment conditions in the current study because of its advantages with respect to considerations such as efficiency, cost, and potential for attrition of subjects. This strategy, however, precluded a statistical analysis of a BAC x Maze interaction since, in the Latin Square configuration, this interaction is confounded with session effects.

The literature suggests, though, that interaction between task demands and alcohol exist. Two forms of interaction have been discussed. First, it is possible that an increase in BAC combined with a high complexity task would serve to reduce subjects' motivation levels such that they would not persevere in the task. As discussed by Fitts and Posner (1968), this is one way of dealing with stress (task demand) overload. Shorter completion times would be expected but would not imply superior performance since they would be expected to be coupled with larger error rates.

Another possibility is that an increase in BAC would serve to reduce subjects' inhibitions or nervousness, as suggested by Carpenter (1962), such that they would be able to perform the task more quickly and more accurately in spite of high task complexity.

This past research suggested that an investigation of the BAC x Maze effect was important. Hence, for each dependent measure, the data were graphed to show BAC effects separately for each maze. Those graphs which were most interpretable are contained in Appendix L.

Generally speaking, interpretable alcohol trends only became manifest when the more difficult mazes were presented. The direction of these trends, however, differed across the dependent variables. Further, for virtually every dependent measure for which an interpretable graph was obtained, the pattern of the means is different on the moderate-high difficulty maze than on the high difficulty maze.

In looking at the perceptual variables, we see that, on the moderately high difficulty maze, there is facilitation, at least through the intermediate doses, on both dependent measures. For the number of attempts to identify the target, performance did not approach placebo levels even at the 0.09% BAC dosage. On the high difficulty maze, both measures suffered impairment at the 0.05 and 0.07% BACs but were returned to placebo levels at the 0.09% BAC. These patterns seem to argue for a reduction in inhibition explanation: on the easier maze, inhibitions may have been decreased by moderate alcohol doses producing superior performance relative to the placebo; on the more difficult maze, the increase in difficulty may have constituted an additional stress such that only the highest alcohol level reduced tension sufficiently to facilitate performance.

For the mediational variables, an interpretable graph is available only for time to trace the path. Here, on the moderate-high difficulty maze, alcohol effects are as expected: planning time increased with each increase in dose. On the high difficulty maze, however, planning time increased, relative to the placebo, at the 0.05% BAC but began to decline with each subsequent increase in dose. Without data for the error-related mediational variables, however, it is difficult to categorize this process with respect to its fit with either the reduction of motivation or the reduction of inhibition hypothesis.

For the communication variables, a reduction in motivation due to the combined stresses of intoxication and task difficulty may have been operative. On the moderate-high difficulty maze, time to verbalize seemed to be impaired (a longer time was taken) and the number of pauses exhibited was increased relative to placebo under the 0.09% BAC. On the high difficulty maze, this effect is reversed -- increasing alcohol doses resulted in fewer pauses and shorter verbalization times. But, the number of incorrect verbalizations increased once alcohol was administered. Thus, subjects were seemingly less able to think before verbalizing (which would increase the number of pauses) and to speak precisely (which would increase the number of errors) in the high complexity/high dose condition.

With respect to the motor variables, most show typical BAC effects at the moderate-high maze difficulty level: increasing times and errors given high alcohol doses. On the high difficulty maze, however, travel time was increased at moderate alcohol doses but facilitated by the 0.09% BAC level. Both distance travelled in reversals and time spent touching the maze walls were similarly affected. Hence, a reduction of inhibition mechanism may have been operative.

In the interests of parsimony, it would have been convenient had the behavioral processes appeared to be mediated by the same mechanism. If one considers, however, that the various behavioral processes have different tolerances for stress and that the "lower" processes are particularly unaffected by stressors, such as alcohol, which are irrelevant to the task (Fitts and Posner, 1968), the fact that the results with respect to the various processes differed may not be surprising. Indeed, the pattern of observations is consistent with the literature.

Regression Analyses

In spite of the somewhat low R^2s, the regression equations given in the Results section seem to produce results which are in keeping with those reported by previous researchers. This congruence can be seen by comparing Figure 12 to Figures 2 (from Levine et al., 1973) and 3 (from Price, 1985). In all these figures, performance declines and the zone of impaired performance widens with increasing BACs. Note, however, that the zone drawn from the predictions yielded by the regression equations is more conservative than that obtained experimentally either in previous research or in the current study (see Figure 17). Users of the equation, then, should be careful to note that the predicted impairment and its associated costs are minimums so that the practical significance of the results is not underestimated.

Several factors probably contributed to the low R^2s. These factors primarily revolve around the issue of subject variability. Circumstances which may have enhanced this variability were present in the current experiment. First, it seems plausible to suggest that intra-subject variability would increase with alcohol administration. Also, the fact that the task at hand was "phased" such that it required subjects to switch from one type of activity to another quite rapidly may also have increased within-subject variability since participants were not given the opportunity to "settle in" to the task. These factors would tend to increase the spread of the data points to which the regression line was being fit, hence reducing R^2.

Use of the equations. In order to obtain valid predictions using the equations given herein, constraints associated with the formulae must be observed.

Specifically, the equations must not be used as predictors for tasks with parameters which are widely different from those which were present on the developmental task. First, since the equations do not employ the gender variable, they may produce erroneous results on a task where sex effects are likely to be observed, for example, on a task where fine manipulative control is important.

Second, while the equations do predict continued impairment with increasing BACs, the predictions for BACs greater than 0.09% are not data based since, in the current study, the highest BAC administered was 0.09%. Readers wishing to estimate performance at BACs greater than 0.09% should do so with caution.

Third, it should be noted that the current task was one which was completed in a relatively short time (approximately 30 s to 1 min of actual task-oriented activity). Consequently, the completion times predicted by the equations are on the order of seconds and might not be appropriate for jobs of longer duration. Potential users can check the adequacy of the equations for their application by employing them with BAC equal to zero and comparing the predicted completion time to the observed or otherwise estimated actual completion time.

Given that the equations are suitable for the desired application, the user must then determine appropriate values for BAC, instruction, and the behavioral process variables. An hypothesized blood alcohol concentration value (i.e., 0.09%) can be employed directly by entering it into the equation.

Next, it must be decided whether the task of interest places more emphasis on speed or accuracy of performance. If the job is speed-intensive, a value of "1" should be used for instruction; if the job is accuracy-intensive, a value of "2" should be used.

Finally, the job must be rated with respect to the contribution of each behavioral process to its successful completion using the same method as was employed in obtaining the values used in developing the equations. First, a group of "expert" raters must be identified. Expert status should be related to the potential raters' ability to identify the specific behaviors listed by Berliner et al. (1964) as belonging to particular behavioral processes. A Q-sort type of exercise should be employed, as described in the Method section. Further, the raters should be job knowledge experts (preferred) or should be given familiarization training on the job being evaluated. Ideally, 10 qualified raters would be available as was the case in the developmental study. Personnel and financial constraints might argue for using fewer raters; however, to help ensure dependable results, a single rater should not be employed.

Raters should be asked to perform the job, if possible, then to assess the importance of each behavioral process represented to successful task completion on the seven-point scale given in Appendix G.

The obtained ratings must then be transformed to ranks for use in the equations. For each behavioral process, the ratings must be arranged, in order, from lowest to highest, then ranked. If there is a tie in the ratings, each member of the tied group must be given the average of the rankings which would otherwise be assigned. For example, if two raters gave a rating of "4" and the appropriate ranks would be "4" and "5", respectively, each rating would be given a rank of "4.5". The average of the ranks should be taken as the value to be used in the equation. These steps should be repeated independently for each behavioral process.

The decision regarding which equation to use is easily made: the equation which omits the behavioral process for which the lowest average ranking was obtained should be employed. This behavioral process should be discarded from the analysis and the obtained average ranks for the remaining three processes should be substituted into the appropriate formula.

To see the expected impairment of workers who have ingested alcohol, the percent mean difference approach can be used. First, the equation should be used to predict completion time given a BAC of 0.00%. Then, the completion time given the hypothesized BAC should be predicted. The percentage by which completion time could be expected to increase if employees were working under the influence of alcohol can be calculated by subtracting the value obtained for the no-alcohol case from that obtained for the alcohol case, dividing by the no-alcohol value, and multiplying by 100%.

RECOMMENDATIONS

There are several limitations to the present study which might be addressed in future research. These include time factors related to the drink-to-test interval and the test interval itself, BAC levels, dosing procedures, population factors, the serial nature of the task, cross-validation of the regressions, expansion of the scope of the regressions, and exploration of the BAC x Maze interaction. Each of these issues is addressed in turn.

Time Factor Considerations

The importance of considering time dimensions is suggested by the work of Levine et al. (1973) in which it was shown that both the time between alcohol ingestion and testing and the duration of the test period affect the influence of alcohol on the behavioral processes.

Both a short ingestion-to-testing period and a short actual testing period were used herein to facilitate rigorous experimental control. In the real world, however, both these periods could reasonably be expected to be of longer duration. It is important, then, to also study the effects of alcohol on the behavioral processes under these types of circumstances while allowing for adequate control. Namely, a comparison within a single study with the ingestion-to-testing interval and the testing interval systematically varied and with all the behavioral processes represented is needed.

This issue should also be recognized by anyone using the regression equations given previously as their reliability (stability) for situations with widely differing time parameters is unknown. And, time parameters should be a subject of future study.

<u>BAC Level Considerations</u>

In the current study, relatively low BACs were employed. This approach was adopted primarily to safeguard the subjects' well-being. In addition, it was thought that employees who reported to work while under the influence of alcohol would not be likely to have greatly elevated BACs since the risk of detection would be increased. However, it is not impossible that BACs higher than 0.09% might be attained. Conceivably, some workers could avoid detection until the point of incapacitation.

Thus, it might be of importance to determine whether or not the results found herein continue to hold at higher

BACs. Specifically, this question must be answered with respect to the relative effects of alcohol on the behavioral processes and the fit and predictive capability of the regressions.

Dosing Procedure Considerations

A problem which is related to the two areas mentioned above is that concerned with whether alcohol is administered in a single dose or in multiple doses over time to attain or maintain a BAC. In the present experiment, the first of these procedures was adopted. Again, concern over experimental control prompted this choice; however, the alternative possibility is also likely to occur in real-world settings.

It is important, then, to evaluate performance effects due to "maintenance" doses as compared to single doses. One would expect performance effects to persist longer under multiple doses than under single doses since alcohol would be present in the system for a longer time. Further, the pattern of effects might differ since there would be a fluctuation of higher and lower BACs given multiple doses that would not be present in the single dose case. Here, BAC would be expected to ascend, peak, and descend. Comparisons would have to be made at several points across time to assess adequately the interaction between type of dose and time. Problems arise, however, in that, after administration of the second dose to the multiple dose group, subjects in each condition would no longer be at the same BAC.

Population Considerations

The population sampled in the present paper consisted wholly of moderate drinkers. In some respects, this group does not represent a chronic problem to industry. While moderate drinkers may sometimes appear at work under the influence of alcohol, this is not likely to be a common occurrence for any individual. And, although there are costs associated with the moderate drinkers' working after imbibing, a more serious problem, dollar-wise, exists in the case of the alcohol-dependent employee. Since alcoholism is so widespread in our society, this issue must be addressed.

It is important to determine how performance in the various behavioral domains is affected by alcohol for the alcoholic subject as the relationships found for moderate drinkers may not be applicable.

Further, performance effects must be examined with respect to the length of time that subjects have been in the alcoholic state as tolerances to alcohol can be built up and can mediate alcohol's effects.

Task Considerations

In the current experiment, it was desirable to isolate, insofar as possible, the four behavioral processes. Hence, the task employed was serial in nature such that the subject moved from a phase which stressed one process to another phase with a different emphasis. While there are serial tasks in real-world settings, more commonly multiple processes are involved and task performance depends upon time sharing.

It seems unlikely that this aspect of the present study influenced the relative effects of alcohol on the behavioral processes as these findings are generally in agreement with those observed by Levine et al. (1973) when less contrived tasks were employed.

As discussed previously, however, the nature of the task may have had an impact on the regression equations developed. Thus, these equations must be cross-validated using data obtained from more typical industrial tasks.

Cross-Validation of the Regressions

Even aside from the task-related considerations, cross-validation of the regression equations is recommended to ensure that the formulae are useful in predictions on actual industrial tasks.

In conducting such cross validations, the same cautions which were expressed for users of the equations must be applied. Specifically, cross-validation is only appropriate if the problem addressed has similar parameters (i.e., gender not of importance, BACs not exceeding 0.09%, short duration of test) as were involved in the development of the equations.

<u>Expansion of Scope of the Regressions</u>

Obviously, not all industrial tasks have the same parameters as were employed herein. The current exercise, however, was meant to evaluate the viability of the regression approach rather than to provide universally applicable equations. Viability was demonstrated. Hence, it would be useful first to determine how far the parameter limits can be exceeded before prediction breaks down. Then the regression approach can be applied to develop equations for problems whose parameters exceed those limits.

<u>Exploration of BAC x Task Difficulty Interaction</u>

Because a Latin Square design was employed in the present study, a statistical analysis of the BAC x Maze interaction was not appropriate. However, both the literature and graphs of the current BAC/Maze data suggest that interactions between task demands and alcohol exist.

Future researchers should attempt a statistical analysis of the BAC x Task Difficulty interaction, by using an experimental protocol, such as a full factorial design, which would allow exploration of such an effect. All behavioral processes would need to be represented in such a study to test the possibility that the "lower" and "higher" processes are governed by different mechanisms. This type of research would make a significant contribution to the literature.

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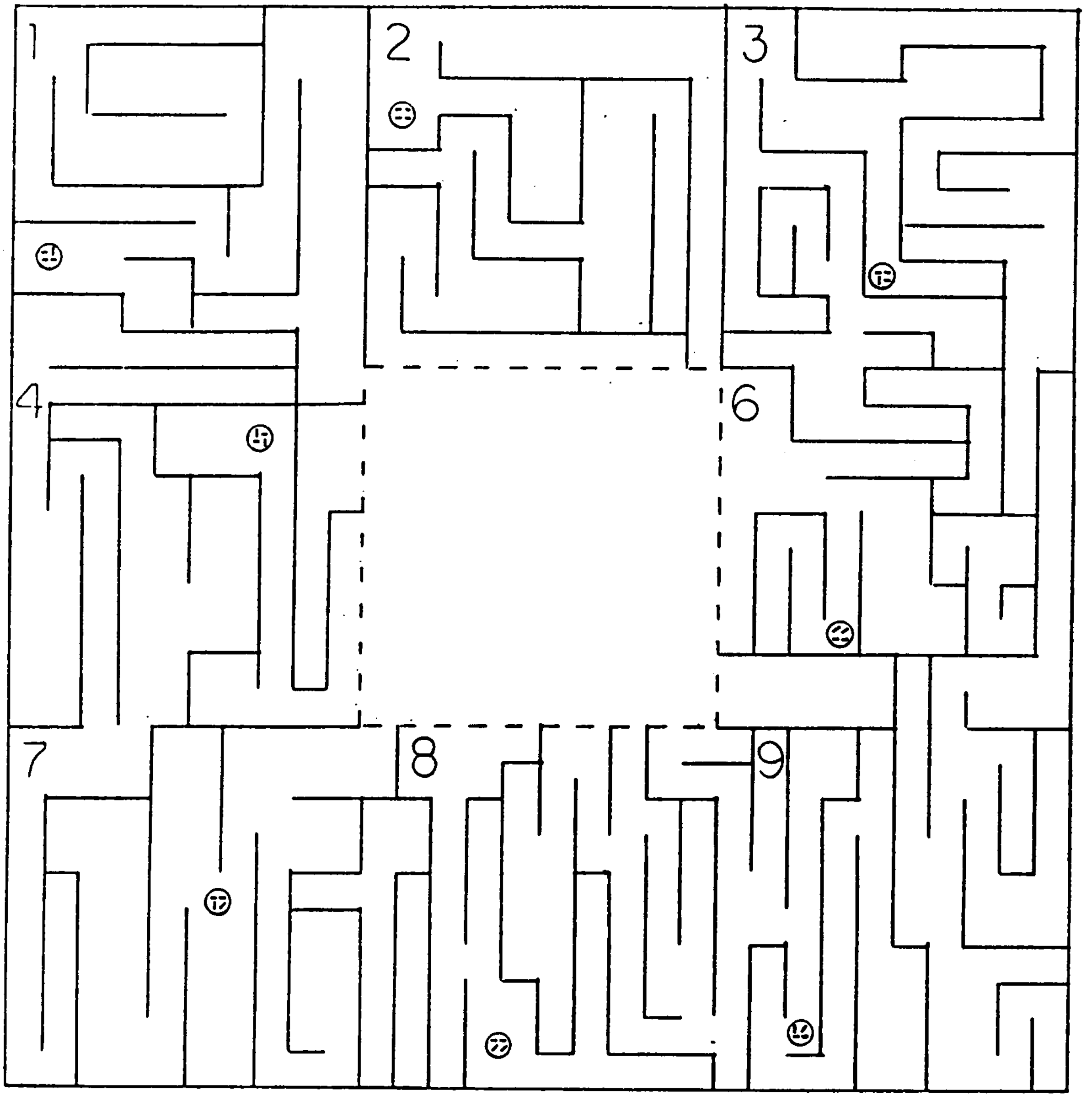
APPENDIX A: SAMPLE STIMULUS SEQUENCE

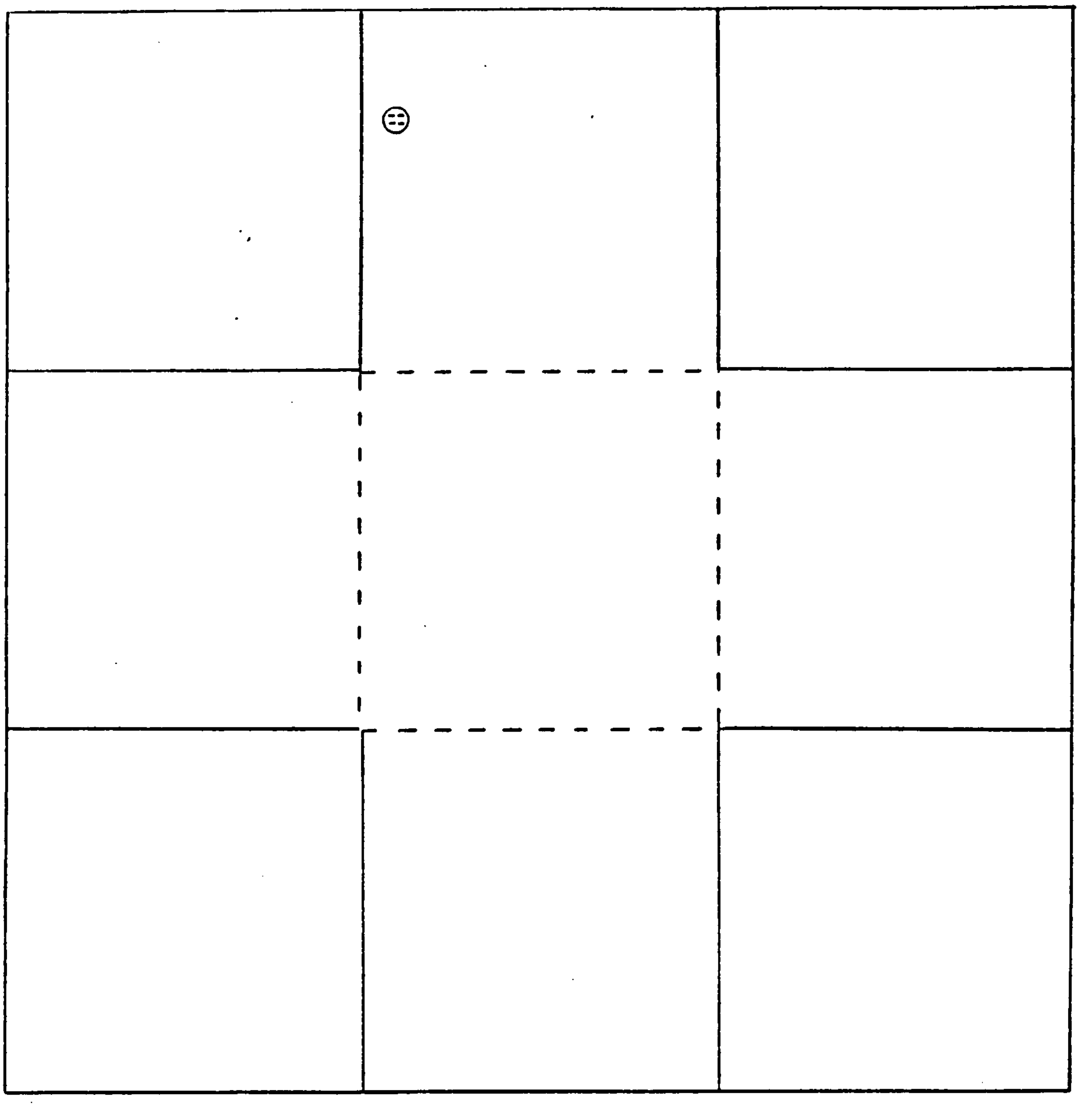
TARGET

⊜

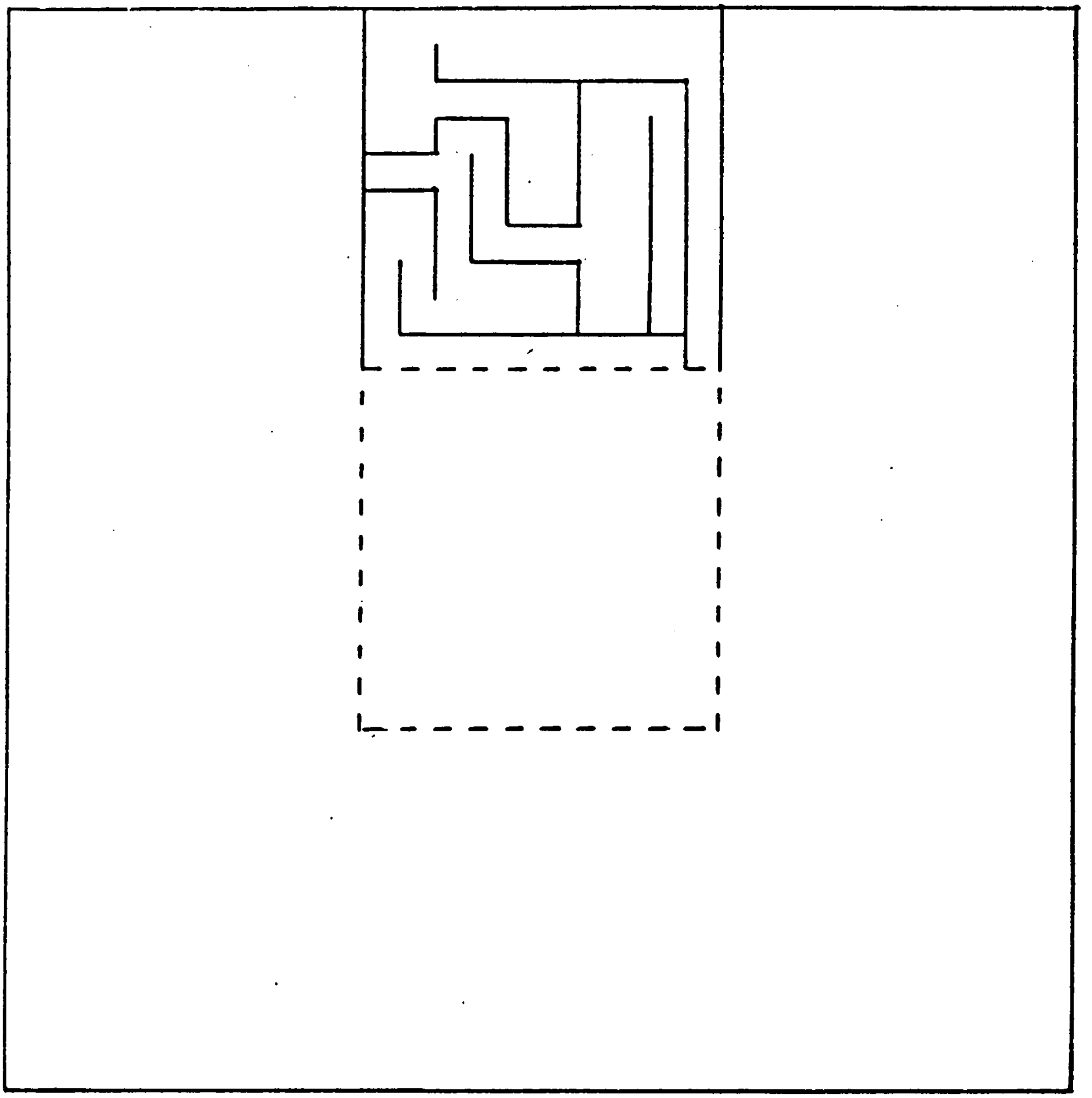
Pre-screening of target stimulus. Subject studies target to be identified in perceptual phase.



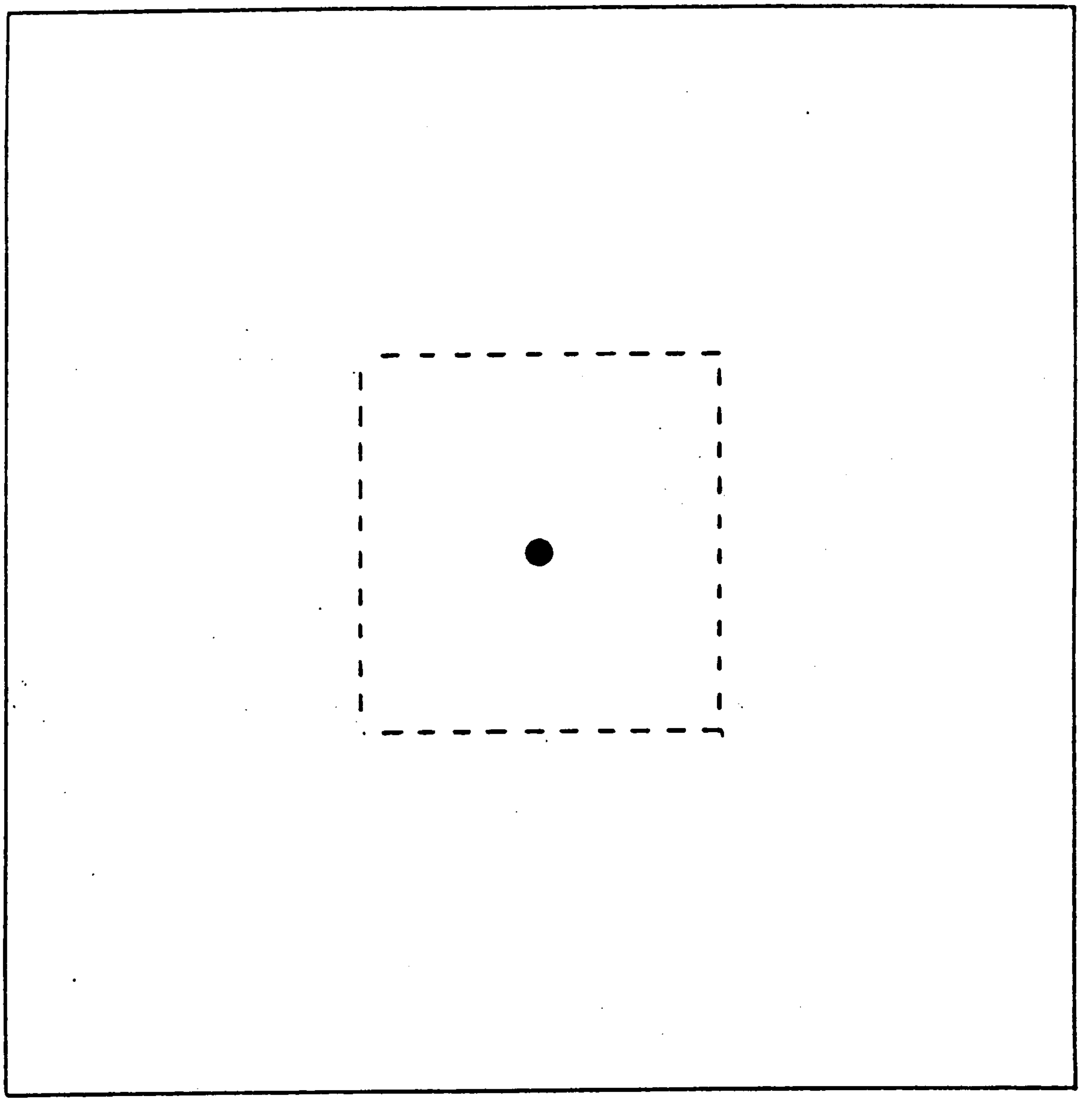
Maze for perceptual phase. Subject identifies location of pre-screened target.



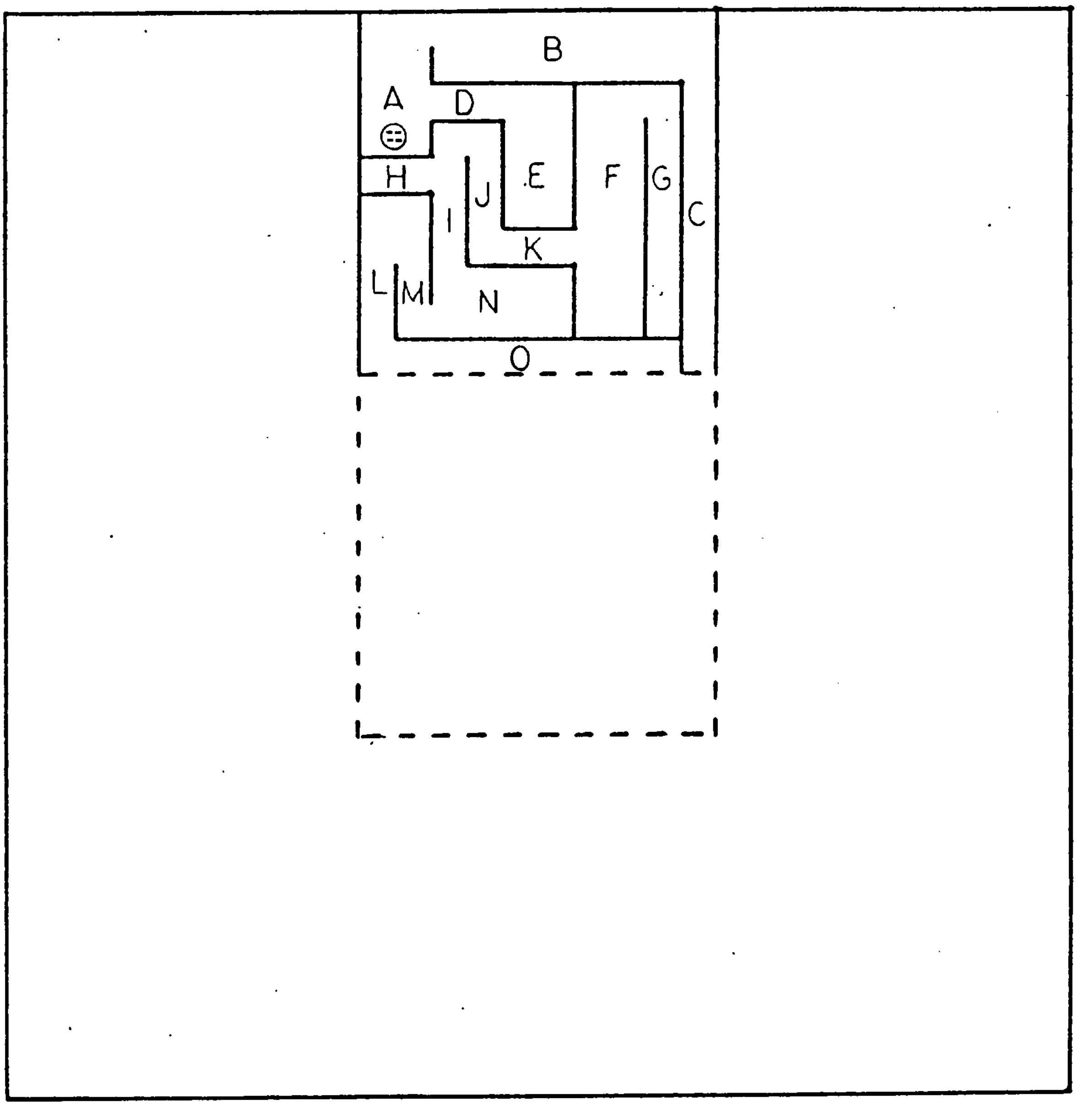
Positioning slide. Subject moves cursor into proper position for mediation phase.



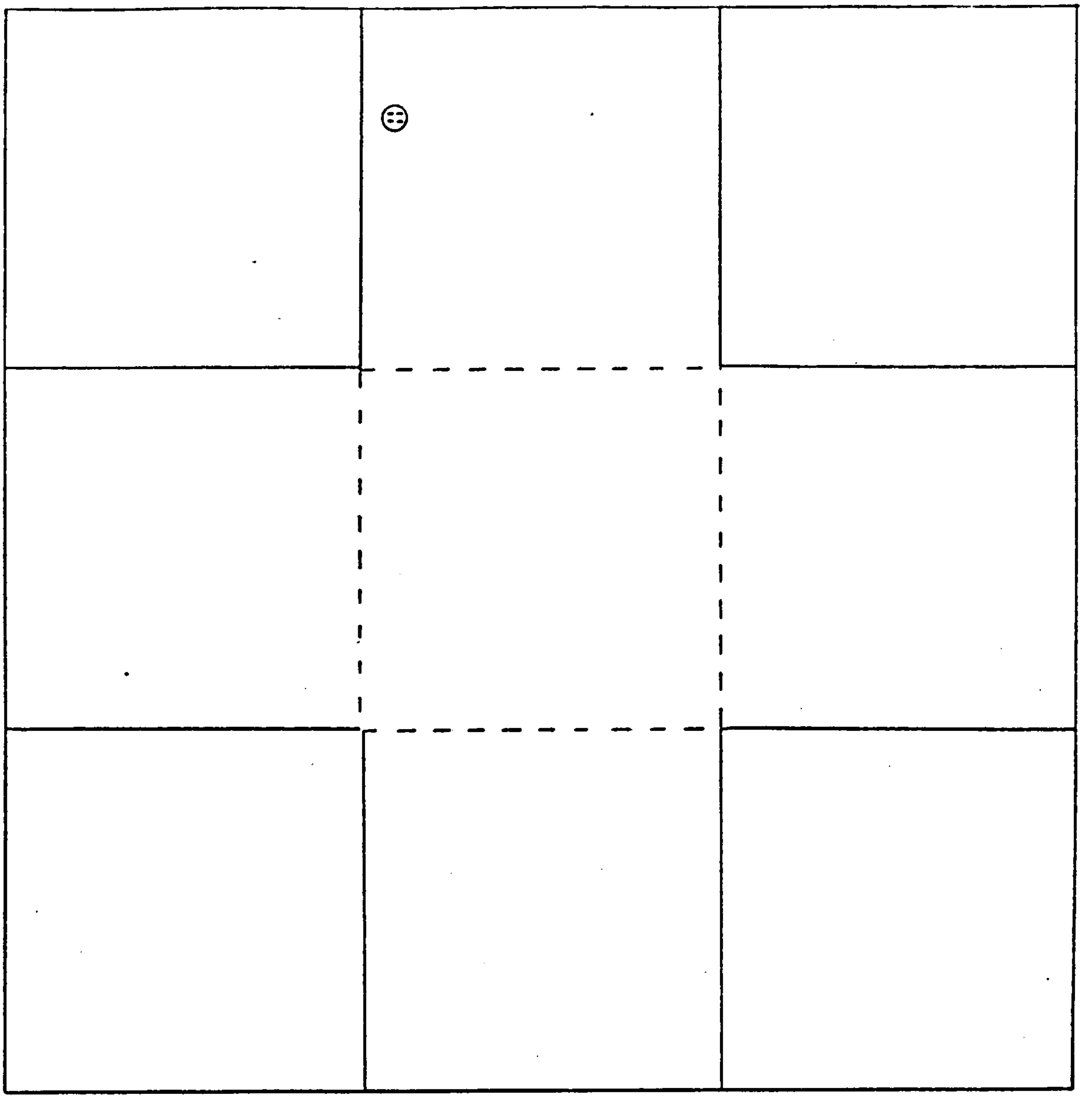
Maze for mediation phase. Subject plans path through maze using cursor to "show" thought process to experimenter.



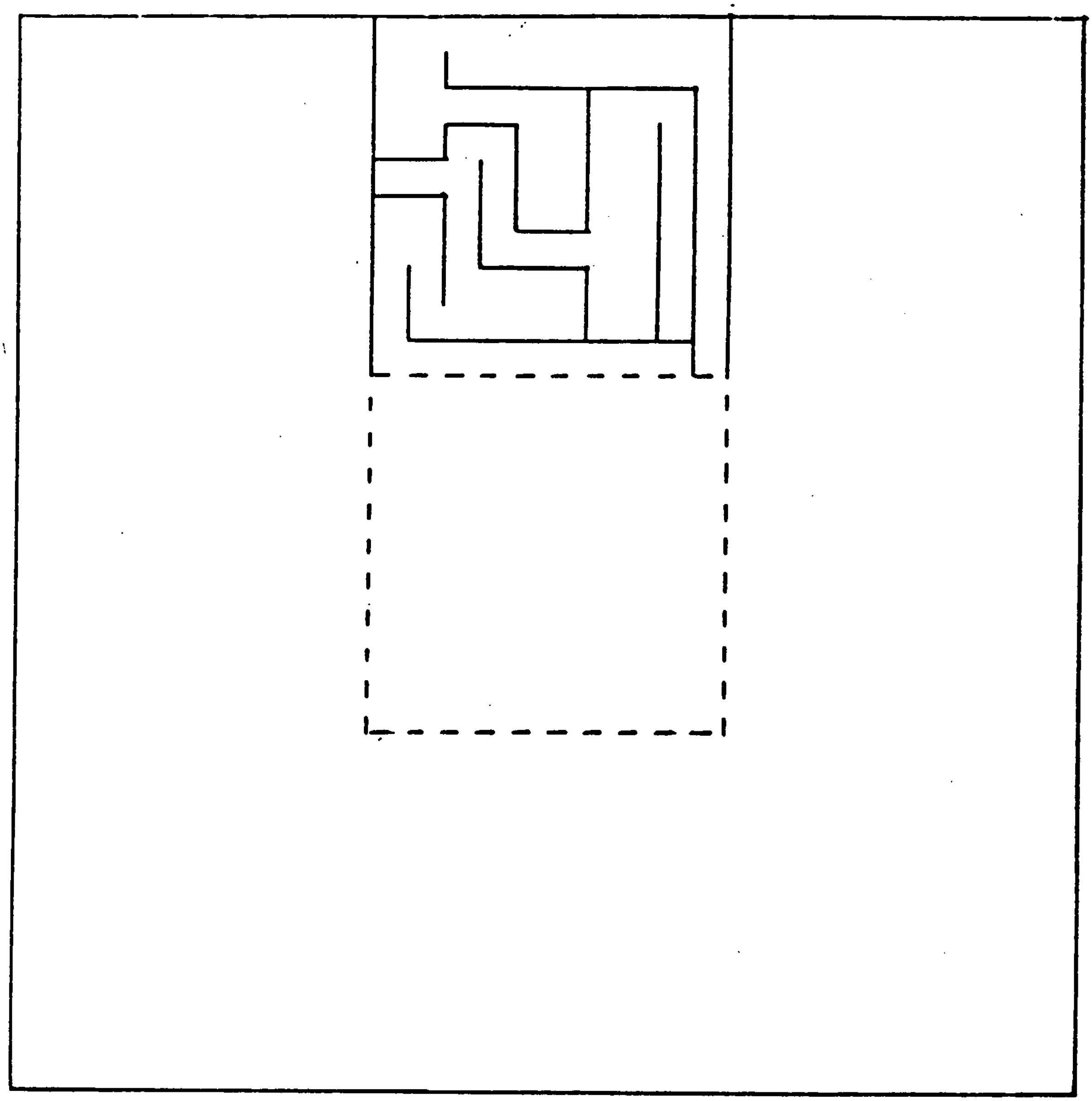
Positioning slide. Subject re-centers cursor in home location such that it is "out of the way" for communication phase.



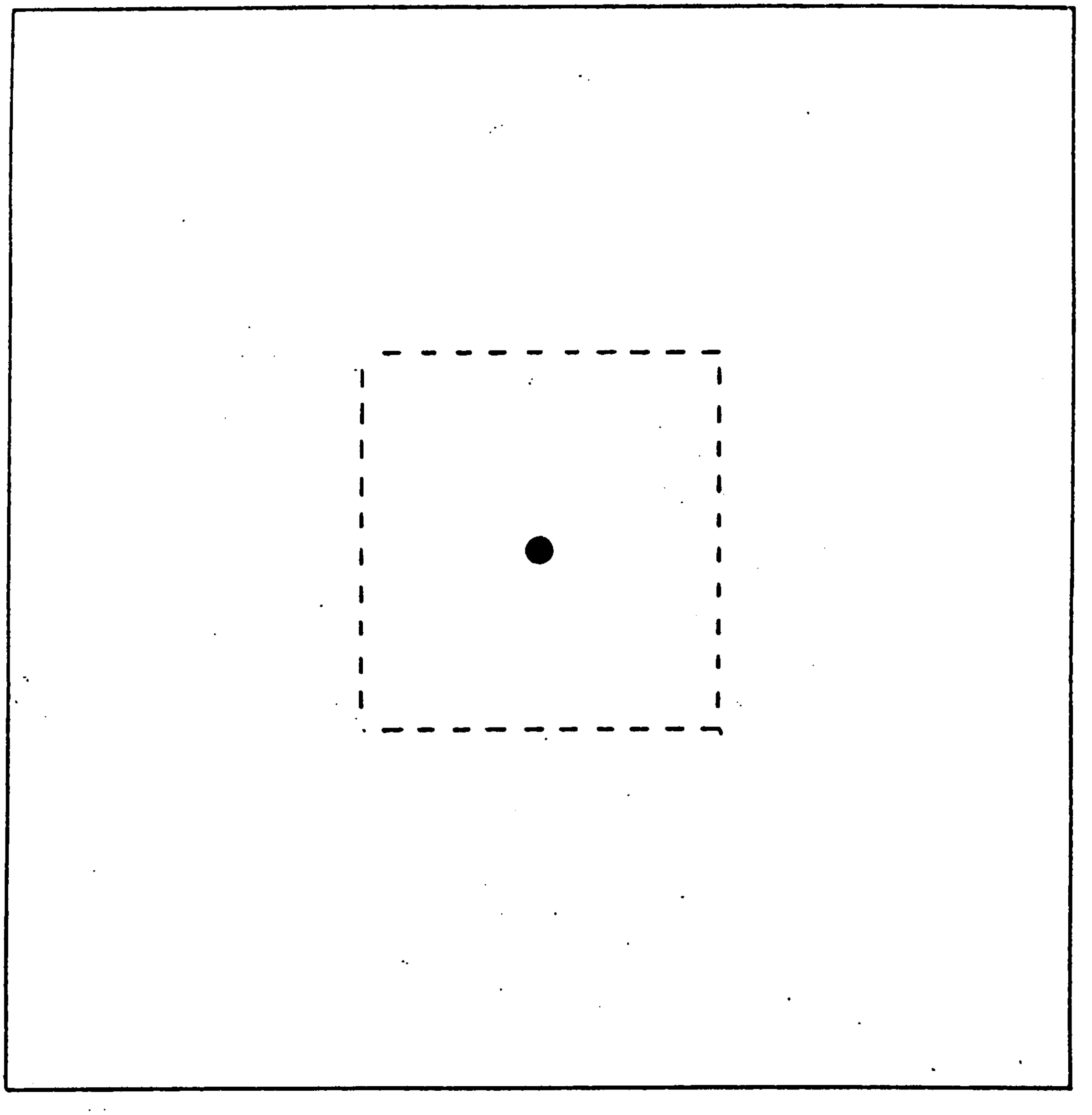
Maze for verbalization phase. Subject verbally describes pathway to experimenter using letters and direction of movement.



Positioning slide. Subject aligns cursor in "ready" position for motor phase.



Maze for motor phase. Subject moves cursor through maze with emphasis on motor control.



Positioning slide. Subject recenters cursor for next run.

APPENDIX B: ALCOHOL DOSAGE CALCULATIONS

The four target levels used in the study (0.00, 0.05, 0.07, and 0.09%) were achieved by administering a certain dosage of vodka based on the subject's body weight and gender. Specifically, for males, for 0.05, 0.07, and 0.09% BAC to be attained, 0.5365, 0.717, and 0.913 ml of pure ethanol per kg of body weight were required as demonstrated in previous research (Barbre and Price, 1982). This follows from the formula:

$$\%BAC = 0.0318d + 0.1652d^2 - 0.0998d^3$$

where d is equal to ml of pure ethanol per kg of body weight. Similarly, for females, 0.356, 0.529, and 0.707 ml of pure ethanol per kg of body weight were needed to obtain BACs of 0.05, 0.07, and 0.09%, respectively, given the formula:

$\%BAC = 0.166d - 0.0803d^2 + 0.0348d^3$ (Tergou and Price, 1982).

The vodka used was 80 proof, that is, 40 percent pure ethanol. The required dosage of vodka was mixed with cold orange juice such that total drink volume was held constant with respect to body weight. For the placebo condition, the full amount of orange juice was administered with a few drops of vodka floated on top for taste.

This beverage, when consumed steadily over a 15 min period as per instructions, yields a BAC close to that desired, given that the subject is in a fasted condition (as required by the study). This BAC is maintained for about 15 min; hence, this time factor was considered in task design.

As was mentioned previously, the dosage formula for males gives counterintuitive results when used to predict dosages to attain BACs of 0.10% or greater. Within the range of dosages used in the current study, however, it does produce correct results.

APPENDIX C: SCREENING QUESTIONNAIRE AND HEALTH SERVICE WAIVER

SCREENING QUESTIONNAIRE

Name:______________________________

Address:______________________________

Phone Number:______________________________

ID Number (SS#):______________________________

Age:________________ Sex:________________

____

TO BE FILLED IN BY EXPERIMENTER:

Visual Acuity:______________________________

Weight:______________________________

PLEASE NOTE:

The following questions are intended to give the experimenters information regarding the general levels of alcohol and caffeine 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, 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.)_______oz per week

2. During the course of a week, on which days do you usually consume alcoholic beverages? (Circle all days that apply.)

   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 ____

   ____

7. If you are female, on what date did your last menstrual period begin? ______________________________

CLINICAL RECORD EVALUATION WAIVER

I, ________________________ authorize C. W. Schiffert, M. D.,
Print Name
Director of the Virginia Tech Health Service, to release requested information about my health to __________________.

Signed ______________________
Signature of Student

I have reviewed the Virginia Tech Clinical record of ____________________ and find a/no medical condition or physical impairment that precludes his/her participation in the following activity ______________________.

____
Director of Student Health Service

APPENDIX D: FORM FOR INFORMED CONSENT

The purpose of the current study is to look at the effects of alcohol on four behavioral processes: perception, mediation, communication, and motor control. Ms. Hahn will meet with you on four occasions for about five hours each time. At each meeting, she 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 a target in a maze, planning a path to get the target out of the maze, telling the experimenter this path, and moving the target through the maze. After this, you will rest in the laboratory until your body has used up almost all the alcohol you were given. During the time you spend resting, Ms. Hahn will answer any questions you may have regarding the experiment except those that might pre-bias the experimental results.

If you agree to participate in this experiment, you have certain rights and obligations. The purpose of this document is to make you aware of these rights and obligations and to obtain your consent to participate.

1. Being in an experiment can make some people nervous even when they know that there are no good or bad scores. If you find yourself getting nervous, or want to stop being in the experiment for any other reason, you have the right to stop the experiment in which you are participating at any time.

Should you terminate the experiment, you will receive pay only for the proportion of time you participate, including all time your presence is required. If you should terminate, you will be required to remain on the premises until you blood alcohol content reaches a level of 0.03% or less. Further, if you should terminate, your legal rights regarding negligence and the liability of the institution and its agents are <u>not</u> waived.

2. You have the right to see your data and to withdraw them 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 quantitative 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. If you do not exercise your right to withdraw your data, any information collected about you during the

project can be used for educational and/or scientific purposes either at the Virginia Polytechnic Institute and State University or at other scientific or educational institutions. If any information about the alcohol project is shown to other people, your name will not appear on it anywhere.

3. You have the right to be informed of 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 in the space provided. A summary will be sent to you. If you would like further information, please contact the Human Factors Laboratory, 961-5635, and a full report will be made available to you.

4. You will be required to refrain from eating any foods or drinking any liquids (including alcohol) for at least four (4) hours prior to the experimental session.

5. You will be required to abstain from drinking any alcohol at least twenty-four (24) hours prior to the experimental session.

6. You will be required to remain under observation until your blood alcohol content, indicated by Breathalyzer tests, is reduced to 0.03% or less.

7. After each experimental session, you will be transported home by a driver who has not ingested any

alcohol. Under no circumstances will you be allowed to drive yourself home.

8. 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.

9. It is your responsibility as a participant to advise Ms. Hahn 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 to the project.

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

____
Signature

____
Printed Name

____
Address

____
City, State, Zip

APPENDIX E: INSTRUCTIONS

This experiment is concerned with your performance on a task designed to tap four behaviors: target identification, planning, verbalization, and motor activity. You will spend about 15 min doing this task. The task is relatively easy, but some training is required so that you know the task very well before starting the experiment. In the target identification task, you will look for a target in a maze and tell the experimenter where in the maze it is. Before you begin, the experimenter will show you the target for 15 sec. It will be a slide that will look like this (show appropriate SLIDE[4]). The figure underneath the word "target" is the actual target. You must remember both the shape of the outer border and the configuration drawn inside the border. Then, you will press the red switch on the table in front of you to show you the maze. Press the switch please (STOP the tape until response is made). This maze will look like this (appropriate SLIDE revealed). When you find the target, press the switch again and tell the experimenter the compartment number where the target was. She will sound a buzzer like this (sound TONE) if you are incorrect. If you are incorrect, you will repeat this step until you find the correct target. You may view the target again if you wish to. Now please identify the target, press the switch, and report the compartment number (STOP).

Once you have found the correct target, you will plan a way to get it through the maze to the center home box. You will use a cursor guided by the two rotary controls in front of you to help you plan. The first step in the planning stage involves moving the cursor from the home location to the target. You will press the switch to see a slide containing only the target. Please press the switch now (STOP, SLIDE). Move the dot that has been in the home box so that it is directly inside the target using the knobs in front of you. Move the cursor now. When you are finished, press the switch again (STOP).

Next, you will move the cursor to help you "think through" the maze. You will press the switch to see a slide containing the appropriate compartment. Please press the switch now (STOP, SLIDE). Start your planning from the target position. As you decide on a possible route, move the cursor along the pathway -- let the cursor reflect all your thoughts. Slow down your thinking so that you can move the cursor as you think. This is important because your thought processes are being put on to videotape by way of your movements. In moving the cursor, you may not cross a maze wall or go into a blank compartment. You may enter home only through the dashed line. Please "think through" the maze, moving the cursor to reflect all you thoughts, now. Once you have moved the cursor into the home box, press the switch again (STOP).

Finally, you will recenter the dot in the home box. You will press the switch to see a slide with a black dot in the center. Press the switch please (STOP, SLIDE). Use the knobs to move the cursor to be within this dot. Do this now. Once you have done this, press the switch again (STOP).

Next, you will tell the experimenter the path. Again, press the switch to see the maze (STOP, SLIDE). Each pathway will be labelled with a letter as shown in this slide. In describing the path to the experimenter, be sure to say where the target is initially, as well as the direction of each movement. For example, for the drawing you have now you might say "Start in G, go left to F, down F and left to E, up E and left to C, then straight to home". The aim here is for you to describe the path you planned in the previous stage. If you should name an incorrect path, you will hear a single beep like this (TONE) which indicates that you should name another path. So if, for example, you said "Start in D" for the maze you have now the experimenter would sound the buzzer once. If the experimenter is having difficulty hearing or understanding you, she will sound the tone twice like this (TONE) indicating that you should repeat what you just said. Please verbalize the entire path, through to the home box, now, then press the switch again (STOP).

In the final stage, you will again move the dot through the maze using the path you planned earlier. Here, however, the emphasis will be on motor control. So, in addition to not crossing maze walls, you should try to not even touch the walls. As was the case with the planning stage, your first task will be to align the cursor with the target. Press the switch now to see the slide containing only the target (STOP, SLIDE). Now move the cursor to be inside the target, then press the switch again (STOP).

Next, you will use the cursor to trace the planned pathway. First, press the switch to see the maze (STOP, SLIDE). It will look like this slide. Now use the knobs to move the cursor to the home box. Again, you may not touch or cross the maze walls or use blank compartments. When you have brought the cursor home, press the switch (STOP).

Finally, you will recenter the dot like you did in the planning stage. Again, press the switch to see the slide with the black dot in the center. Do this now (STOP, SLIDE). Now, move the knobs to bring the cursor within this dot. When you are finished, press the switch (STOP).

At each experimental session, you will do this task twice. One time you will be asked to do it as quickly as possible. The other time, you will be asked to do it as accurately as possible. The best way to be productive is to minimize the time spent on each component. For example, you will want to find the target as quickly as you can, plan as quickly as you can, verbalize as quickly as you can, and do the motor task as quickly as you can. The best way to be accurate is to minimize targeting errors, to minimize the number of wrong paths you follow, to minimize errors in communication, and to minimize touching the maze wall.

At this session, you will only learn how to do the task. No speed or accuracy instructions will be given. Please indicate to the experimenter if you have any questions at this time.

APPENDIX F: SUMMARY OF MAZE CHARACTERISTICS

CHARACTERISTIC	MAZE							
	1	2	3	4	5	6	7	8
<u>Targeting phase</u>								
-- # of different symbols drawn inside target	1	1	3	3	4	4	4	4
-- target and distractors same shape	yes	yes	no	no	yes	yes	no	no
-- target and distractors contain same symbols	no	no	yes	yes	yes	yes	no	no
<u>Mediation phase</u>								
-- # of turns needed to solve maze correctly	4	4	2	2	1	1	3	3
-- # of possible false paths	3	3	2	2	1	1	4	4
<u>Verbalization phase</u>								
-- # of commands needed to describe path	4	4	3	3	2	2	5	5
<u>Motor phase</u>								
-- alley width	w	w	n	n	mw	mw	mn	mn

Legend: w = wide
n = narrow
mw = mostly wide
mn = mostly narrow

APPENDIX G: RATING FORM

Rater:____________________________

Maze #:___________________________

Please rate the relative importance of each of the following tasks to successful task completion by placing an "X" at the appropriate number.

(1) Perception

```
    |--------|--------|--------|--------|--------|--------|
    1        2        3        4        5        6        7
not at all                 of moderate                 very
important                  importance             important
```

(2) Mediation

```
    |--------|--------|--------|--------|--------|--------|
    1        2        3        4        5        6        7
not at all                 of moderate                 very
important                  importance             important
```

(3) Communication

```
    |--------|--------|--------|--------|--------|--------|
    1        2        3        4        5        6        7
not at all                 of moderate                 very
important                  importance             important
```

(4) Motor Processes

```
    |--------|--------|--------|--------|--------|--------|
    1        2        3        4        5        6        7
not at all                 of moderate                 very
important                  importance             important
```

APPENDIX H: CALIBRATION OF THE BREATHALYZER

The calibration of the Breathalyzer was checked using an alcoholic breath simulator (Smith and Wesson Mark II Simulator) which provides a standard alcohol-air mixture against which the Breathalyzer read-out is compared.

Stock solutions were prepared as per the manufacturer's instructions (Breathalyzer instruction manual, 1978) to simulate 0.05, 0.07, and 0.09% BACs. Three batches of solution were made and tested for each BAC used in the current study. For the 0.05 solutions, the obtained readings were 0.045, 0.05, and 0.05, respectively. For the 0.07 solutions, the obtained readings were 0.07, 0.07, and 0.065. Finally, for the 0.09 solutions, the obtained readings were all 0.09.

APPENDIX I: CORRECTION FACTORS FOR DISTANCE MEASURES

All distance measures obtained in the current study were taken from the video monitor rather than the projection screen. This was necessary since the measurements could not be obtained directly during experimentation.

Correction factors to translate the measurements taken into the actual distances travelled on the screen were needed due to differences in size between the video monitor screen and the projection surface. Further, since the camera could not be mounted to face the screen head-on (it would have been blocked by the subject), camera angle produced different distortions at different locations on the screen. Hence, corrections were determined individually for the maze compartment of interest on each slide.

These correction factors are listed in Table I1 below. To achieve the actual distance travelled, the distance measured on the monitor (in cm) was multiplied by the conversion factor. The resulting value was used in all subsequent analyses.

TABLE I1: Correction Factors for Distance Measures.

Slide	Measurement				Correction	
	From Projector		From Monitor			
	Width	Height	Width	Height	Width	Height
1	13.8	13.9	11.4	10.9	1.211	1.275
2	14.2	14.3	12.4	11.5	1.145	1.244
3	14.1	14.1	12.7	11.6	1.110	1.216
4	14.2	14.3	12.5	11.5	1.136	1.244
5	14.1	14.0	12.1	10.7	1.165	1.308
6	13.8	14.1	11.3	11.2	1.221	1.259
7	14.1	14.1	12.9	11.0	1.093	1.282
8	13.7	13.9	11.0	10.5	1.246	1.324

APPENDIX J: RESULTS OF NEWMAN-KEULS TESTS

TABLE J1

Newman-Keuls Test for the Effect of Session on Target Identification Time

Session	Mean time (s)	Newman-Keuls grouping
1	8.15	A
2	6.59	B
3	6.49	B
4	6.10	B

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J2

Newman-Keuls Test for the Effect of BAC on Target Identification Time

%BAC	Mean time (s)	Newman-Keuls grouping	
0.09	7.89	A	
0.07	6.82	A	B
0.05	6.27		B
0.00	6.37		B

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J3

Newman-Keuls Test for the Effect of Maze on Target Identification Time

Maze Difficulty	Mean time (s)	Newman-Keuls grouping		
4	8.52	A		
3	7.96	A	B	
2	6.88		B	
1	3.98			C

Note: (1) Maze difficulty of 1 represents the easiest maze; (2) Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J4

Newman-Keuls Test for the Effect of Maze on Number of Attempts for Target Identification

Maze Difficulty	Mean number attempts	Newman-Keuls grouping	
4	1.11		B
3	1.27	A	
2	1.16	A	B
1	1.00		B

Note: (1) Maze difficulty of 1 represents the easiest maze; (2) Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J5

Newman-Keuls Test for the Group x Sex x Instruction Interaction on Number of Attempts to Identify the Target

Group	Sex	Instruction	Mean number attempts	Newman-Keuls grouping
6	females	speed	1.25	B
6	females	accuracy	1.625	D
6	males	speed	1.375	B
6	males	accuracy	1.125	A
7	females	speed	1.00	A
7	females	accuracy	1.00	A
7	males	speed	1.50	C
7	males	accuracy	1.00	A
8	females	speed	1.00	A
8	females	accuracy	1.00	A
8	males	speed	1.375	B C
8	males	accuracy	1.00	A

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J6

Newman-Keuls Test for the Effect of Session on Pathway Planning Time

Session	Mean time (s)	Newman-Keuls grouping
1	13.25	A
2	9.88	B
3	10.65	B
4	10.53	B

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J7

Newman-Keuls Test for the Effect of BAC on Pathway Planning Time

%BAC	Mean time (s)	Newman-Keuls grouping
0.09	11.70	A
0.07	11.27	A
0.05	11.40	A
0.00	9.94	B

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J8

Newman-Keuls Test for the Effect of Maze on Pathway Planning Time

Maze Difficulty	Mean time (s)	Newman-Keuls grouping	
4	12.80	A	
3	12.43	A	
2	9.71		B
1	9.37		B

Note: (1) Maze difficulty of 1 represents the easiest maze; (2) Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J9

Newman-Keuls Test for the Group x Sex x Instruction Effect on Pathway Planning Time

Group	Sex	Instruction	Mean time (s)	Newman-Keuls grouping
3	females	speed	9.87	A B
3	females	accuracy	14.97	C
3	males	speed	12.04	B
3	males	accuracy	11.80	B
4	females	speed	11.82	B
4	females	accuracy	11.93	B
4	males	speed	8.33	A
4	males	accuracy	12.04	B

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J10

Newman-Keuls Test for the Effect of Maze on Number of False Paths Travelled

Maze Difficulty	Mean number paths	Newman-Keuls grouping	
4	0.73	A	
3	0.73	A	
2	0.19		B
1	0.45	A	B

Note: (1) Maze difficulty of 1 represents the easiest maze; (2) Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J11

Newman-Keuls Test for the Effect of Session on Distance Travelled in False Paths

Session	Mean distance (cm)	Newman-Keuls grouping	
1	1.71	A	
2	1.45	A	B
3	1.43	A	B
4	0.43		B

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J12

Newman-Keuls Test for the Effect of BAC on Distance Travelled in False Paths

%BAC	Mean distance (cm)	Newman-Keuls grouping	
0.09	1.78	A	
0.07	1.35	A	B
0.05	1.46	A	B
0.00	0.43		B

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J13

Newman-Keuls Test for the Effect of Maze on Distance Travelled in False Paths

Maze Difficulty	Mean distance (cm)	Newman-Keuls grouping	
4	2.00	A	
3	1.28	A	B
2	0.35		B
1	1.40	A	B

Note: (1) Maze difficulty of 1 represents the easiest maze; (2) Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J14

Newman-Keuls Test for the Effect of Session on Verbalization Time

Session	Mean time (s)	Newman-Keuls grouping	
1	12.99	A	
2	12.07	A	B
3	10.98		B
4	13.27	A	

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J15

Newman-Keuls Test for the Effect of Maze on Verbalization Time

Maze Difficulty	Mean time (s)	Newman-Keuls grouping
4	15.06	A
3	13.96	B
2	11.08	C
1	9.22	D

Note: (1) Maze difficulty of 1 represents the easiest maze; (2) Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J16

Newman-Keuls Test for the Session x Instruction Interaction on Verbalization Time

Session	Instruction	Mean time (s)	Newman-Keuls grouping
1	speed	12.04	A
1	accuracy	13.94	B
4	speed	12.25	A
4	accuracy	14.29	B

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J17

Newman-Keuls Test for the Effect of BAC on Number of Incorrect Verbalizations

%BAC	Mean number incorrect	Newman-Keuls grouping
0.09	0.59	A
0.07	0.56	A
0.05	0.53	A
0.00	0.22	B

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J18

Newman-Keuls Test for the Effect of Maze on Number of Incorrect Verbalizations

Maze Difficulty	Mean number incorrect	Newman-Keuls grouping	
4	0.61	A	
3	0.61	A	
2	0.31		B
1	0.38		B

Note: (1) Maze difficulty of 1 represents the easiest maze; (2) Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J19

Newman-Keuls Test for the Effect of Session on Number of Words Produced

Session	Mean number words	Newman-Keuls grouping		
1	22.66		B	
2	25.39	A		
3	20.55			C
4	25.17	A		

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J20

Newman-Keuls Test for the Effect of BAC on Number of Words Produced

%BAC	Mean number words	Newman-Keuls grouping	
0.09	23.97	A	
0.07	23.15	A	B
0.05	24.58	A	
0.00	22.08		B

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J21

Newman-Keuls Test for the Effect of Maze on Number of Words Produced

Maze Difficulty	Mean number words	Newman-Keuls grouping		
4	27.23	A		
3	27.52	A		
2	21.59		B	
1	17.42			C

Note: (1) Maze difficulty of 1 represents the easiest maze; (2) Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J22

Newman-Keuls Test for the Session x Instruction Interaction on Number of Words Produced

Session	Instruction	Mean number words	Newman-Keuls grouping
1	speed	21.38	B
1	accuracy	23.94	C
3	speed	22.16	B
3	accuracy	18.94	A

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J23

Newman-Keuls Test for the Effect of Session on Number of Pauses Produced

Session	Mean number pauses	Newman-Keuls grouping		
1	4.64	A	B	
2	4.31		B	C
3	3.84		B	C
4	5.19	A		

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J24

Newman-Keuls Test for the Effect of Maze on Number of Pauses Produced

Maze Difficulty	Mean number pauses	Newman-Keuls grouping
4	5.63	A
3	5.56	A
2	3.78	B
1	3.02	C

Note: (1) Maze difficulty of 1 represents the easiest maze; (2) Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J25

Newman-Keuls Test for the Effect of Session on Proportion of Pauses to Words

Session	Mean proportion	Newman-Keuls grouping
1	0.20	A
2	0.17	B
3	0.18	B
4	0.21	A

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J26

Newman-Keuls Test for the Effect of BAC on Proportion of Pauses to Words

%BAC	Mean proportion	Newman-Keuls grouping	
0.09	0.18		B
0.07	0.19	A	B
0.05	0.19	A	B
0.00	0.21	A	

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J27

Newman-Keuls Test for the Effect of Maze on Proportion of Pauses to Words

Maze Difficulty	Mean proportion	Newman-Keuls grouping	
4	0.21	A	
3	0.21	A	
2	0.18		B
1	0.17		B

Note: (1) Maze difficulty of 1 represents the easiest maze; (2) Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J28

Newman-Keuls Test for the Effect of Session on Time to Trace the Path

Session	Mean time (s)	Newman-Keuls grouping
1	8.66	A
2	7.37	B
3	6.77	B
4	8.34	A

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J29

Newman-Keuls Test for the Effect of Maze on Time to Trace the Path

Maze Difficulty	Mean time (s)	Newman-Keuls grouping		
4	9.01	A		
3	8.37	A	B	
2	7.83		B	
1	5.94			C

Note: (1) Maze difficulty of 1 represents the easiest maze; (2) Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J30

Newman-Keuls Test for the Effect of BAC on Number of Tracking Reversals

%BAC	Mean number reversals	Newman-Keuls grouping	
0.09	2.00	A	
0.07	1.61	A	B
0.05	1.69	A	B
0.00	1.19		B

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J31

Newman-Keuls Test for the Effect of BAC on Distance Travelled in Reversals

%BAC	Mean distance (cm)	Newman-Keuls grouping	
0.09	1.67	A	
0.07	1.24	A	
0.05	1.35	A	
0.00	1.11		B

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J32

Newman-Keuls Test for the Effect of BAC on Number of Wall Touches

%BAC	Mean number touches	Newman-Keuls grouping	
0.09	0.94	A	
0.07	0.83	A	B
0.05	0.77	A	B
0.00	0.50		B

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J33

Newman-Keuls Test for the Effect of Maze on Number of Wall Touches

Maze Difficulty	Mean number touches	Newman-Keuls grouping	
4	1.22	A	
3	0.95	A	
2	0.47		B
1	0.39		B

Note: (1) Maze difficulty of 1 represents the easiest maze; (2) Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J34

Newman-Keuls Test for the Effect of Session on Time Spent Touching Walls

Session	Mean time (s)	Newman-Keuls grouping	
1	0.76	A	
2	0.47		B
3	0.60	A	B
4	0.41		B

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J35

Newman-Keuls Test for the Effect of BAC on Time Spent Touching the Maze Wall

%BAC	Mean time (s)	Newman-Keuls grouping	
0.09	0.68	A	
0.07	0.65	A	
0.05	0.57	A	B
0.00	0.35		B

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J36

Newman-Keuls Test for the Effect of Maze on Time Spent Touching the Maze Wall

Maze Difficulty	Mean time (s)	Newman-Keuls grouping
4	0.93	A
3	0.74	A
2	0.29	B
1	0.28	B

Note: (1) Maze difficulty of 1 represents the easiest maze; (2) Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J37

Newman-Keuls Test for the Sex x Instruction x Maze Interaction on Time Spent Touching Walls

Sex	Instruction	Maze	Mean time (s)	Newman-Keuls grouping
females	speed	1	0.49	C D
females	accuracy	1	0.21	A B
females	speed	2	0.13	A
females	accuracy	2	0.35	B C
females	speed	3	0.55	D E
females	accuracy	3	0.67	E
females	speed	4	1.55	F
females	accuracy	4	0.63	E

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J38

Newman-Keuls Test for the Effect of Session on Total Time for Task Completion

Session	Mean time (s)	Newman-Keuls grouping		
1	43.05	A		
2	35.91		B	C
3	34.90			C
4	38.25		B	

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

TABLE J39

Newman-Keuls Test for the Effect of BAC on Total Time for Task Completion

%BAC	Mean time (s)	Newman-Keuls grouping	
0.09	39.87	A	
0.07	38.27	A	B
0.05	37.76	A	B
0.00	36.20		B

Note: Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

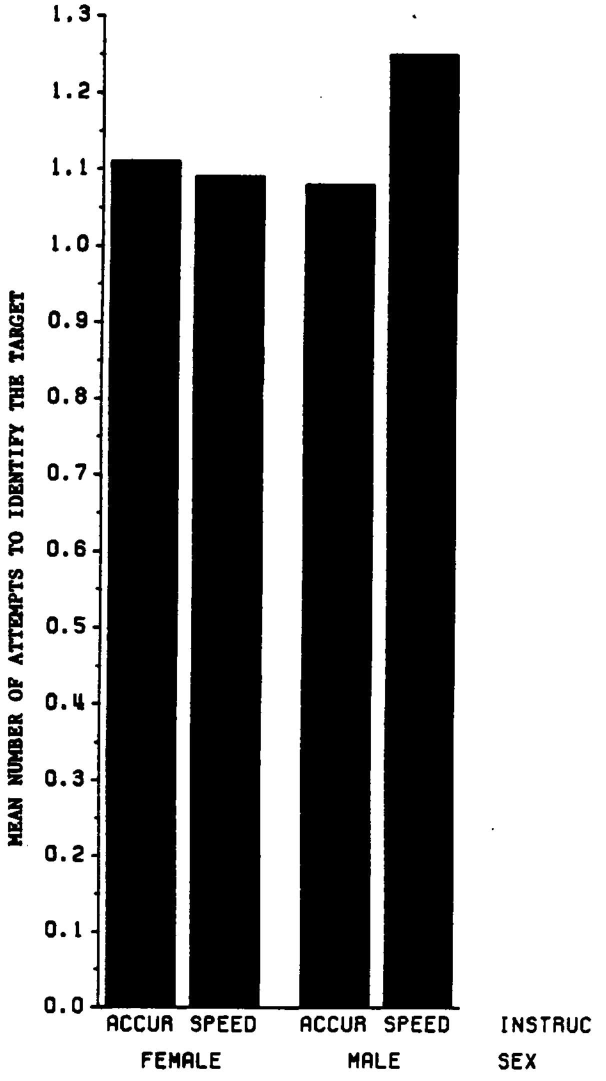
TABLE J40

Newman-Keuls Test for the Effect of Maze on Total Time for Task Completion

Maze Difficulty	Mean time (s)	Newman-Keuls grouping
4	45.39	A
3	39.84	B
2	35.47	C
1	31.40	D

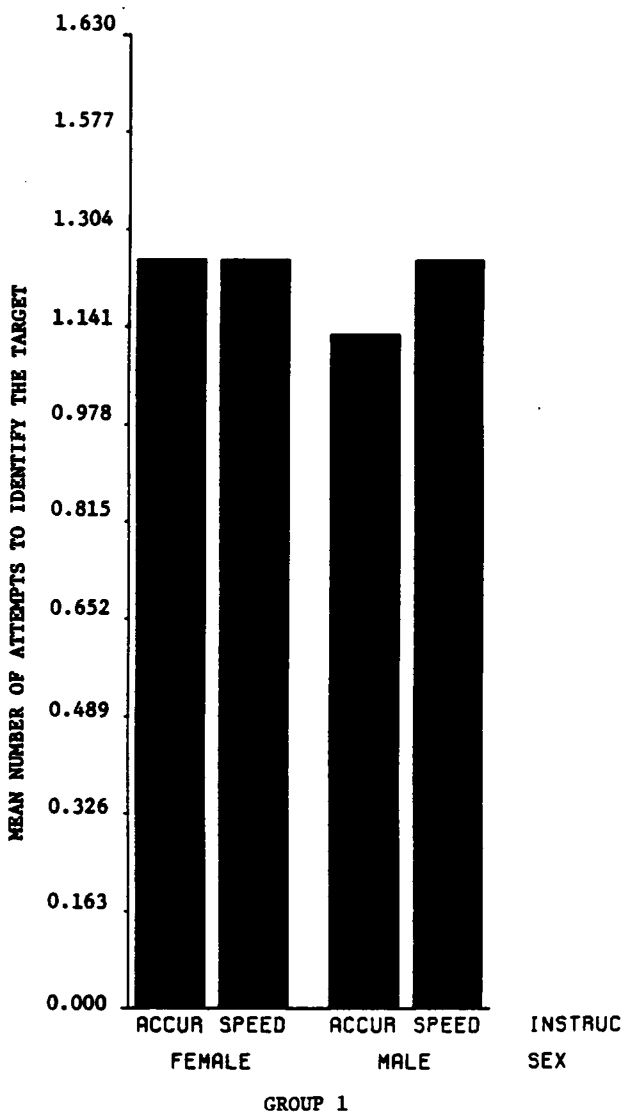
Note: (1) Maze difficulty of 1 represents the easiest maze; (2) Means with the same Newman-Keuls grouping letter are not significantly different at alpha = 0.05.

APPENDIX K: GRAPHS OF SIGNIFICANT INTERACTION EFFECTS



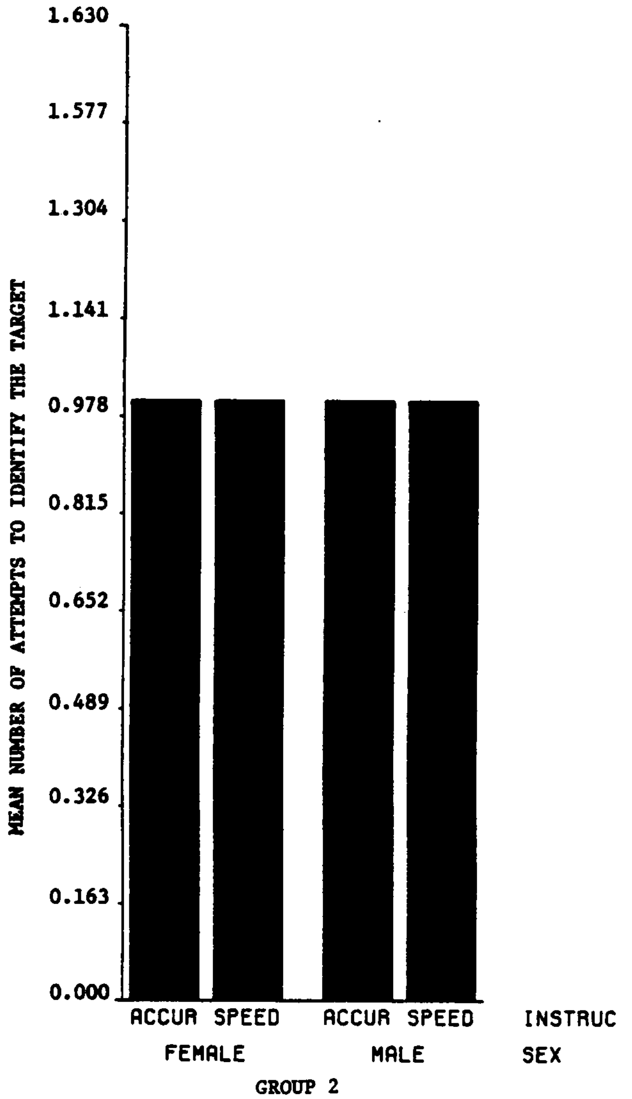
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K1: Sex x Instruction interaction for number of attempts to identify the target.



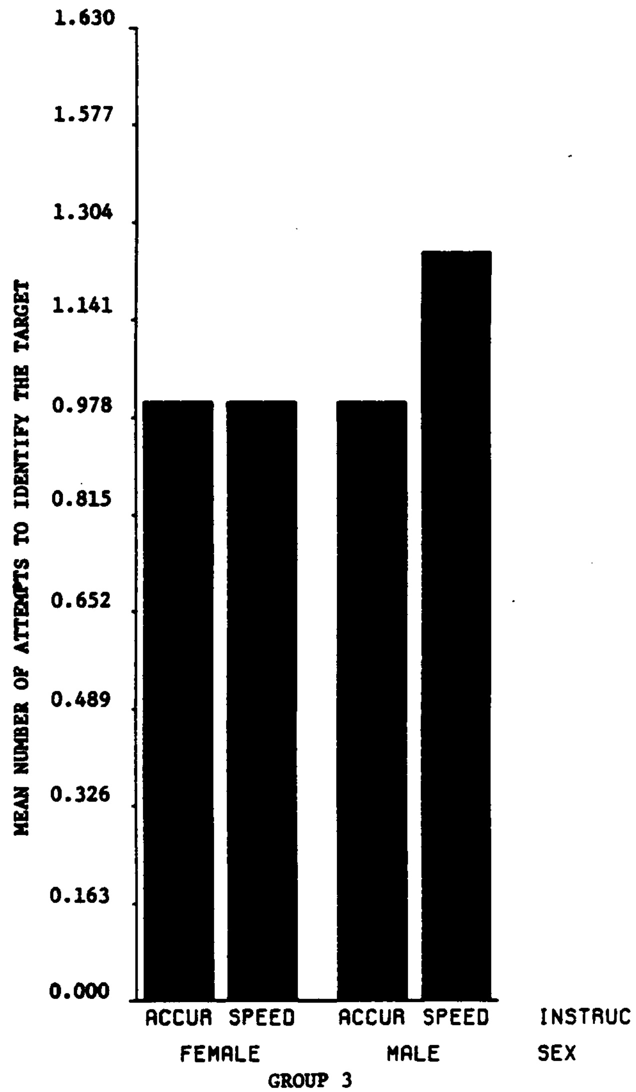
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K2: Group x Sex x Instruction interaction for number of attempts for target identification.



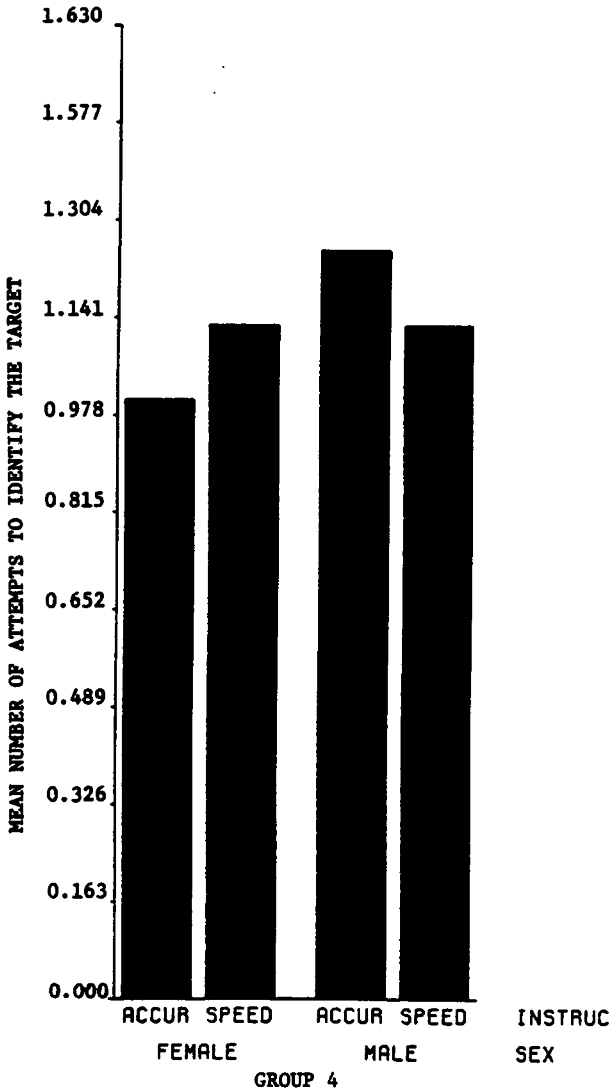
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K2 continued.



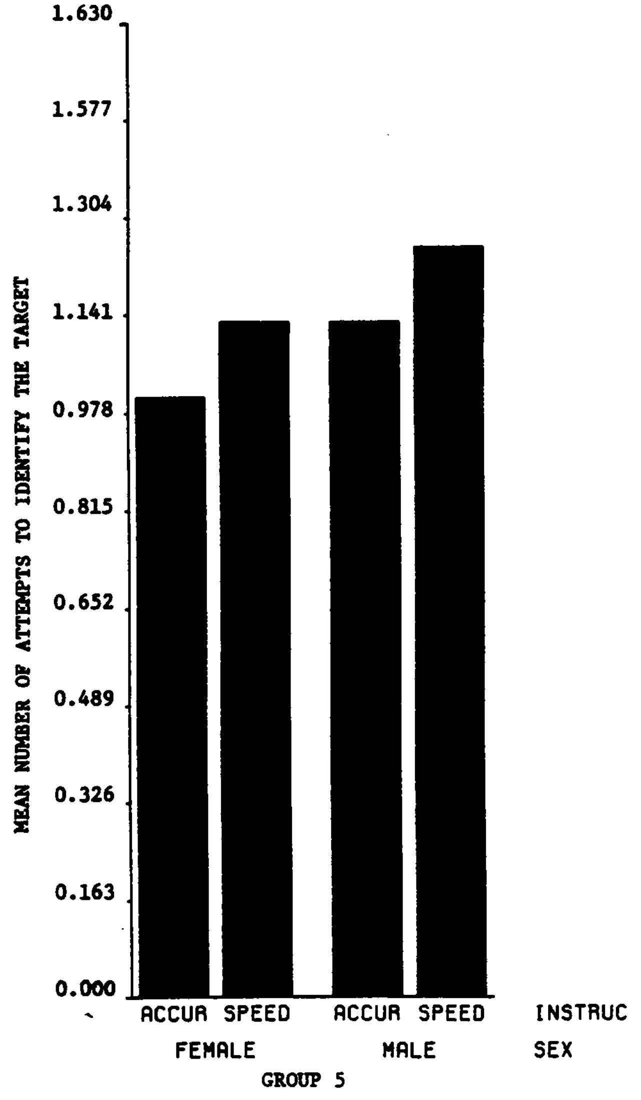
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K2 continued.



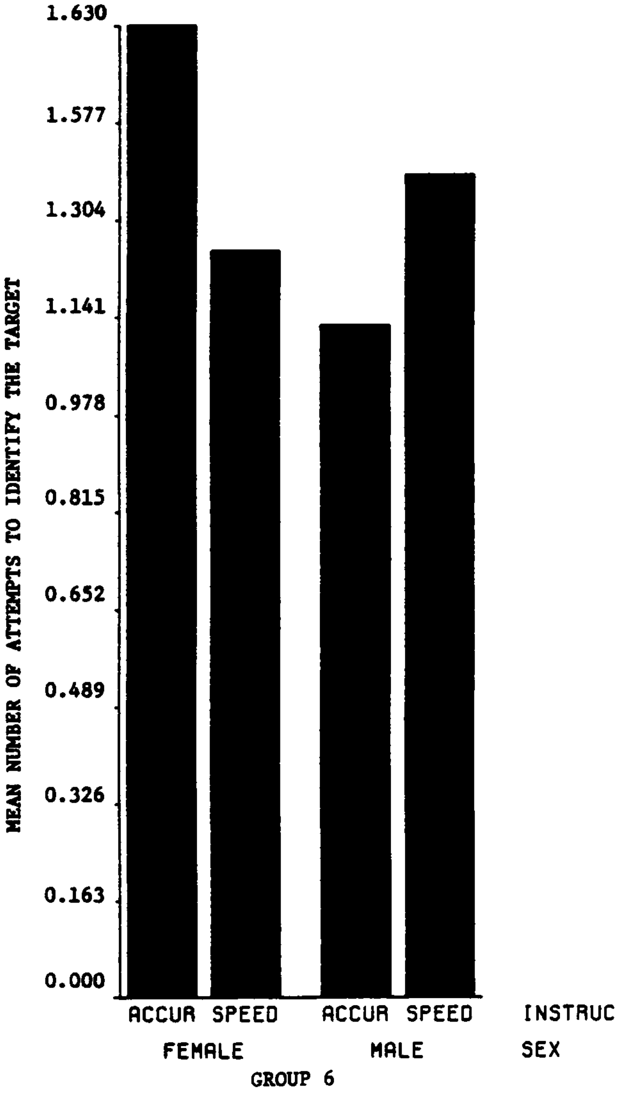
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K2 continued.



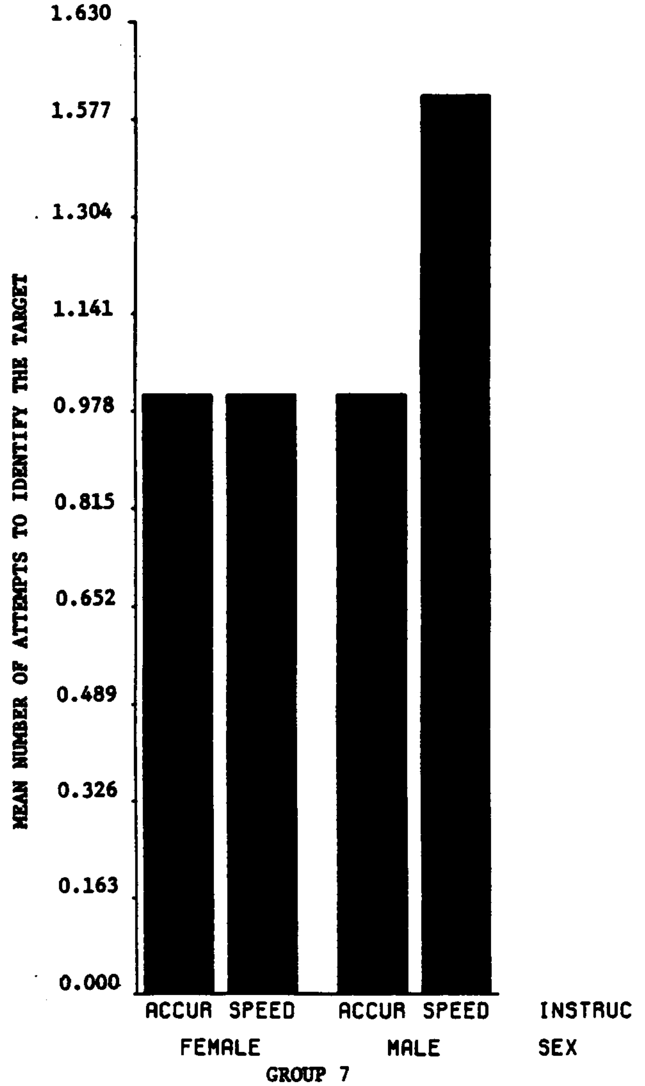
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K2 continued.



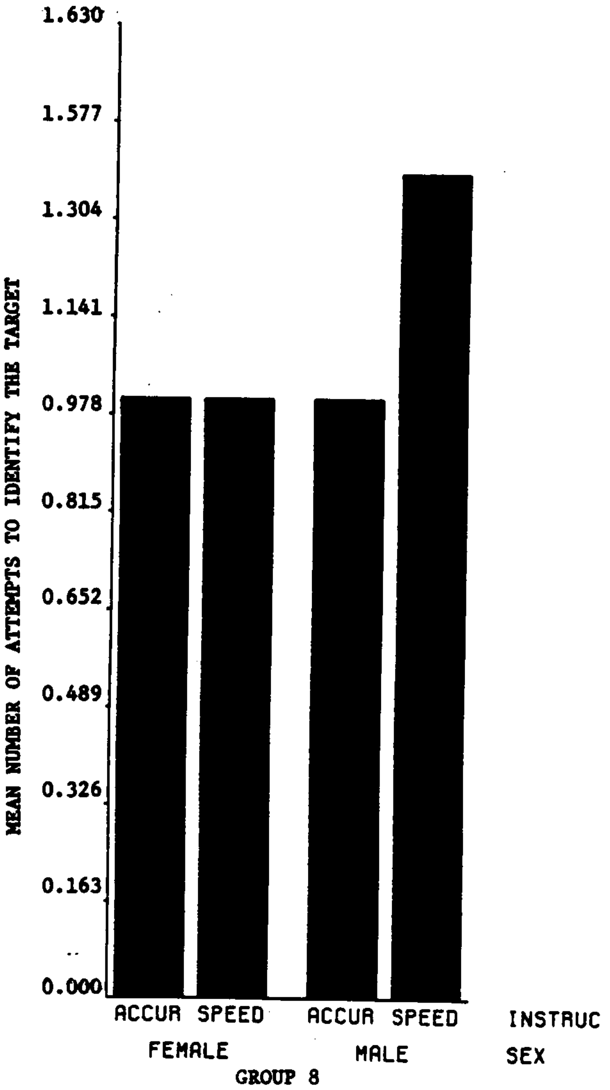
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K2 continued.



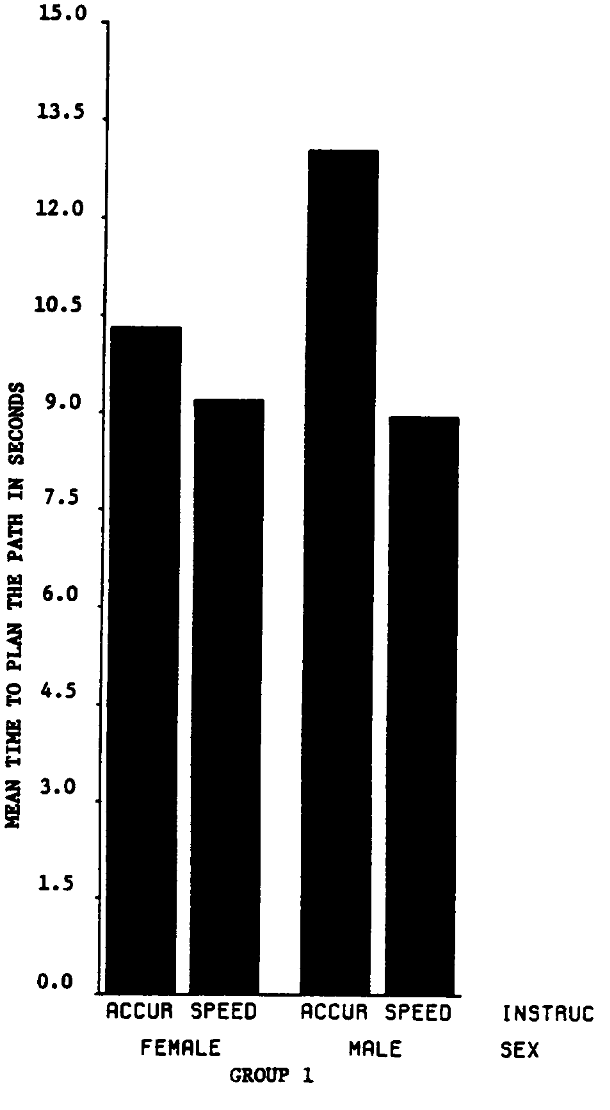
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K2 continued.



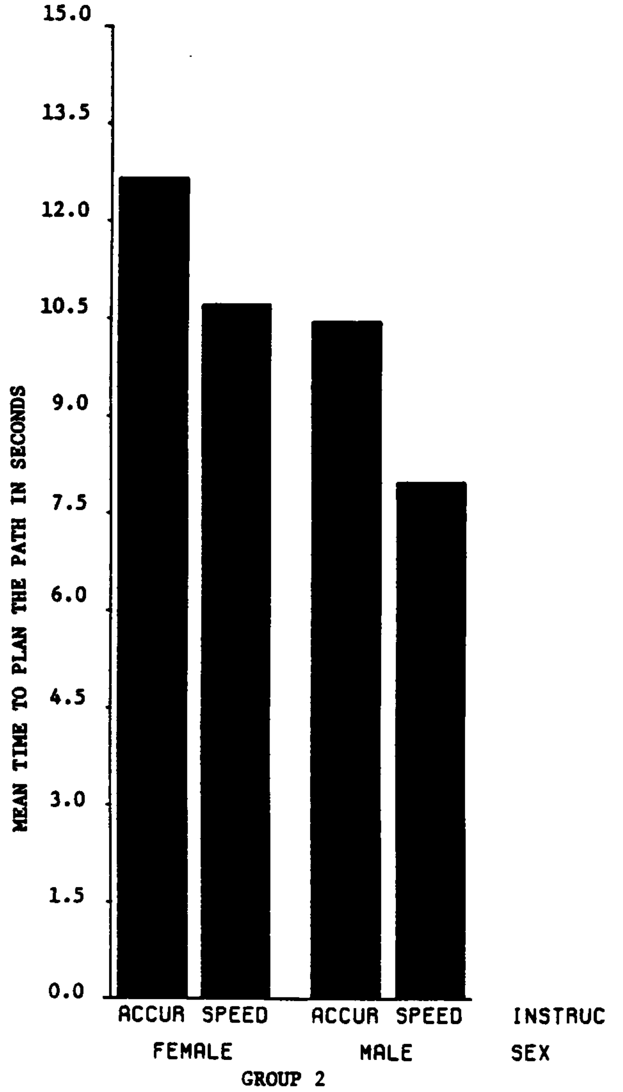
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K2 continued.



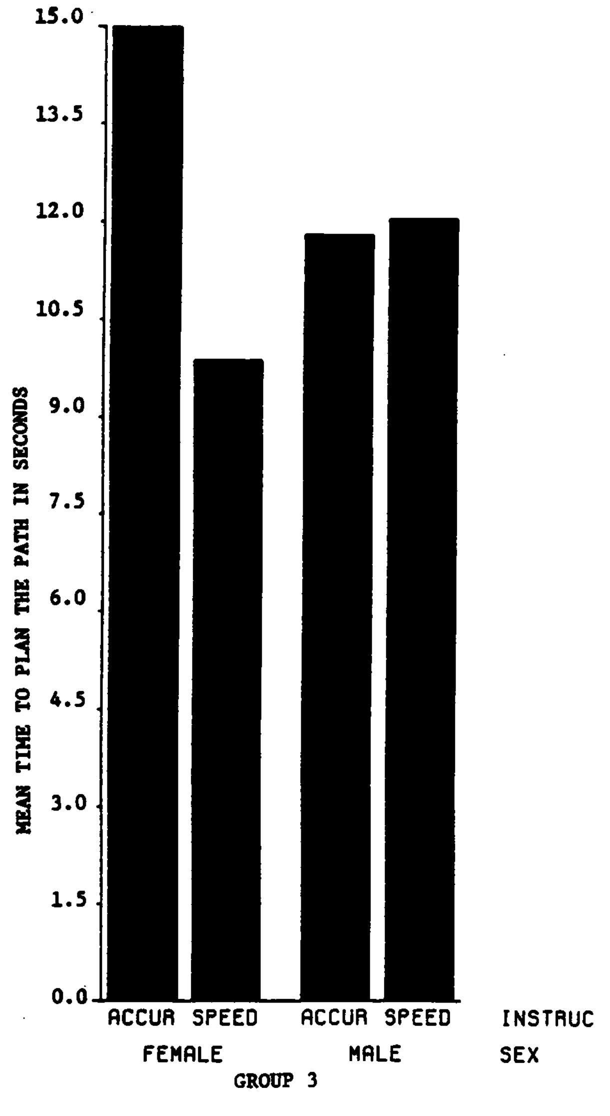
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K3: Group x Sex x Instruction interaction for pathway planning time.



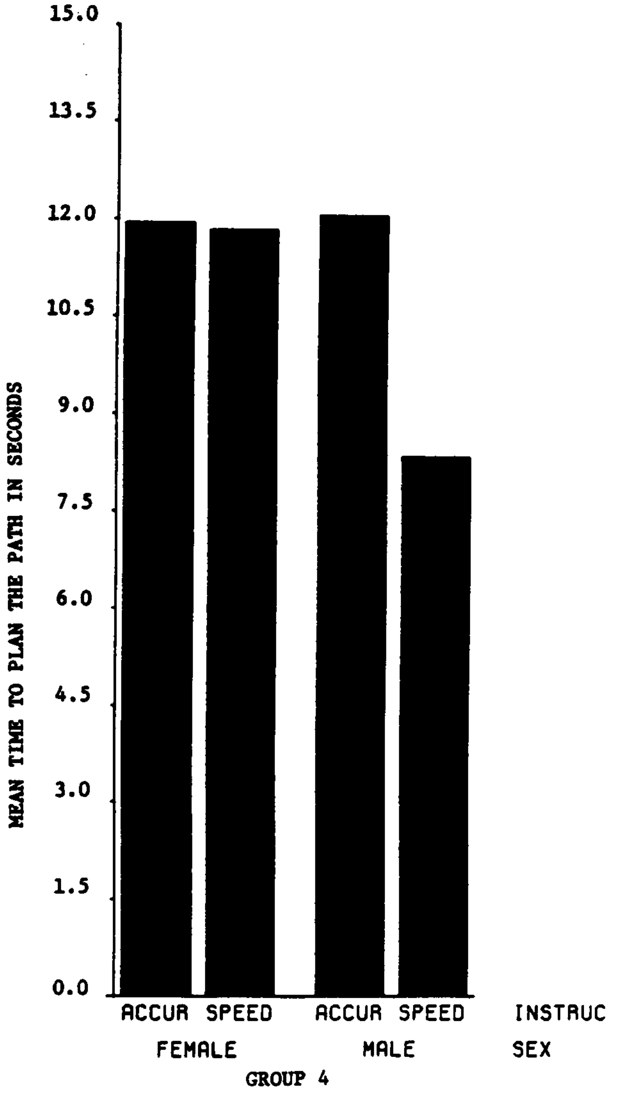
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K3 continued.



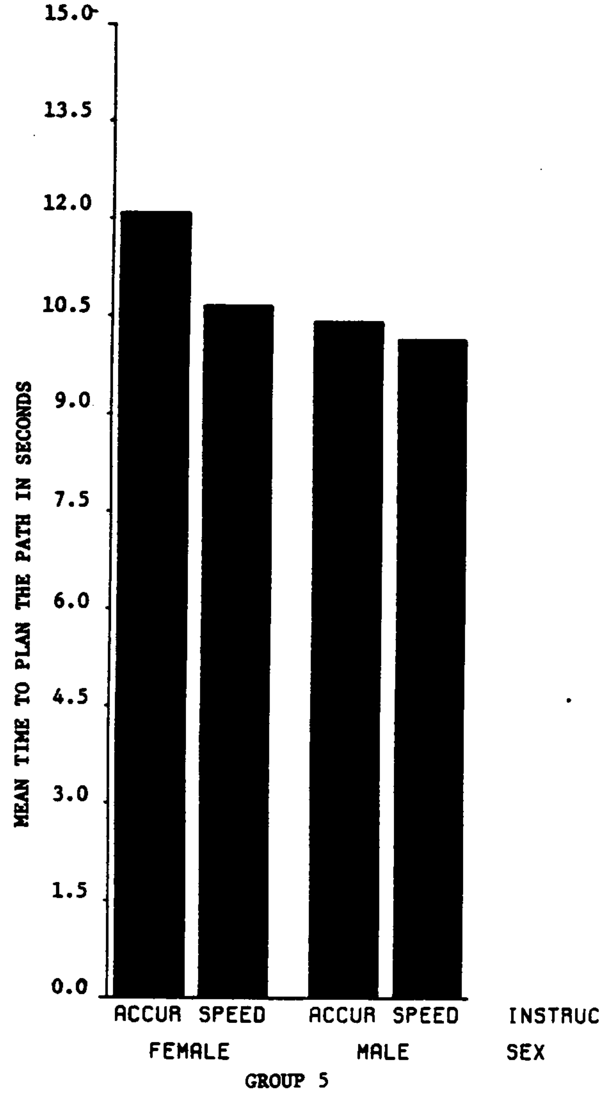
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K3 continued.



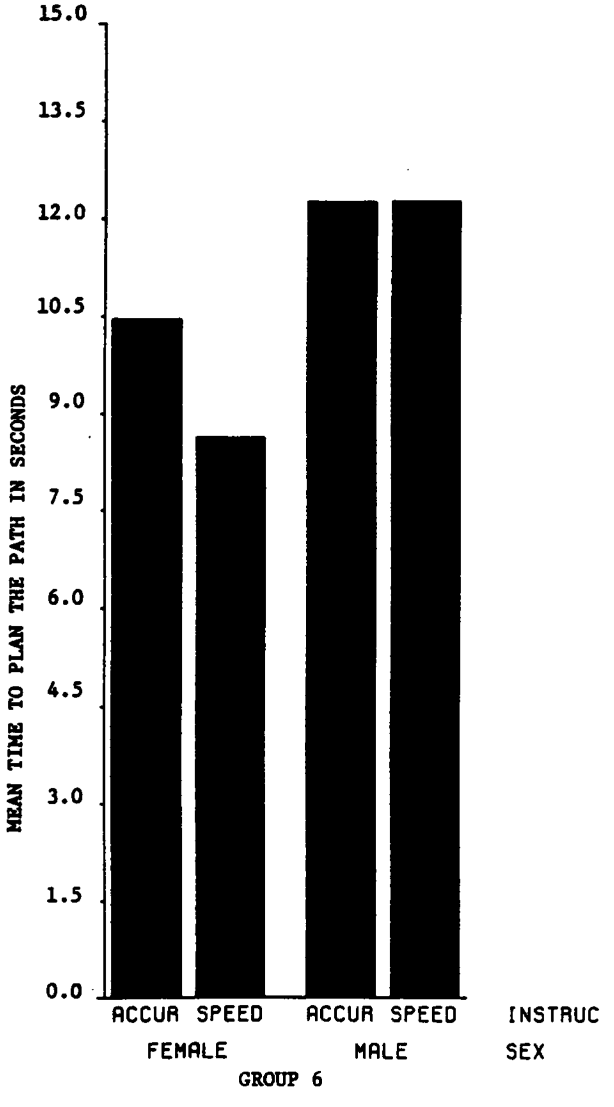
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K3 continued.



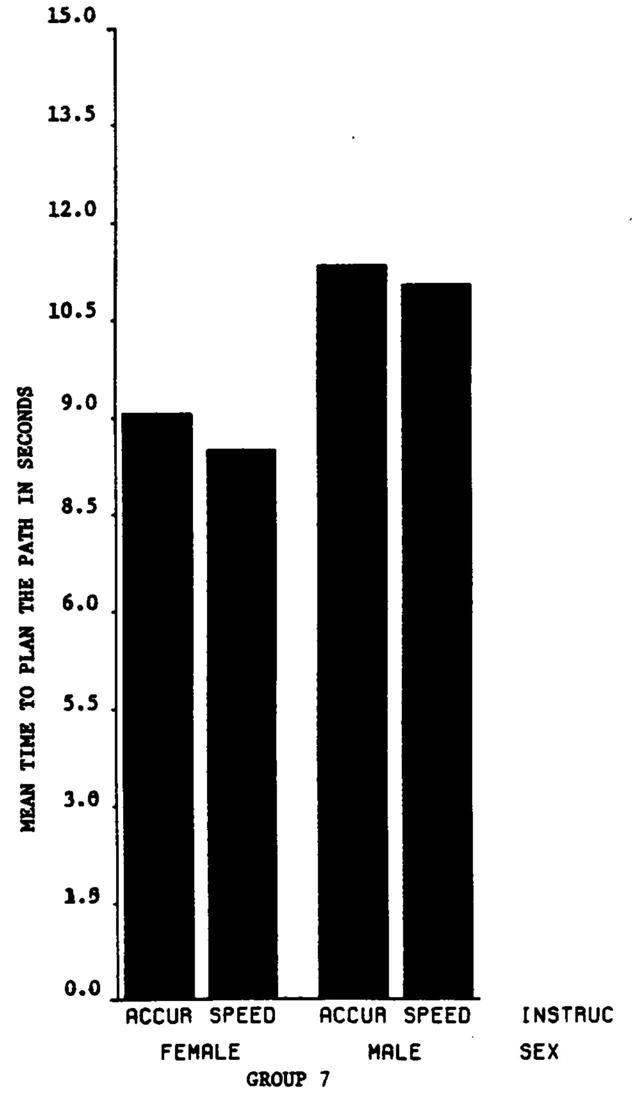
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K3 continued.



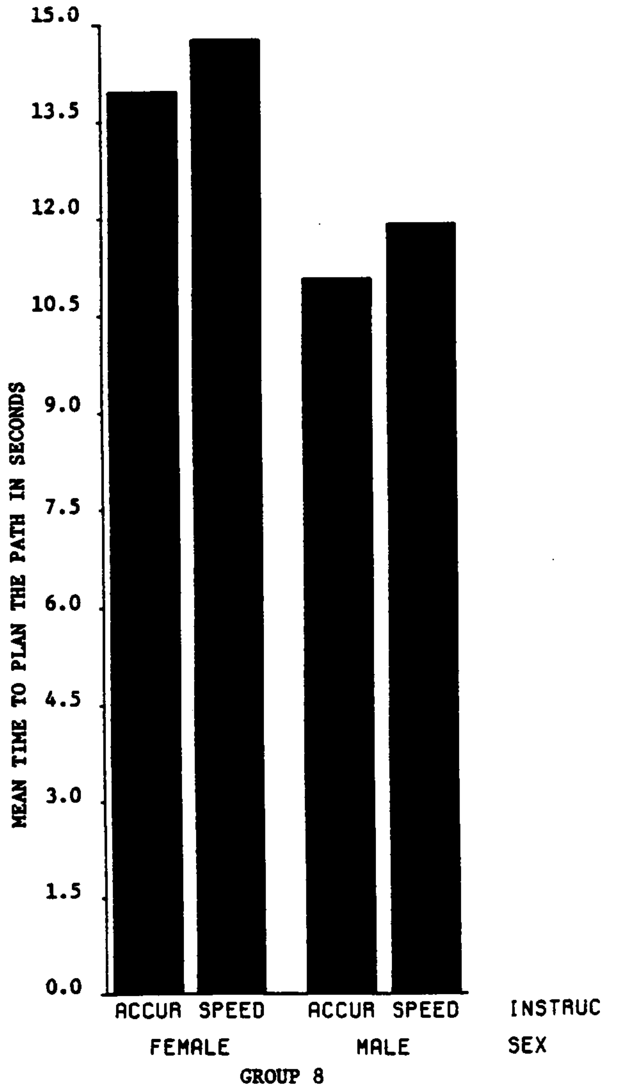
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K3 continued.



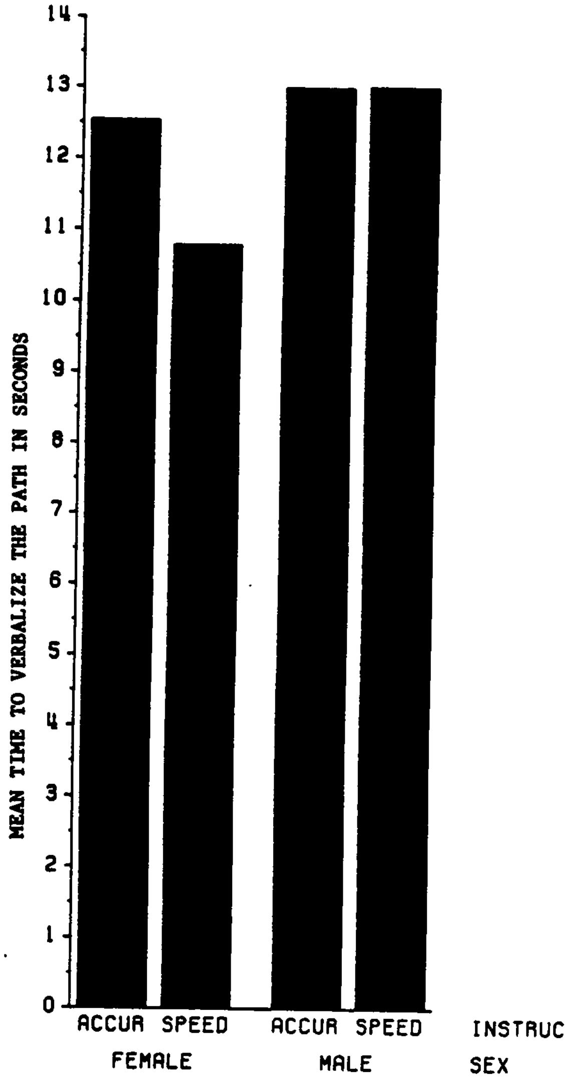
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K3 continued.



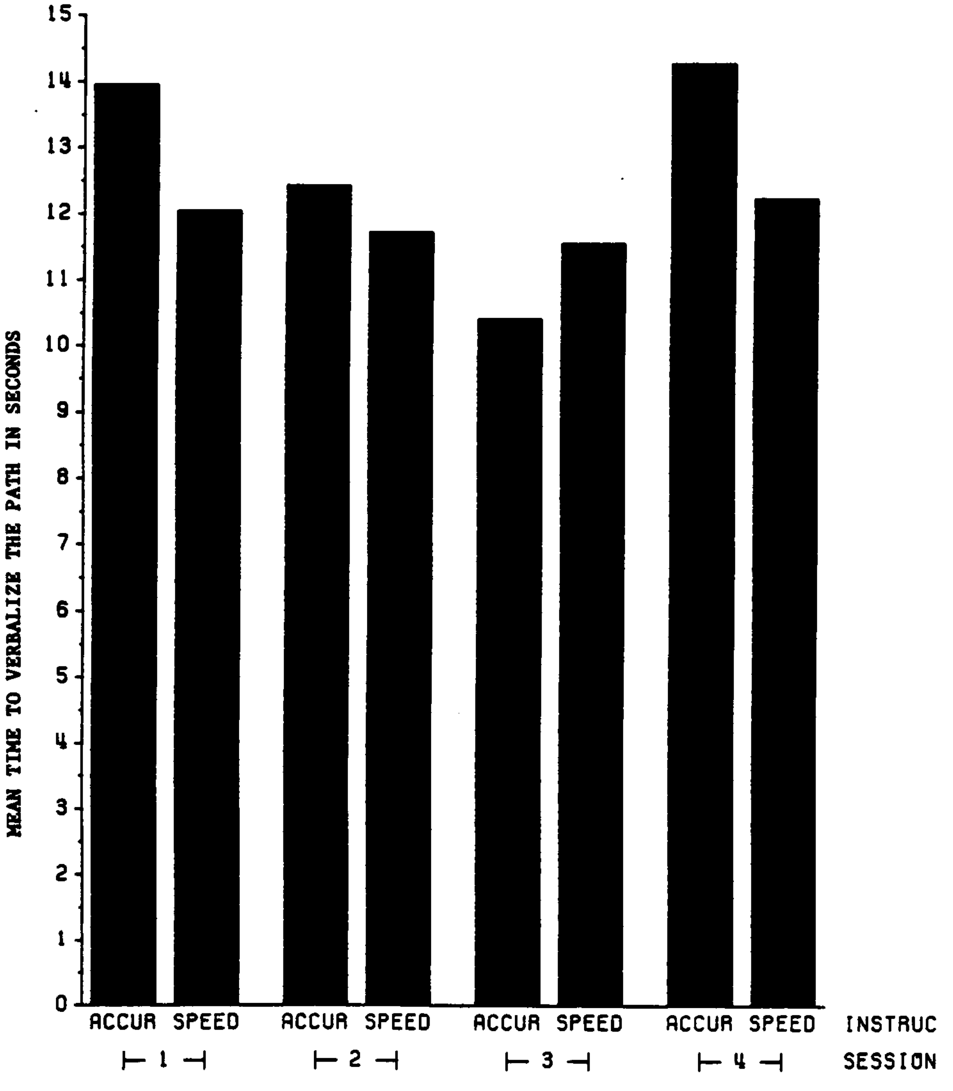
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K3 continued.



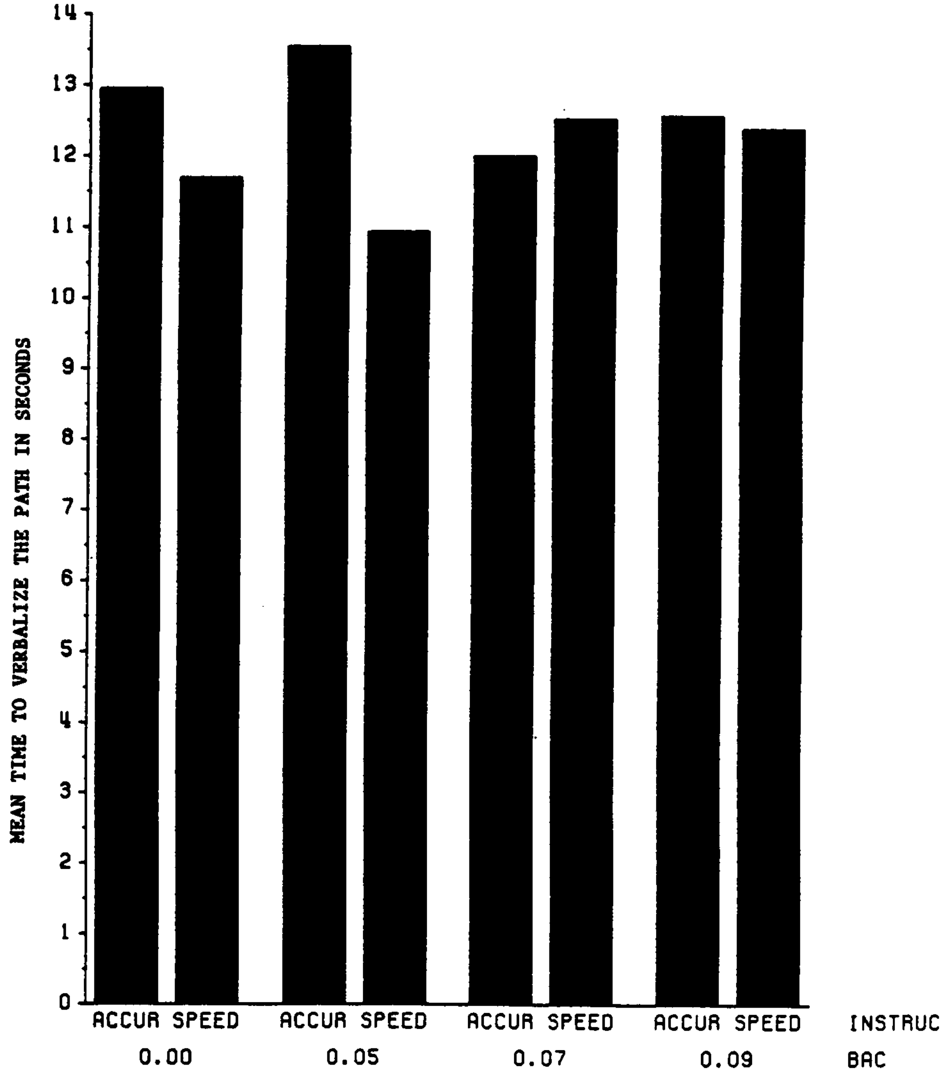
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K4: Sex x Instruction interaction for time to verbalize the pathway.



where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K5: Session x Instruction interaction for time to verbalize the pathway.



where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K6: BAC x Instruction interaction for time to verbalize the pathway.

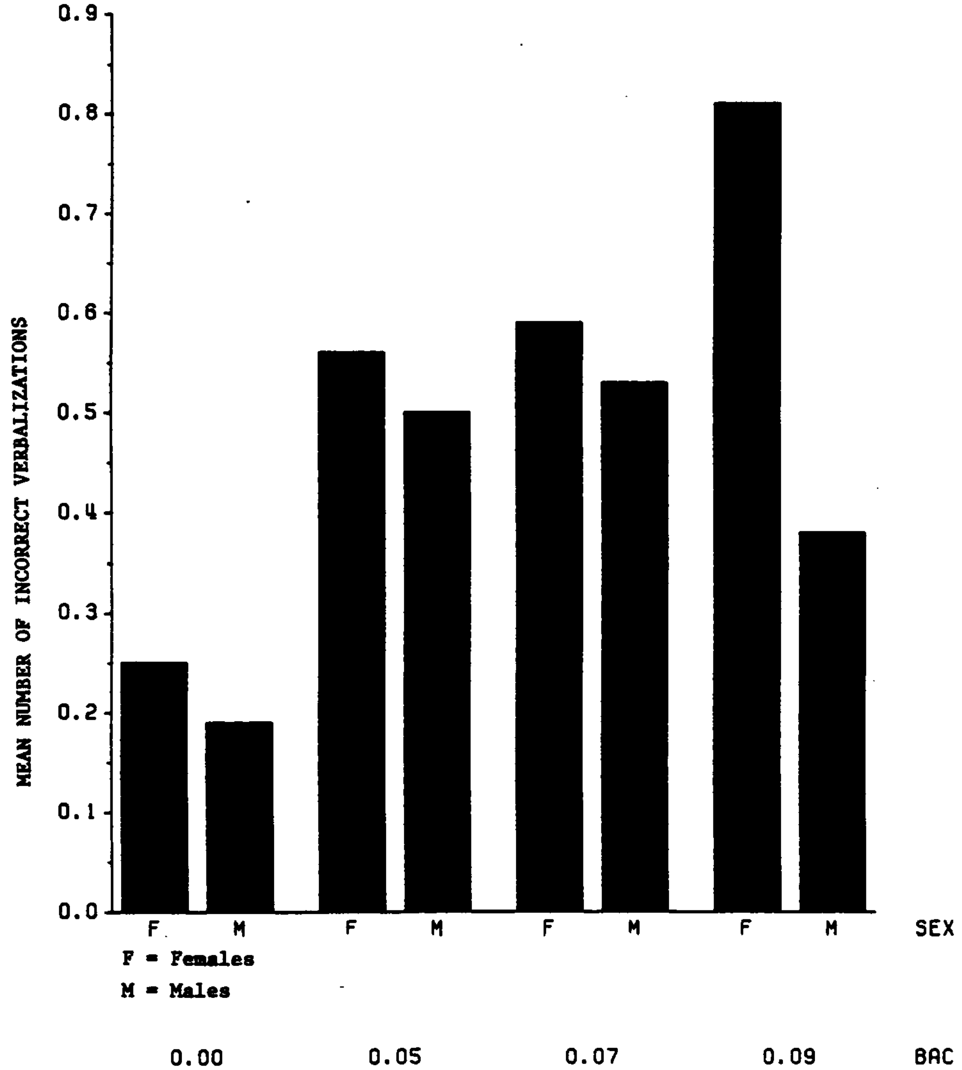
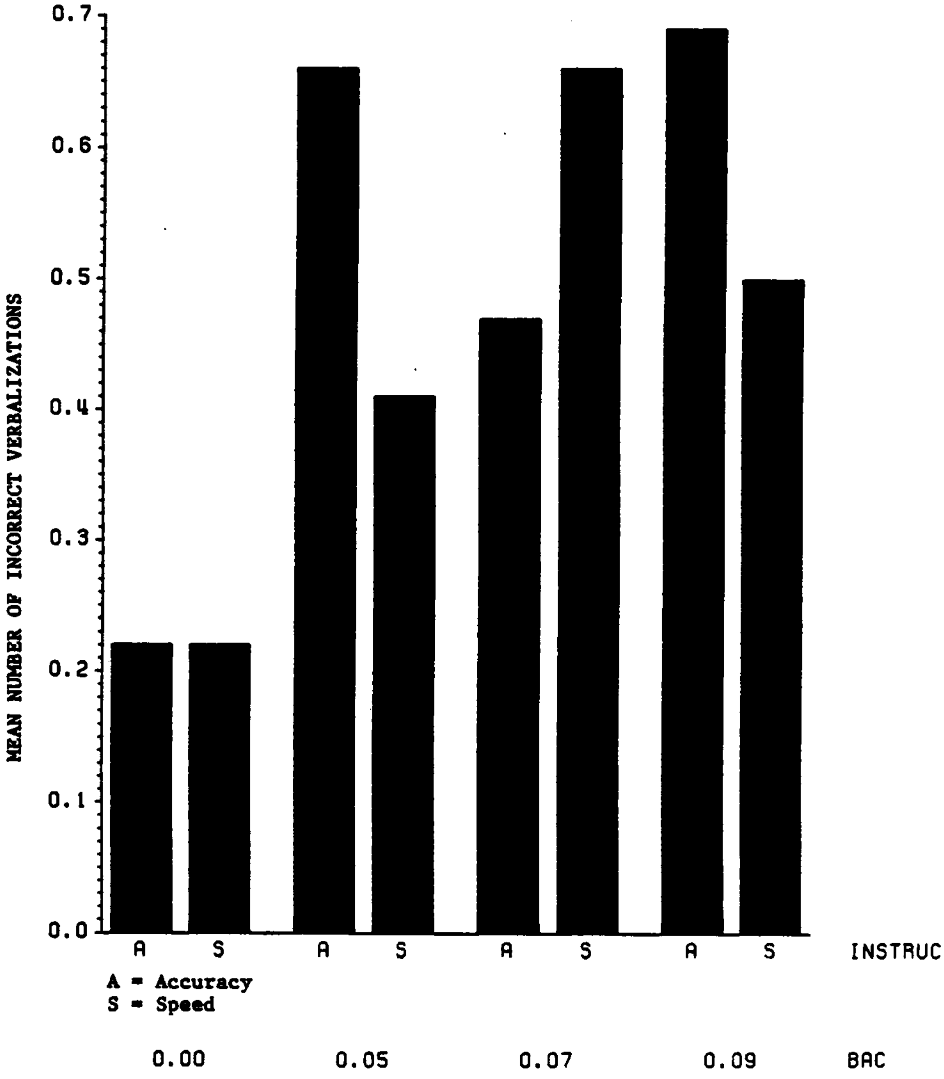


Figure K7: Sex x BAC interaction for number of incorrect verbalizations.



where INSTRUC = Instruction.

Figure K8: BAC x Instruction interaction for number of incorrect verbalizations.

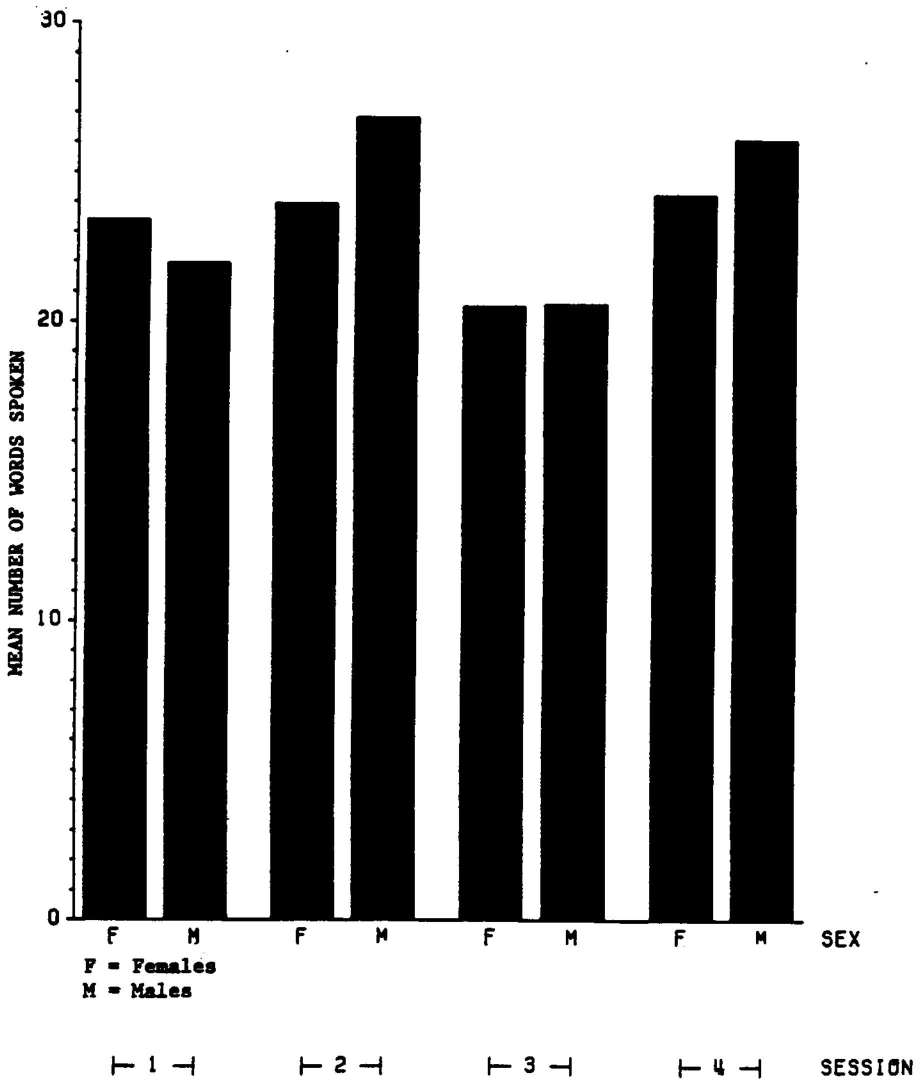
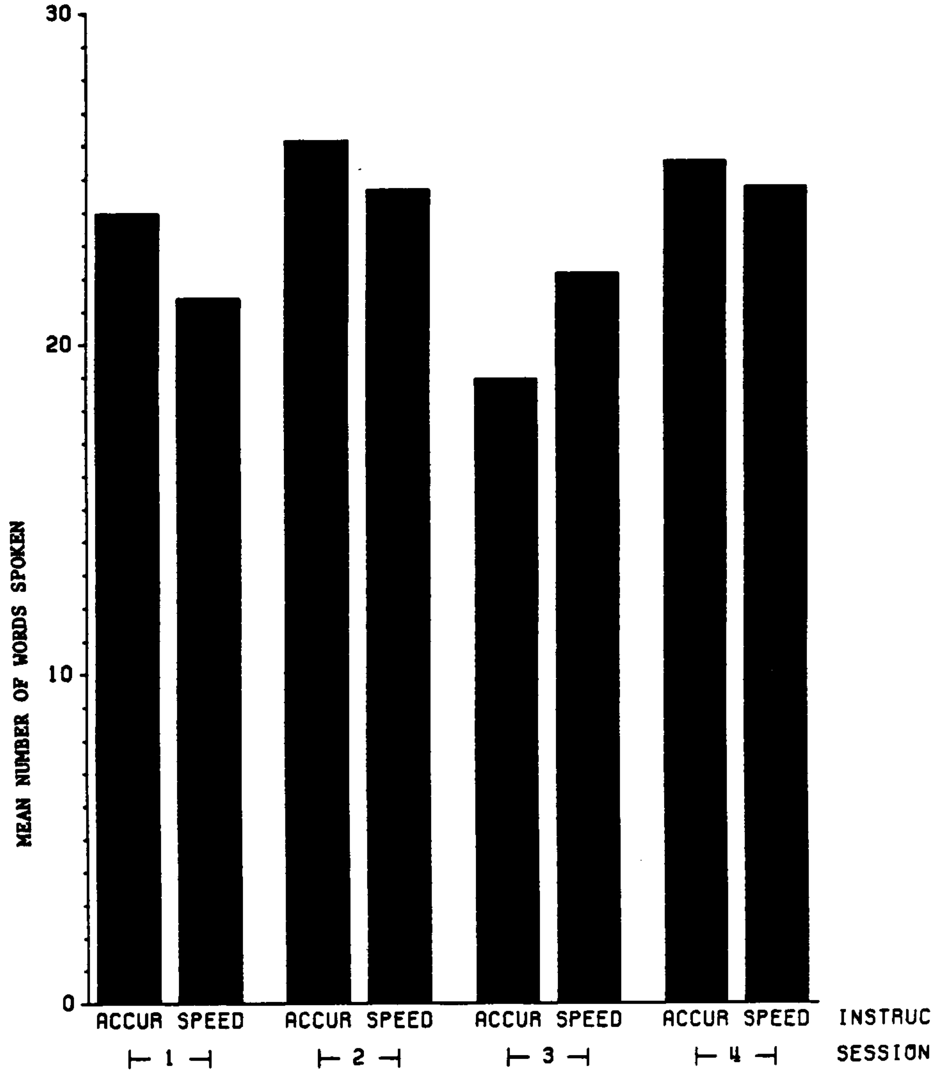


Figure K9: Sex x Session interaction for number of words spoken while verbalizing the pathway.



where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K10: Instruction x Session interaction for number of words spoken while verbalizing the pathway.

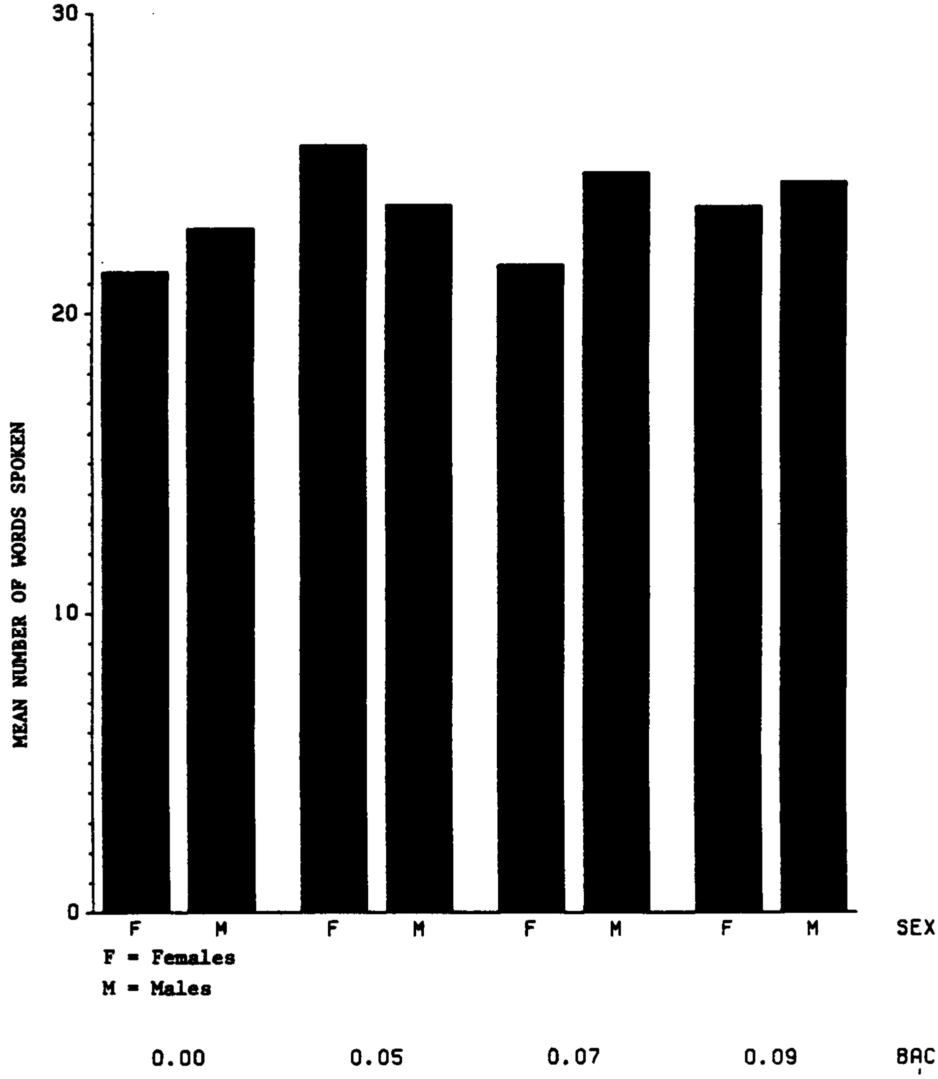
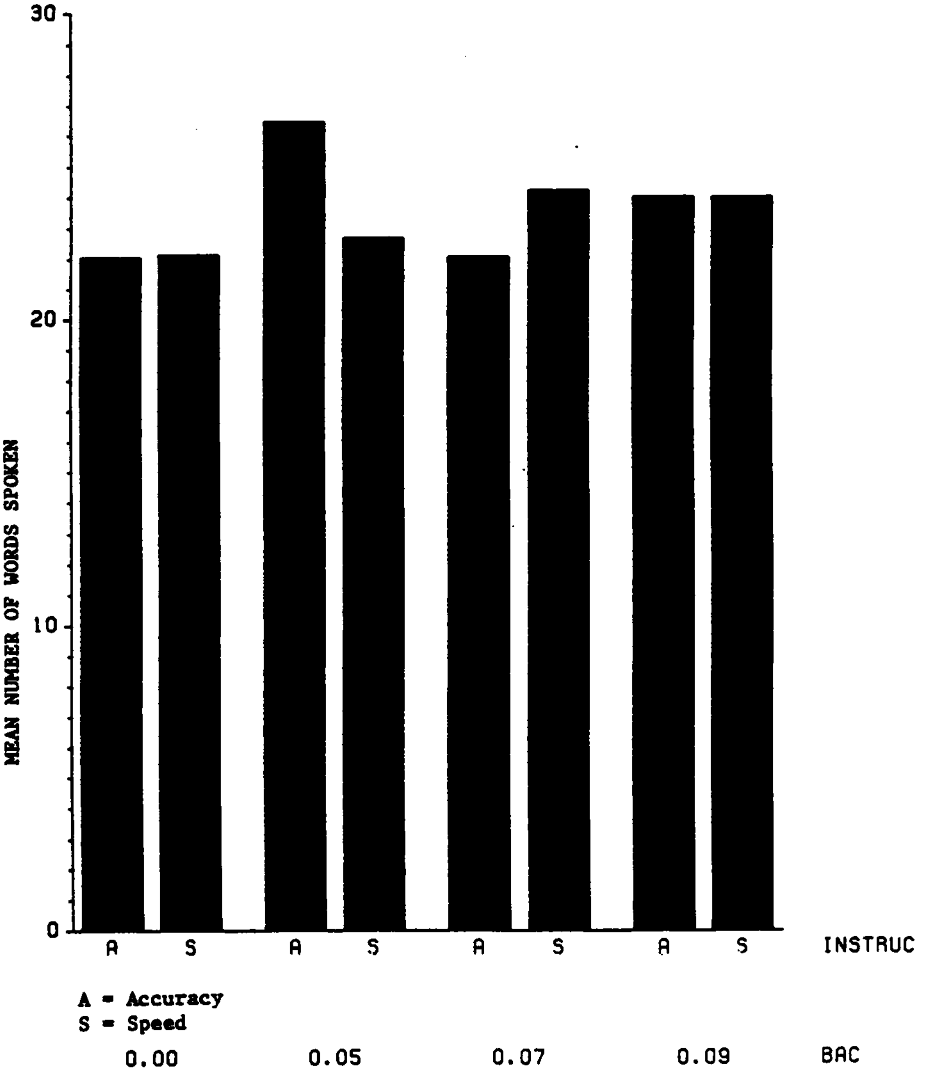
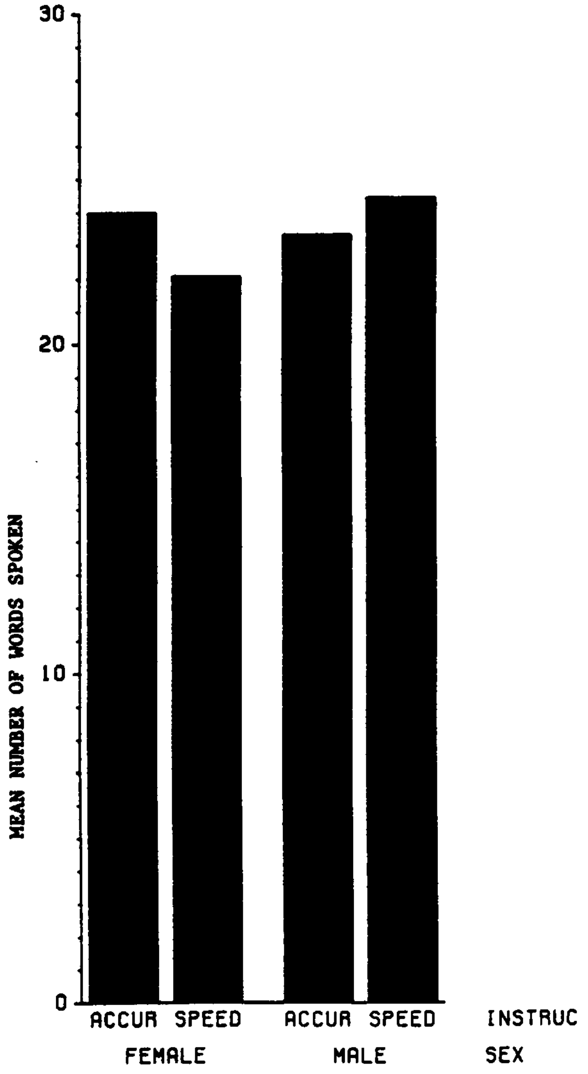


Figure K11: Sex x BAC interaction for number of words spoken while verbalizing the pathway.



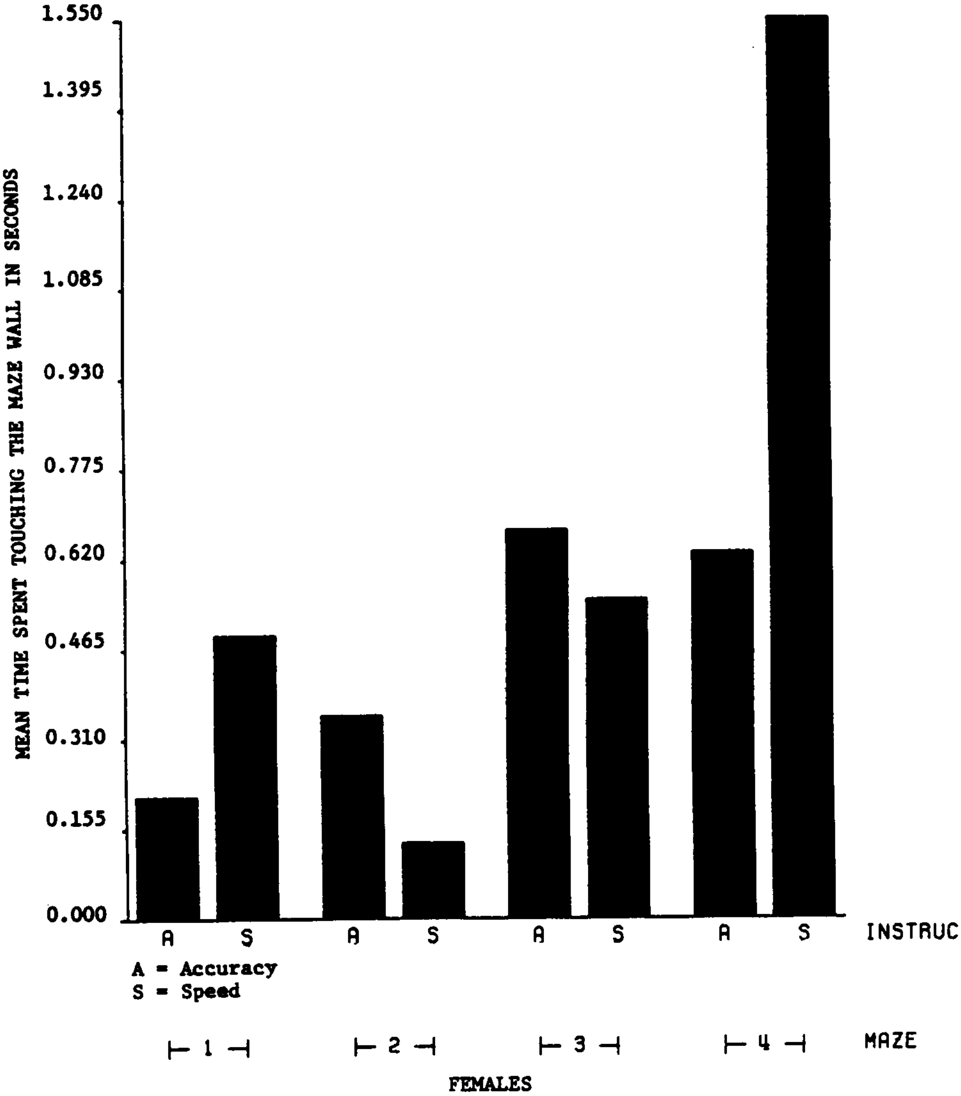
where INSTRUC = Instruction.

Figure K12: BAC x Instruction interaction for number of words spoken while verbalizing the pathway.



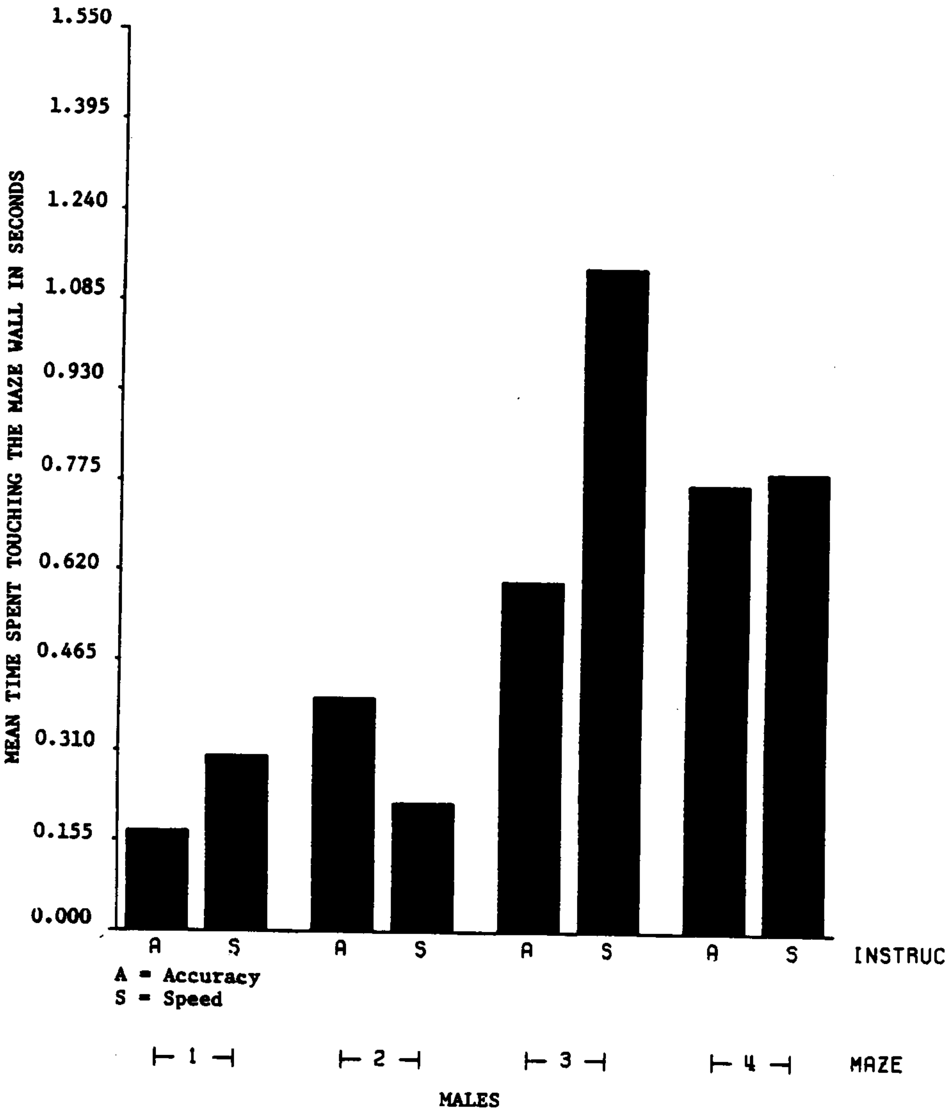
where ACCUR = Accuracy and INSTRUC = Instruction.

Figure K13: Sex x Instruction interaction for number of words spoken while verbalizing the pathway.



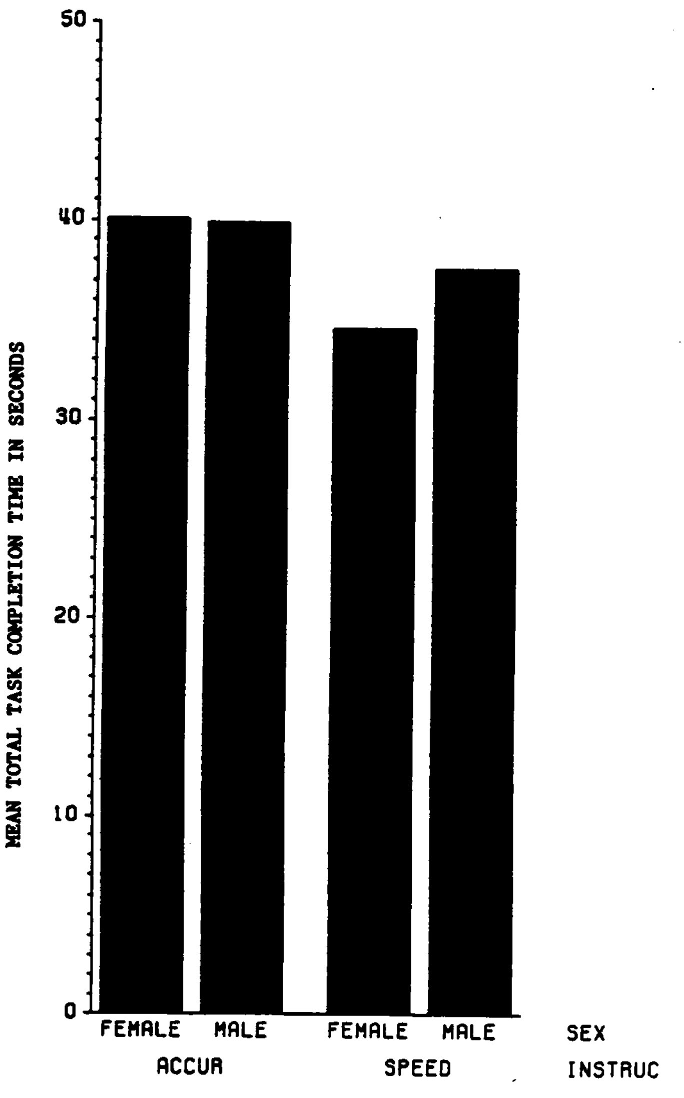
where INSTRUC = Instruction.

Figure K14: Sex x Instruction x Maze interaction for time spent touching the maze walls while tracing the path.



where INSTRUC = Instruction.

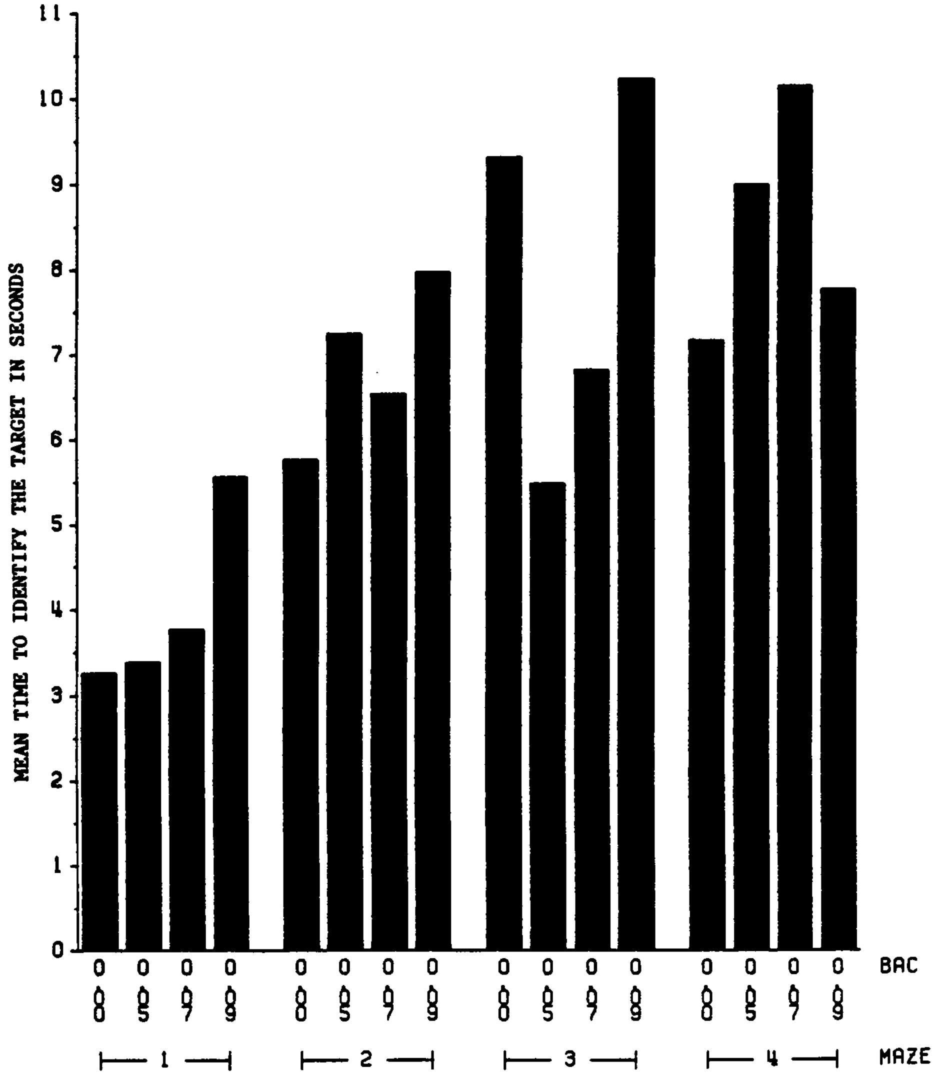
Figure K14 continued.



where ACCUR = Accuracy and INSTRUC = Instruction.

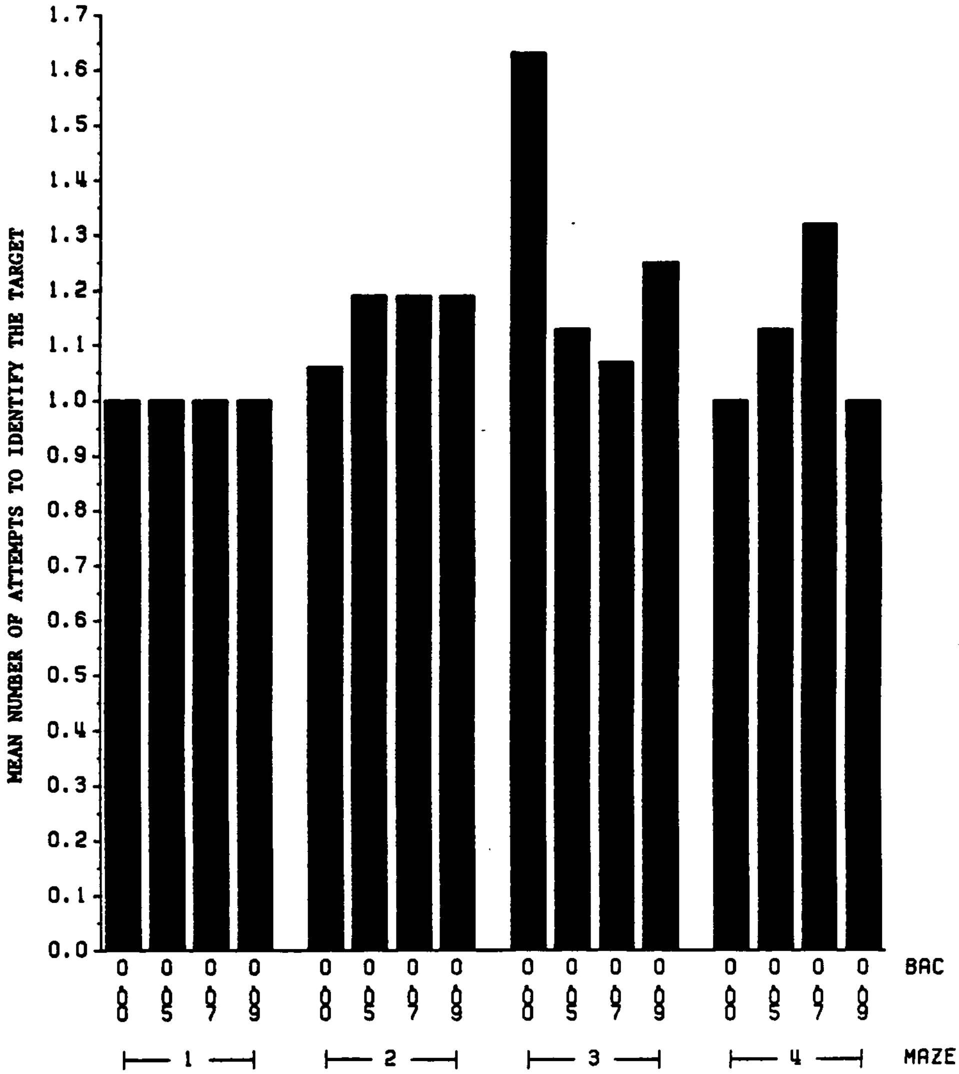
Figure K15: Sex x Instruction interaction for total time to complete the task.

APPENDIX L: GRAPHS OF INTERPRETABLE BAC/MAZE EFFECTS



where BAC = Percent Blood Alcohol Concentration.

Figure L1: Mean times to identify the target for each BAC by maze.



where BAC = Percent Blood Alcohol Concentration.

Figure L2: Mean number of attempts at target identification for each BAC by maze.

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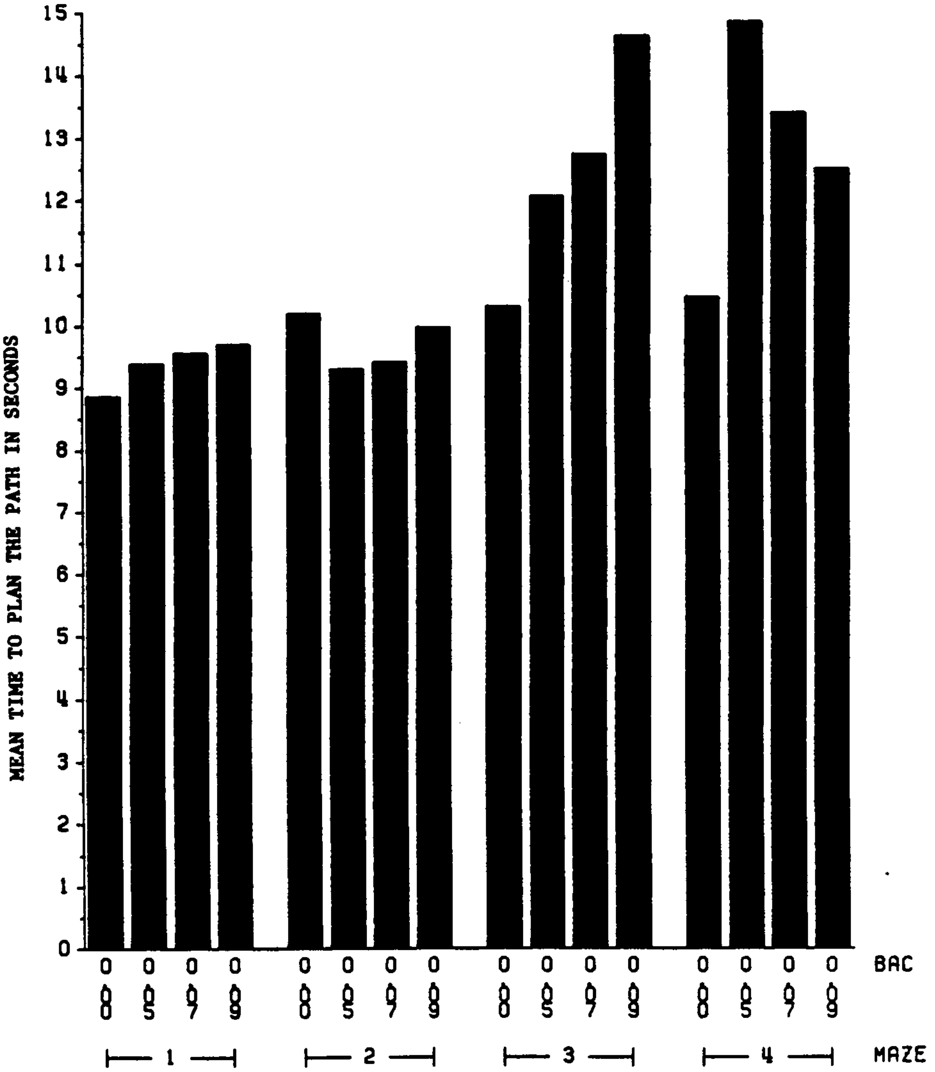
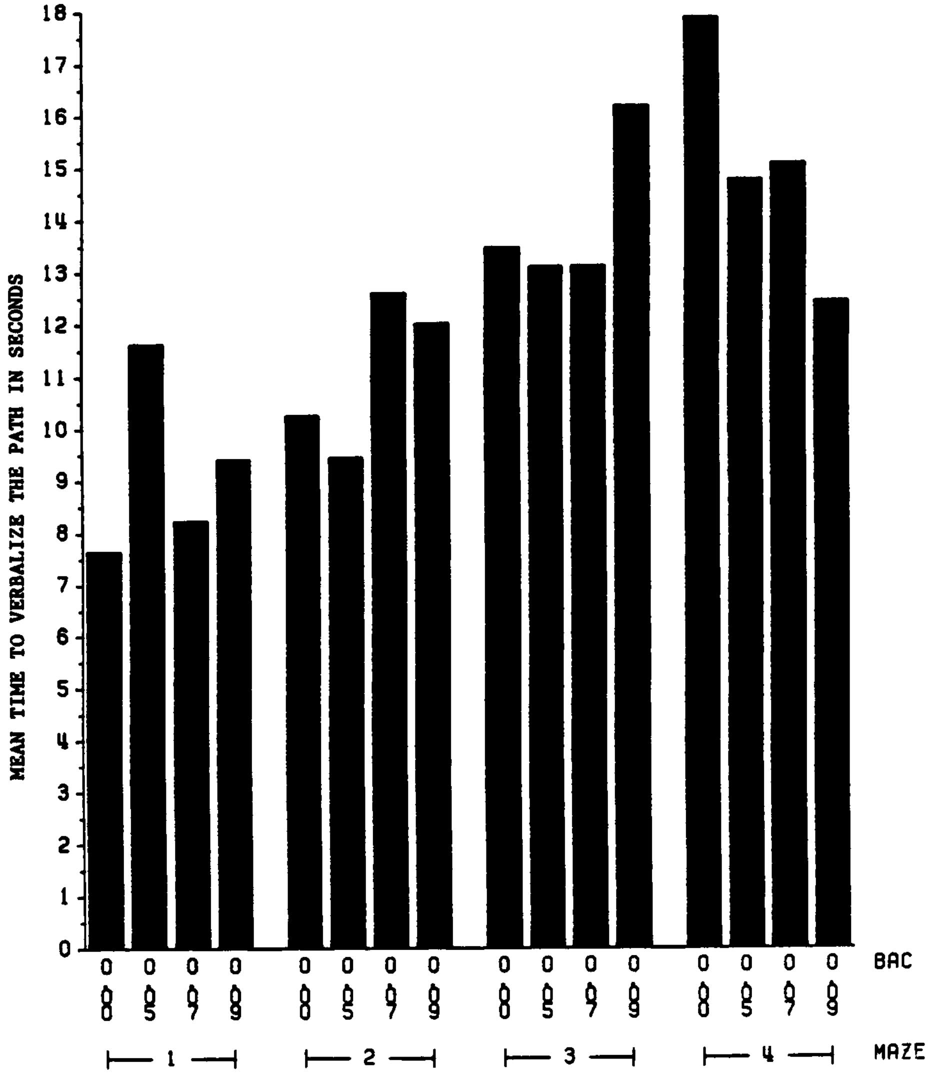


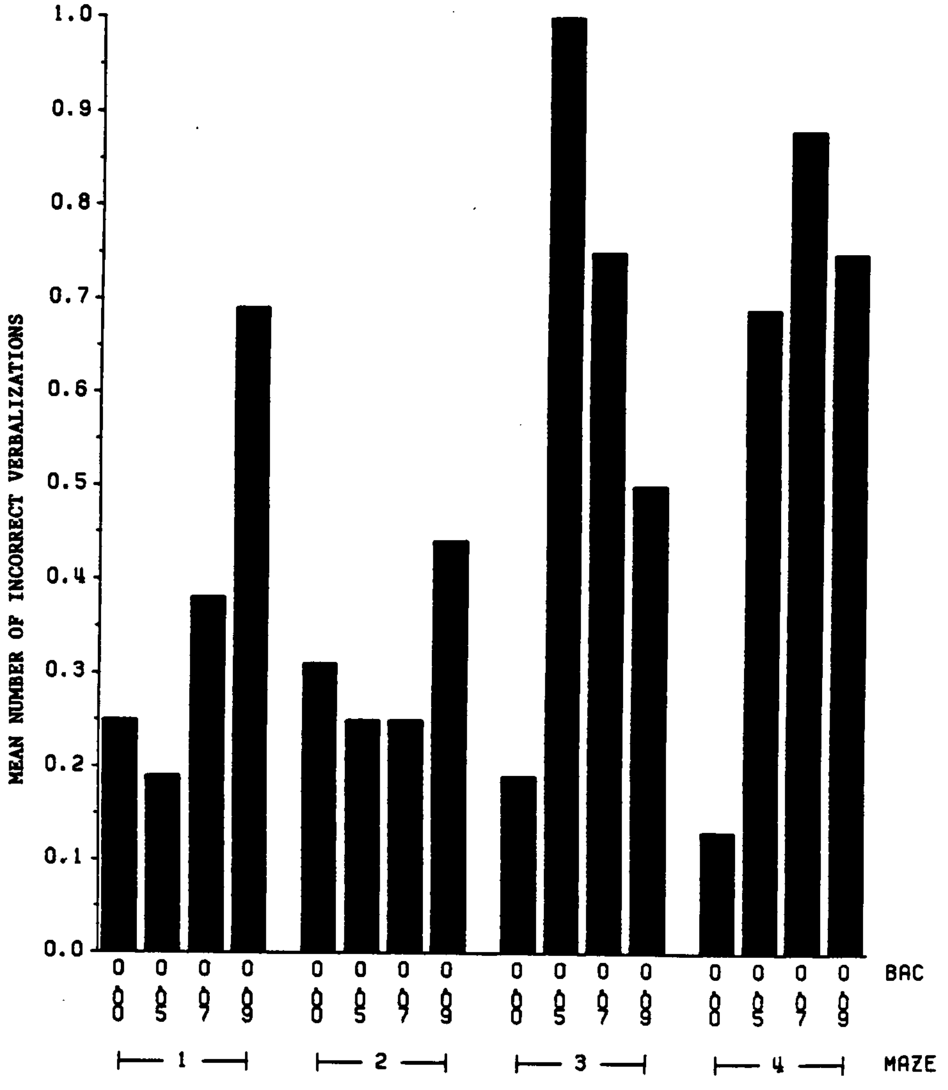
where BAC = Percent Blood Alcohol Concentration.

Figure L3: Mean time to trace the path for each BAC by maze.



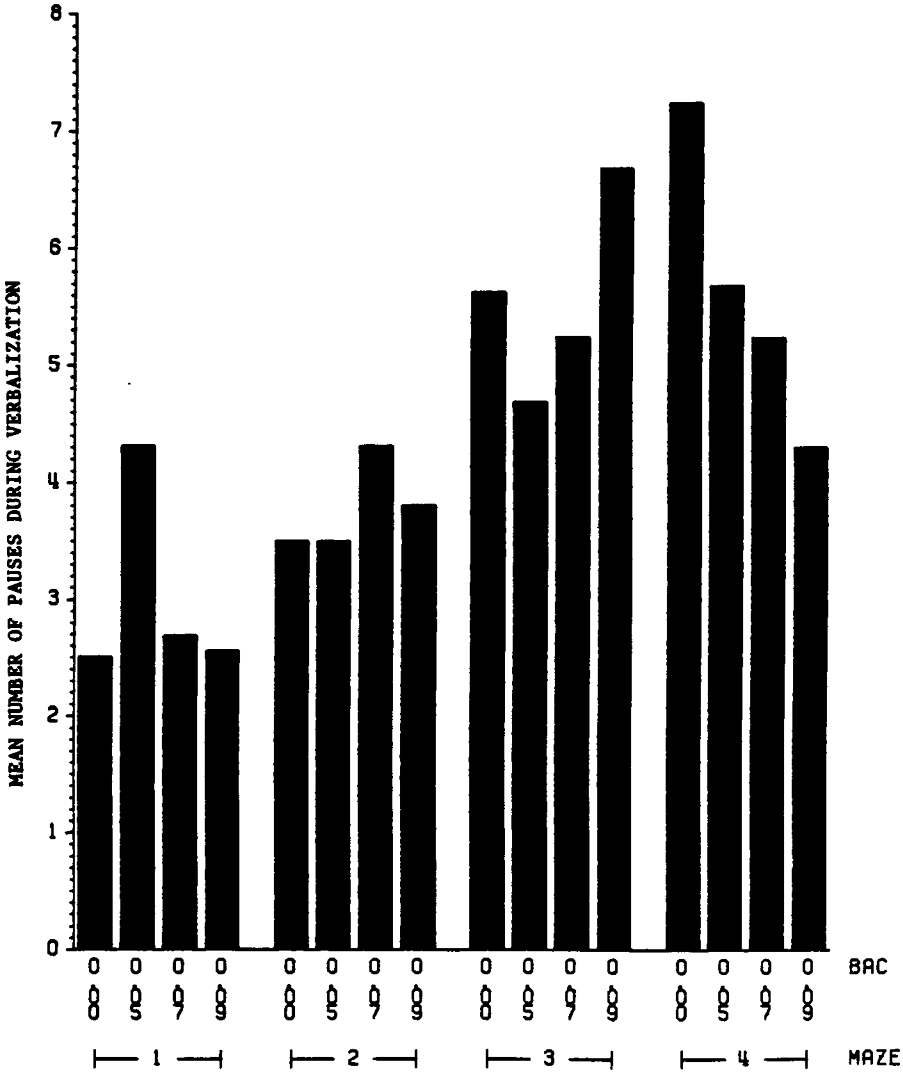
where BAC = Percent Blood Alcohol Concentration.

Figure L4: Mean time to verbalize the path for each BAC by maze.



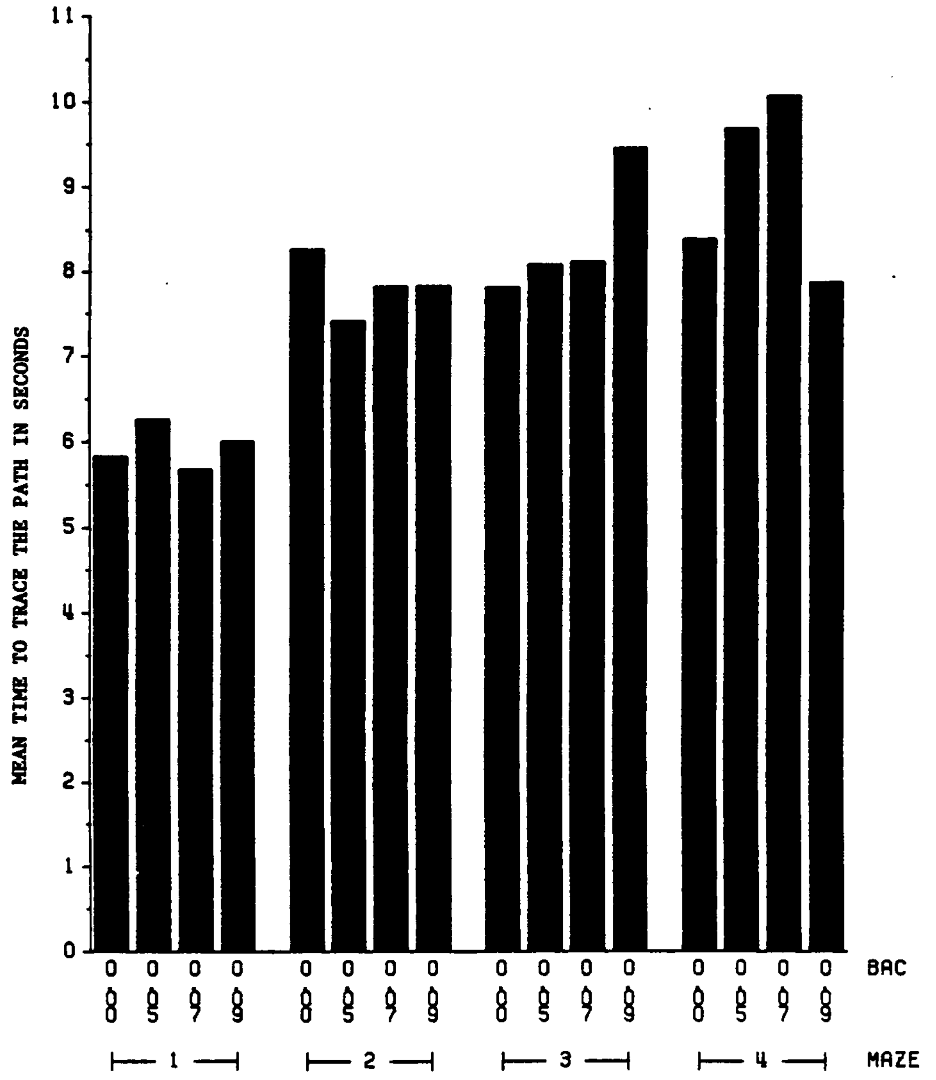
where BAC = Percent Blood Alcohol Concentration.

Figure L5: Mean number of incorrect verbalizations for each BAC by maze.



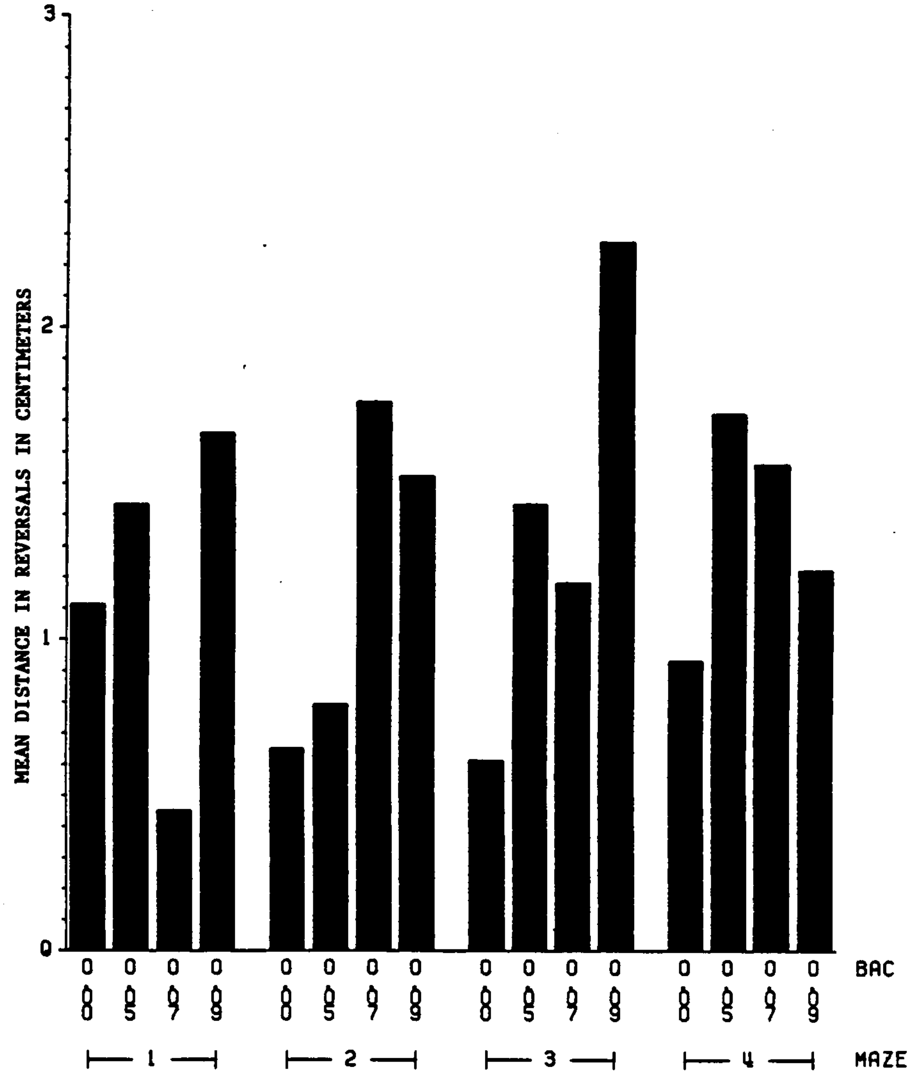
where BAC = Percent Blood Alcohol Concentration.

Figure L6: Mean number of pauses for each BAC by maze.



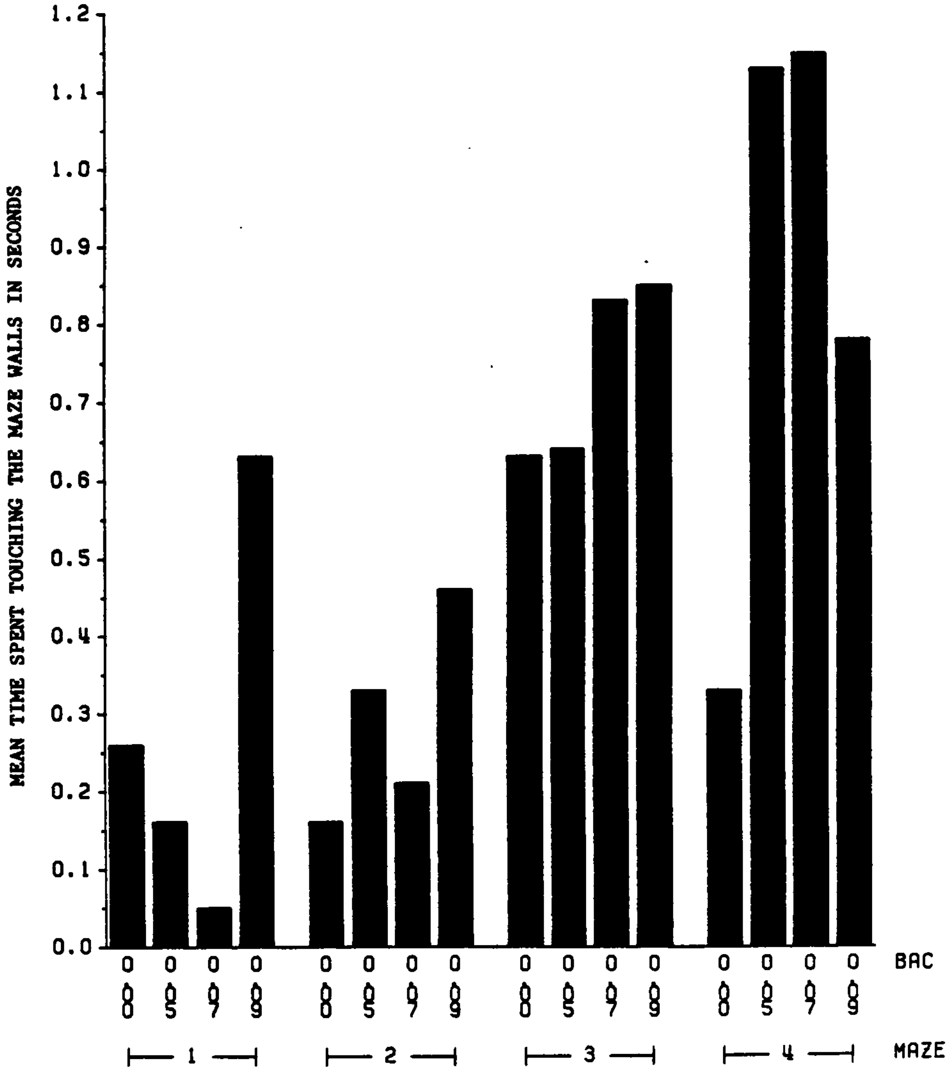
where BAC = Percent Blood Alcohol Concentration.

Figure L7: Mean time to trace the path for each BAC by maze.



where BAC = Percent Blood Alcohol Concentration.

Figure L8: Mean distance travelled in reversals for each BAC by maze.



where BAC = Percent Blood Alcohol Concentration.

Figure L9: Mean time spent touching the maze wall for each BAC by maze.

FOOTNOTES

[1] For dosages greater than 0.1 g/kg, the formula for females, $0.1666d - .0803^2 + 0.0348^3$, was employed since the formula for males gives counterintuitive results at dosages greater than 0.10% BAC. For doses above 0.1 g/kg, then, the estimated BACs given herein most likely underestimate the actual BACs of male subjects.

[2] One exception is that, on the first night the experiment was conducted, mouth rinses were omitted on the specimen collected immediately following the experimental task due to an oversight on the part of the experimenter. This probably accounts for the one abnormally high BAC reading at the 0.09% level shown in the BAC range data.

[3] Mr. Styles is an employee of the Commonwealth of Virginia Consolidated Laboratories Forensic Science Division and is involved in the testing of such instruments.

[4] Parenthetical comments were not spoken aloud on the tape.

[5] Information regarding computer implementation of PRESS can be obtained from Mrs. Sharon Myers of the Virginia Tech Department of Statistics.

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