THE EFFECTS OF ALCOHOL ON THREE LEVELS OF COMPLEX HUMAN BEHAVIOR

by

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Thesis

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Abstract of the Effects of Alcohol on Three Levels of Complex Human Behavior by Grady V. Maraman, Department of Physiology, Medical College of Virginia, Health Sciences Center, Virginia Commonwealth University, June 1970.

The effects of alcohol on three levels of complex human behavior were studied in twelve male subjects between the ages of 21 and 35 using the LRC Complex Coordinator. Each level of complexity contained an increasing component indicative of cognitive behavior. The motor component of all three levels was maintained approximately constant. The blood alcohol concentrations studied were 0.000, 0.010, 0.050, and 0.100 percent, as determined with the Breathalyzer^{R}. Alcohol was administered in the form of 50 percent ethanol mixed with frozen orange juice concentrate. All blood alcohol concentrations were studied in the same subject during one test session. The study was replicated. The study was repeated twice without alcohol.

Analysis of variance was performed on the data for ten subjects using as dependent variables the time to perform 100 problems and the total errors for all four limbs for 100 problems. The variability between subjects was significant for both the alcohol test sessions and the control sessions. The variability due to blood alcohol concentrations was significant only for the test sessions during which the subjects received alcohol. The variability due to complexity of the task was significant for both the alcohol and control test sessions. There was a component of variability which indicated that the subjects responded differently to the increasing complexity. When the time to

perform 100 problems was analyzed, there was an indication that as the task became more complex the alcohol effect became more pronounced but this did not hold true when the total errors per 100 problems was analyzed. When the time to perform 100 problems was analyzed, there was a component of variability that indicated that all subjects responded in the same direction to increasing blood alcohol concentrations but this relation did not hold when the total errors was analyzed.

Data are presented which indicate that cognitive processes were not affected by these blood alcohol concentrations. Performance on all three tasks was affected significantly; however, the effect of the alcohol appeared to be on the subject's ability to make precision positioning movements of the limbs.

This thesis by Grady Vancil Maraman is accepted in its present form as satisfying the thesis requirement for the degree of Doctor of Philosophy.

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The author was born on a farm in [redacted] He attended the Covington County High School in Florala, Alabama, and graduated in 1955. In 1955, he applied for admission to the second class of the U.S. Air Force Academy. While awaiting notification of acceptance or rejection he enlisted for a four-year tour in the Air Force where he served as a nuclear weapons specialist. He was not accepted for the second class for the Academy and was married to the former Charlotte Ruth Johnson of Florala, Alabama, in 1956 making him ineligible for any future classes at the Academy.

While stationed at Langley Air Force Base in Hampton, Virginia, he started his college education with the George Washington University. Following his discharge from the Air Force in 1959, he enrolled in the school of engineering at Auburn University. Since receiving the degree Bachelor of Engineering Physics in 1962 from Auburn University, he has been employed by the NASA-Langley Research Center in Hampton, Virginia, as an Aero-Space Technologist. His first three years with NASA were spent in engineering management. The past five years have been spent in man-machine systems engineering. During this time the author has completed a number of graduate courses at the Virginia

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CHAPTER 1

INTRODUCTION

1.1 Survey of Pertinent Literature

That alcohol affects human behavior has been known for centuries. However, how and why it affects behavior has not been precisely established despite extensive research and study. The inconsistent action of alcohol at different doses on different tissue systems and on different response systems has been well documented (Kalant referenced in 39). The exact sites of action of alcohol in the central nervous system and the relative influence of each of these sites in cognitive and motor behavior are not known. The primary purpose of this experiment was to study the effects of blood alcohol concentrations below 0.100 percent[1,2] on the motor and cognitive components of complex human behavior using replicable and quantifiable measures.

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[1]Blood alcohol concentrations are reported in so many different units that a review of the literature can lead to confusion. The most common unit for blood alcohol concentration is percent and this unit will be used throughout this study. Percent blood alcohol is not a true percent on a weight/weight or volume/volume basis but is defined on a weight/volume basis. Other units used are mg%, mg/cc, and per mil. 0.10 percent = 1.00 mg/cc = 1 per mil = 100 mg%. Sometimes blood alcohol is reported on a weight/weight basis and this is more difficult to compare. Some investigators only report the dose of alcohol given as grams alcohol/Kg body weight. In this case it is impossible to compare the dose to a given blood concentration.

[2]In this literature review, only those experiments in which the blood alcohol concentrations studied were below 0.150 percent are discussed.

The importance of the question on the effects of alcohol on human behavior has received impetus from the automobile and more recently from the airplane. Drinking automobile drivers are involved in more than their share of accidents (2) and alcohol may contribute significantly to aircraft accidents. While many aspects of complex behavior may be affected by alcohol, operation of machines such as the automobile and the airplane in the public domain, where lives are affected, demands that the effects of alcohol on complex human behavior be understood. Mohler, Berner, and Goldbaum (41) reported that in 1967, 23 percent of the aircraft accidents investigated toxocologically presented blood alcohol levels in excess of 150 mg percent. Harper and Albers (27) reported the study of 158 general aviation fatal accidents in which routine toxicological examinations were performed on the pilots. These 158 accidents represented one-third of the total number of general aviation fatal accidents for the year 1963. It was found that 56 of the 158 cases were positive for blood and/or tissue alcohol, representing 35.4 percent of the total general aviation fatal accidents study. Although the positive alcohol group contributed to over one-third of the general aviation fatal accidents, it should be noted that this group comprised less than 0.6 percent of the total general aviation population.

In attempts to identify the behavioral effects of alcohol on man, numerous measuring systems have been utilized. Automobiles and driving simulators (15, 20, 35, 38, 42, 53) have been popular in studies to

determine why drinking drivers are involved in more than their share of accidents. Aircraft simulators (6, 29, 48, 55) have revealed the effects of alcohol on pilot performance. Numerous psychomotor test devices and complex coordinators (7, 9, 10, 11, 12, 14, 16, 17, 19, 21, 22, 23, 30, 36, 37, 43, 44, 54, 56) have increased man's knowledge of some of the behavioral components influenced by alcohol.

Among the investigators who used automobiles or driving simulators are Loomis and West (38), who used a simulated automobile driving apparatus and found impairment with a blood alcohol concentration as low as 0.05 percent. Mortimer (42) used a tracking task under simulated day- and night-driving conditions and glare at night, and found that a decrement in tracking accuracy of at least 30 percent at a peak blood alcohol concentration of 0.068 percent occurred during both day and night conditions. However, his results suggested that vision may not be seriously affected by small doses of alcohol. Spitler and Trubitt (53) reported that the most significant impairment caused by alcohol on driving skills was inability to make constant and rapid judgments coupled with proper physical coordination. Drew, Colquhoun, and Long (15) used the Miles Motor Driving Trainer with small doses of alcohol and found that the accuracy of steering decreased, mean error increased, and the amount of steering wheel movement increased.

Among the investigators who used airplane simulators or simulated aircraft conditions and reported decrements in performance were Tang and Rosenstein (55), who used a device similar to the one used in the present experiment and found that alcohol alone produced a 12.5 percent

decrease in performance when the blood alcohol concentration was between 44 and 50 mg percent.

Several investigators using various psychomotor test devices and complex coordinators reported a decrement in performance. Idestrom and Cadenius (31), using a battery of psychomotor tests (choice-reaction-time, tapping speed, bimanual hand coordination, critical fusion frequency, standing steadiness, and Bourdon's test), reported decrements in performance which correlated with time after a dose of alcohol. Bohne, Luff, and Trautman (7) tested attention and motor coordination by means of a Bourdon test, a modified Bourdon test, and a psychotechnic device following alcohol consumption. At blood alcohol levels ranging between 0.98 and 1.38 per mil (which is somewhat above the upper limit in this experiment), impairment of attention was observed in all subjects, and the impairment averaged about 48 percent. Disturbances of coordination and synchronization of hand movements, indicating impairment in depth perception, were observed.

Nagatsuka and Maruyama (44) found that alcohol affected performance (motor action) and, hence, weakened motor inhibition. In a descriminative reaction test, the mean reaction time increased. Alcohol did not increase the error in choice reaction but did delay the response. It was concluded that alcohol reduces the function of consciousness and retards reaction performance. Cass and Frederik (14) used the Performance Indicator (a machine which measures response time to a stimulus of lights) and found that when they gave their subjects 1.5 ounces of whisky in water every 30 minutes and scored their

performance every 30 minutes, the subjects showed a shift to longer reaction times and an increase in errors at 1.5 hours and at 2.5 hours, corresponding to 4.5 and 7.5 ounces of whisky, respectively.

Boyd, Morken, and Hodge (9) developed a psychomotor test to demonstrate a depressant action of alcohol. The instrument measured reaction time modified by elements of choice and of memory. The results of the second and third tests in three annual classes of medical students, with each student serving as his own control, showed a net increase in response time of about 14 percent after the ingestion of 45 ml of alcohol. Grüner (26) found that tenacity and vigilance suffered greater on the rising phase of the blood alcohol curve than on the falling phase. Goldberg (24 and 25) determined that performance on objective tests suffered from alcohol. He also found at least three different types of ocular phenomena: positional nystagmus, alcohol gaze nystagmus, and roving ocular movements. Gibbs (23) found that decision processes as measured by response latencies and errors suffered from small doses of alcohol but found no significant effect on simple reaction time. Hutchinson, Tuchtie, Gray, and Steinberg (30) studied the effect of alcohol on mental functions and showed that mental functions were not uniformly affected. They concluded that impairment can occur at relatively low concentrations of blood alcohol.

Joyce, Edgecombe, Kennard, Weatherall, and Woods (32) concluded from a study on the potentiation by phenobarbital of ethanol that if speed and confidence on judgment are the criteria, then alcohol stimulated and phenobarbital depressed performance; but if accuracy and correctness of judgment are the criteria, then phenobarbital stimulated and alcohol depressed performance. Moskowitz and DePry (43),

while studying the differential effect of alcohol on auditory vigilance and divided attention tasks, found an effect on a divided attention task but no effect on auditory vigilance. It was the process of divided attention which was susceptible to alcohol but not the tasks comprising the divided attention situation. Forney and Hughes (19, 21) found that verbal output, reverse reading, reverse count, addition, and progressive reading were affected by alcohol, but there was no effect on verbalization, forward or progressive counts, or subtraction.

Although this review indicates sufficient evidence that alcohol impairs performance, other investigators have been unable to measure performance decrement caused by alcohol. A few have even reported facilitation. The investigators in this case who have used automobiles or driving simulators are Forney, Hughes, Hulpieu, and Davis (20), who found that performance in a gymkhana sports car event improved at a blood alcohol concentration of 0.050 percent as measured by average scores. There was one event (reversing through pylons) in which there was significant impairment. Landauer, Milner, and Patman (35) used three motor skill tests related to driving ability to study the effects of alcohol and amitriptyline. On the simulated driving test, alcohol alone caused very little, if any, decrement in performance, the dot tracking test performance actually improved, and with the pursuit rotor test there was no change in performance.

Investigators who have used either aircraft simulators or simulated aircraft conditions and reported no effect or improvement with alcohol are Higgins, Davis, Vaughn, Funkhouser, and Galerston (29), who were

unable to detect significant differences in performance due either to alcohol or hypoxia while studying the effects of alcohol at three simulated aircraft cabin conditions. Synergistic effects were observed. Pearson (48) studied alcohol-hypoxia effects on operator tracking, monitoring, and reaction time. Tracking data suggested both a separate effect of alcohol and an alcohol-hypoxia synergism, but these were not supported statistically. Monitoring performance was found to improve significantly with time on task, a finding which contrasts with traditional conceptions of skill fatigue.

Other psychomotor tests or complex coordinator studies resulted in no effect or improvement with alcohol. Laties and Weiss (36) studied the effects of alcohol on timing behavior as measured in terms of pauses between successive responses, or inter-response time. The mean number of responses was comparable on the two occasions when the subjects received orange juice and when they received 0.5 g of alcohol in orange juice per kg of body weight, and the inter-response time did not change. To prevent the subjects from counting, they were given the same task and were asked to do concurrent continuous subtraction of the number 17 beginning with 1000. In this case, the mean number of responses dropped with alcohol. Frakenhaeuser, Myrsten, and Jarpe (22), using four tests of intelligence (verbal, numerical, inductive, and spatial) following an oral dose of 0.8 g of absolute alcohol per kg of body weight, found that numerical and spatial test performance was significantly impaired, whereas verbal and inductive test performance was unaffected. Performance speed was less affected than accuracy. As the inductive test is

considered the most complex, the results do not confirm the belief that the more complex tasks are those affected by alcohol.

Talland (54) found that performance in continuous attention tasks in alcohol addicts and control subjects was not significantly affected by alcohol when working in isolation. Working under competitive instructions in a group setting, alcohol impaired accuracy in both types of subjects. Carpenter, Moore, Snyder, and Lisansky (11) found that problem solving efficiency on the "calculus method" was a curvilinear function of alcohol doses. A dose of 0.33 ml per kg of body weight facilitated problem solving efficiency, while a dose of 1.0 ml per kg of body weight decreased efficiency. They also found that task relevant activity increased linearly with higher doses. Carpenter and Ross (12), using the Running Matching Memory Task to study the effect of alcohol on short-term memory, found that the effect of alcohol on total error was related to the initial performance level of the subject. Subjects with the highest degree of skill showed linear deterioration with increasing doses, but subjects with less proficiency showed improvement at low doses and less absolute deterioration than the best subjects. Improvement in performance was suggested at approximately 0.024 to 0.055 percent blood alcohol concentration with obvious deterioration not occurring until the blood alcohol exceeded 0.070 percent. Forbes (17) concluded that reaction time readings cannot be applied as definite tests for the determination of the degree of alcoholic intoxication because of individual differences and the considerable overlaps observed in the reaction times of the clinically fit and unfit men.

Vogel (56) found evidence from the complex task measure of the Toronto Complex Coordinator to support the hypothesis that after either one or two alcoholic drinks (at blood alcohol concentrations between 0.10 and 0.80 mg per cc) better adjusted men consistently displayed more accurate responses while the performance of more poorly adjusted men did not increase in accuracy until they had taken two alcoholic drinks (at blood alcohol concentrations between 0.50 and 0.80 mg per cc). Ferret, Barbut, and Ducos (16) found that seven of twelve subjects who drank 0.5 g of absolute alcohol per kg body weight improved their performance on three classic psychotechnic tests while the alcohol concentration in their blood was high; however, this improvement disappeared with the decrease in alcohol concentration.

Wilkinson and Colquhoun (57) used a choice serial reaction test to study the interaction of alcohol with incentive and with sleep deprivation. Their conclusions were that, behaviorally, a moderate dose of alcohol appears to act as an arouser, not a depressant, except in susceptible subjects who had lost sleep. Buffard (10) studied the psychomotor reactions of 22 subjects after ingestion of a moderate quantity of alcohol (0.12 to 1.0 per mil blood alcohol). The tests included measurements of reaction time, memory, manual dexterity, automatization, and control of gestures and tremors. Except on the tremometer, the subjects performed better after alcohol than in the control tests. Lewis, Dustman, and Beck (37), using blood alcohol concentrations of 0.03, 0.06, and 0.09 percent, found that auditory-pulse-rate discrimination, the ability to position a rod vertically

while seated in a chair in a vertical position with the head inclined at an angle of 30°, and cognitive and motor tasks were not affected by alcohol. Critical flicker fusion was facilitated. Perception of the spiral after effect and visual and somatosensory evoked responses suffered from alcohol.

In 1962, Carpenter (13) reviewed the effects of alcohol on some psychological processes as related to automobile driving skill. Examination of the reaction time experiments indicated that reaction time is lengthened at relatively low blood alcohol levels, but it was concluded that this type experiment would produce more useful results if greater attention were given to such procedural details as the specification of stimulus and response characteristics and the clear separation of results obtained from different sensory modalities. He questioned laboratory behaviors as being valid indicators of driving performance and the traditional idea that intellectual functions are particularly susceptible to deterioration by alcohol. He proposes two hypothesis to account for the findings by some investigators that cognitive or intellectual processes are not adversely affected by alcohol: (1) Intellectual processes, considered in the evolutionary scheme of things, are advantageous only if they are relatively resistant to adverse and unusual conditions. If this were true, the higher processes would be expected to continue to function, within limits, despite increased blood alcohol concentrations. (2) Intellectual functions are not more complex but simpler. (The use of "complex" for "higher" is also an assumption which may only indicate confusion. There is no

necessary reason for "higher" (however it is defined) processes to be more "complex" (however that is defined) than "lower" ones). Since they are simpler, there is less to go wrong; hence they are more resistant to adverse conditions such as alcohol or other forms of intoxication, high altitude, extreme temperature, etc.

These various approaches have resulted in considerable controversy. From the literature it would appear that some investigators felt obligated to report a decrement in performance caused by alcohol, or if no decrement occurred, explain why they were unable to measure a decrement. Mello (39) concludes that there have been few systematic attempts to determine dose effect curves for alcohol on quantifiable and replicable measures of behavior.

1.2 Objectives

Various investigators have reported both facilitation and deterioration in performance caused by low to medium doses of alcohol. Other investigators have been unable to measure any changes caused by these same blood alcohol concentrations. These results appear to be products of the different types of tasks used. Most investigators report that alcohol has diverse effects on behavior. This can be interpreted to mean that the various components of behavior are affected differently.

Conceivably, the controversy in the alcohol literature might be resolved if complex behavior is broken down into a sensory component, a motor component, and a cognitive component, and each component studied separately. Blood alcohol concentrations must be controlled in order to determine dose-response relationships. In order to control blood alcohol

concentrations, an analysis of blood alcohol concentrations is necessary. Since the blood concentration is dependent on the past history of the subject as well as the quantity of alcohol consumed, reporting the alcohol dose is not sufficient.

The object of this study was to test the hypothesis that alcohol at low to medium concentrations in the blood would facilitate behavior having a large motor component but cause a decrement in behavior requiring cognitive processes. This might be considered the inverse of the two hypotheses proposed by Carpenter.

The test device used to measure changes in behavior was capable of providing quantitative and replicable results. Sensory input was maintained at a constant level. The test contained a large motor component which was approximately constant over three levels of cognitive complexity. The design of the experiment and the analysis of the data considered the differential response of subjects.

CHAPTER 2

METHODS

2.1 Subjects

Twelve male subjects (engineers, engineering technicians, physicists, chemists, and mathematicians from the staff of the Langley Research Center) between the ages of 21 and 35 volunteered as unpaid subjects for this study. The experiments were carried out during the subjects' normal duty hours and the subjects received time off from normal duties for both the experiment and the training prior to the experiment. None of the subjects was a problem drinker and none was an abstainer. The degree of experience with alcohol ranged from very light to medium. Each subject was well motivated to determine the effects of various blood alcohol concentrations on his performance.

A medical evaluation of each subject was required prior to his participation. This evaluation included a complete medical history, physical examination, and laboratory work which included an hematocrit, a white blood cell count, a determination of the blood glucose concentration two hours following a meal, and a liver function test as determined by serum glutamic oxaloacetic transaminase (SGOT). The examinations were performed by Drs. Jess P. Miller and Michael H. Temko.

2.2 Alcohol Doses

Alcohol was administered in the form of 50 percent ethanol; i.e., 200 proof ethanol, U.S.P., was diluted to 100 proof as soon as opened, and then mixed with frozen orange juice concentrate. The orange juice

component and the total volume of the drinks were standard for all subjects. Drink number 1 contained 50 ml of orange juice concentrate plus the required ethanol to produce a blood level of 0.010 percent in a given subject. The concentrate and ethanol was then diluted to 150 ml total volume. Drinks 2 and 3 contained 100 ml of orange juce concentrate plus the required ethanol and then were diluted to 200 ml total volume.

2.3 Breath Analysis for Blood Alcohol

In order to provide rapid on-the-spot analysis for alcohol, a breath analysis was chosen. All breath alcohol analyses depend on the fundamental principle that the distribution of alcohol between pulmonary blood and alveolar air occurs by simple diffusion and like that of other volatile substances, obeys Henry's law. This law states that distribution equilibrium exists, and, consequently, for a given temperature a constant ratio exists between the concentrations of alcohol in the blood and in alveolar air. The accepted mean value of this ratio at the average temperature of exhaled air (34^{o} C) is 2,100:1; that is, 2,100 ml of alveolar air contain the same quantity of alcohol as 1 ml of blood.

A breath analysis provides a blood alcohol concentration measure within a few minutes. Breath as the analyzed material reflects the actual blood alcohol level at the time of the test, without lag or overrun, and is often obtainable nearer the time at issue than other materials. The problem of positive identification of the specimen donor is eliminated. Requirements for the technical background and

skill of the analyst are greatly reduced and required test facilities and costs per test are much lower than for comparable laboratory analysis. There is less objection by the tested subject to collection of a breath sample for alcohol analysis than to the body penetration required to obtain a blood specimen. Multiple, replicable, and serial alcohol determinations at frequent brief intervals are practical. The breath analysis can be expected to yield blood alcohol concentration results within 0.015 weight percent ethanol of those obtained by direct analysis of blood (3).

Of the six breath alcohol tests available, the Breathalyzer[R][1] was selected because it was designed for quantitative breath alcohol analysis (some of the breath tests are for screening purposes only), a complete analysis takes less than six minutes, and the readout is in percent blood alcohol.

The Breathalyzer[R] is designed to trap a constant volume of alveolar air, that is 52.5 ml, at the temperature it leaves the mouth (34° C), and then react the alcohol with potassium dichromate in acid solution. The reaction is as follows

(Yellow) (Green)

$$2K_2Cr_2O_7 + 8H_2SO_4 + 3C_2H_5OH \rightarrow 2Cr_2(SO_4)_3 + 2K_2SO_4 + 3CH_3COOH + 11H_2O$$

The change in color is measured with an integral photoelectric filter photometer. The increased light transmission through the test ampul,

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[1]Developed by Borkenstein and produced by the Stephenson Corporation, Red Bank, New Jersey.

resulting from the color change from the yellow of the dichromate to the green of the chromic sulfate, is measured with a balanced electrical circuit from two photovoltaic cells. A light bulb is mounted on a movable carriage between two ampuls. The distance through which the light must be moved to reestablish the original photometric balance between light transmission through the ampuls prior to analysis is registered by the movement of a coupled pointer across a scale. This scale is calibrated directly in blood alcohol concentration in percent (weight/volume).

Preliminary work in the present study showed that readings of blood alcohol obtained with the Breathalyzer^{R} shortly after drinking alcohol were higher than could be accounted for on the basis of the amount of alcohol consumed. Figure 2.1 shows the readings obtained from the Breathalyzer^{R} after having the subject use various concentrations of alcohol diluted with water or concentrated frozen orange juice as a mouthwash. The alcohol solution was expectorated and the subject rinsed his mouth with water. Clearly, in this case, no alcohol was ingested, yet the Breathalyzer^{R} continued to give a positive reading for alcohol for at least twenty minutes. Using the mouthwash with the higher blood alcohol concentrations caused the Breathalyzer^{R} to read off scale (greater than 0.50 percent) for about five minutes.

To clarify these findings, the experiments were repeated and venous blood samples taken simultaneously with the breath samples. These results are shown in Figure 2.2, in which blood alcohol concentrations determined with the Breathalyzer^{R} are compared to venous blood alcohol

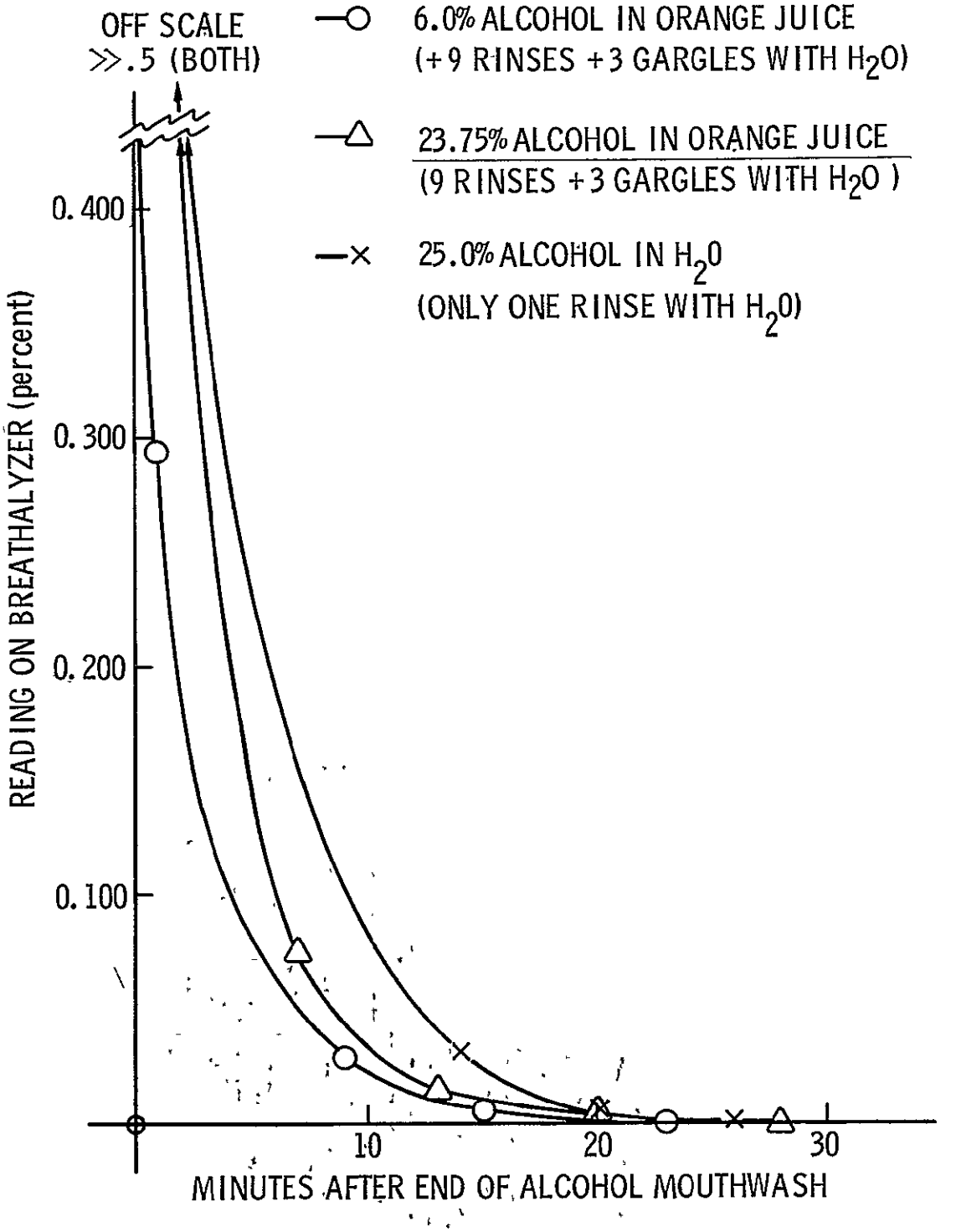

Figure 2.1.- The effect of alcohol used as a mouthwash on Breathalyzer^{R} readings. Data for one subject.

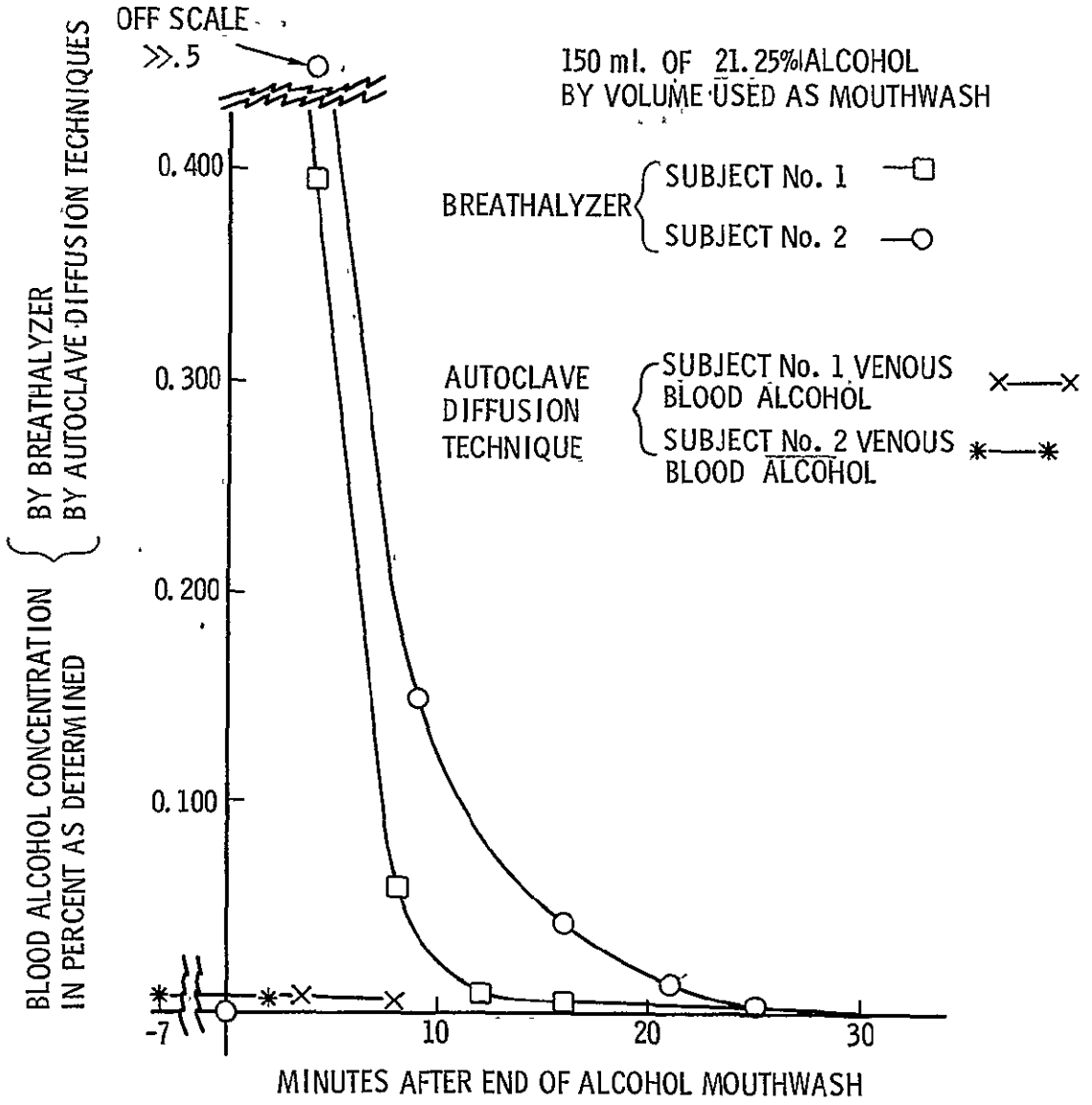

Figure 2.2.- The effect of alcohol mouthwash on Breathalyzer^{R} readings and on blood alcohol as determined by autoclave diffusion technique. Data for two subjects.

concentrations determined by the autoclave diffusion technique. It is clear that the Breathalyzer[R] does not reflect a true blood alcohol concentration until at least twenty minutes after alcohol was last contained in the mouth. Because of this problem, a period of at least twenty minutes was allowed to elapse between the time the subject finished a dose of alcohol and the Breathalyzer[R] readings were taken.

2.4 The LRC Complex Coordinator[2]

2.4.1 Introduction

The LRC Complex Coordinator shown in Figure 2.3 is an electrical device which presents to the subject a set of predetermined stimuli (pattern of colored lights presented on the subject's display panel). The subject responds to these stimulus lights by manipulating four limb controls which cause response lights to glow on the subject's display panel. One set of stimulus lights plus the correct set of response lights is called a problem. A test consists of 50 problems.

2.4.2 Subject's Display Panel

The subject's display panel is shown in Figures 2.4 and 2.5. The display panel is divided into four quadarants. Each quadrant represents the stimuli and responses of one limb. The top left quadrant represents the left hand, top right - right hand, bottom left - left foot, and bottom right - right foot. The five colored lights in the left hand column of each quadrant are the stimulus lights and the five lights in

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[2]Developed by Dr. Jim Scow. See reference numbers 5, 45, 46, 47, 50, 51, 52.

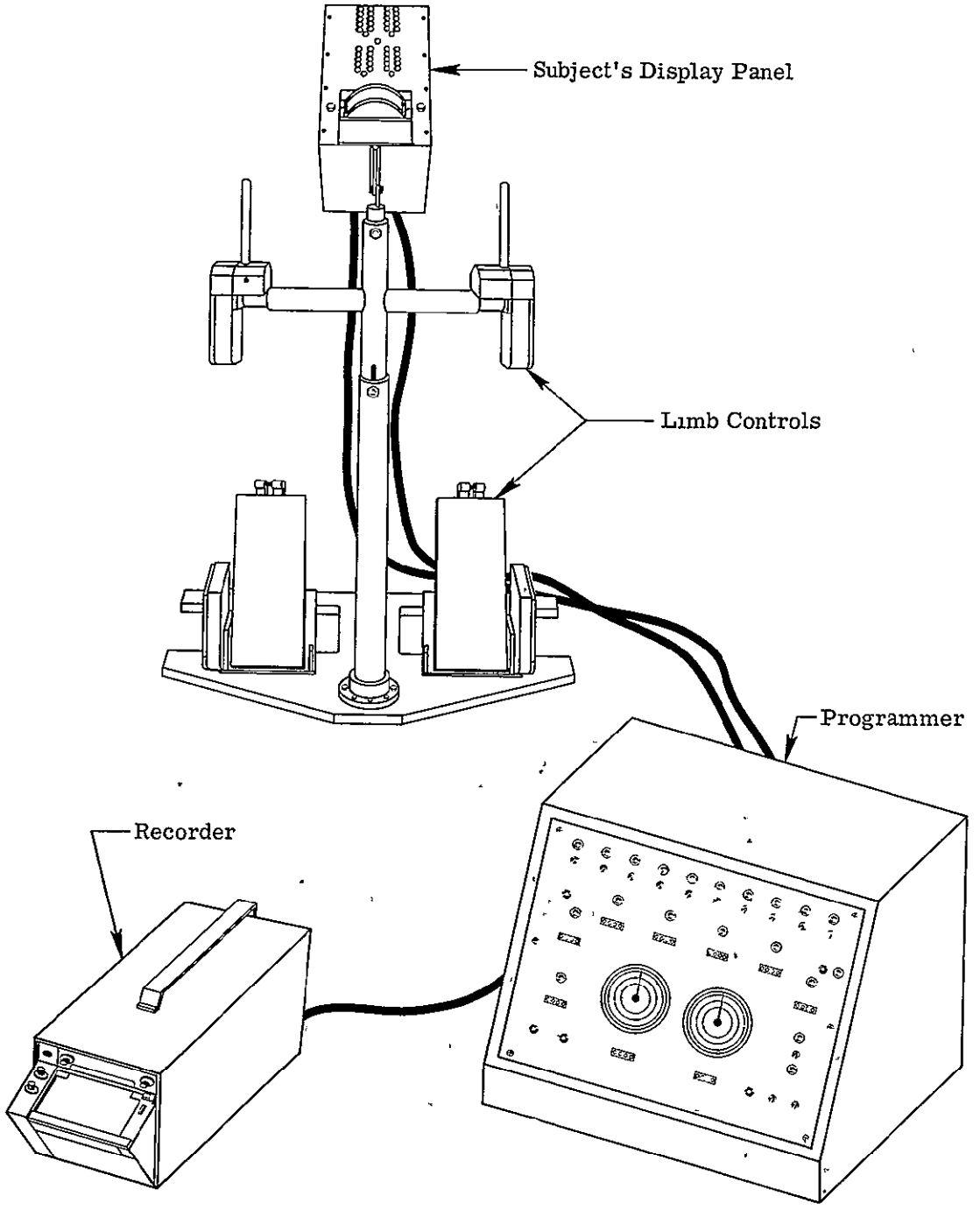

Figure 2.3.- LRC Complex Coordinator.

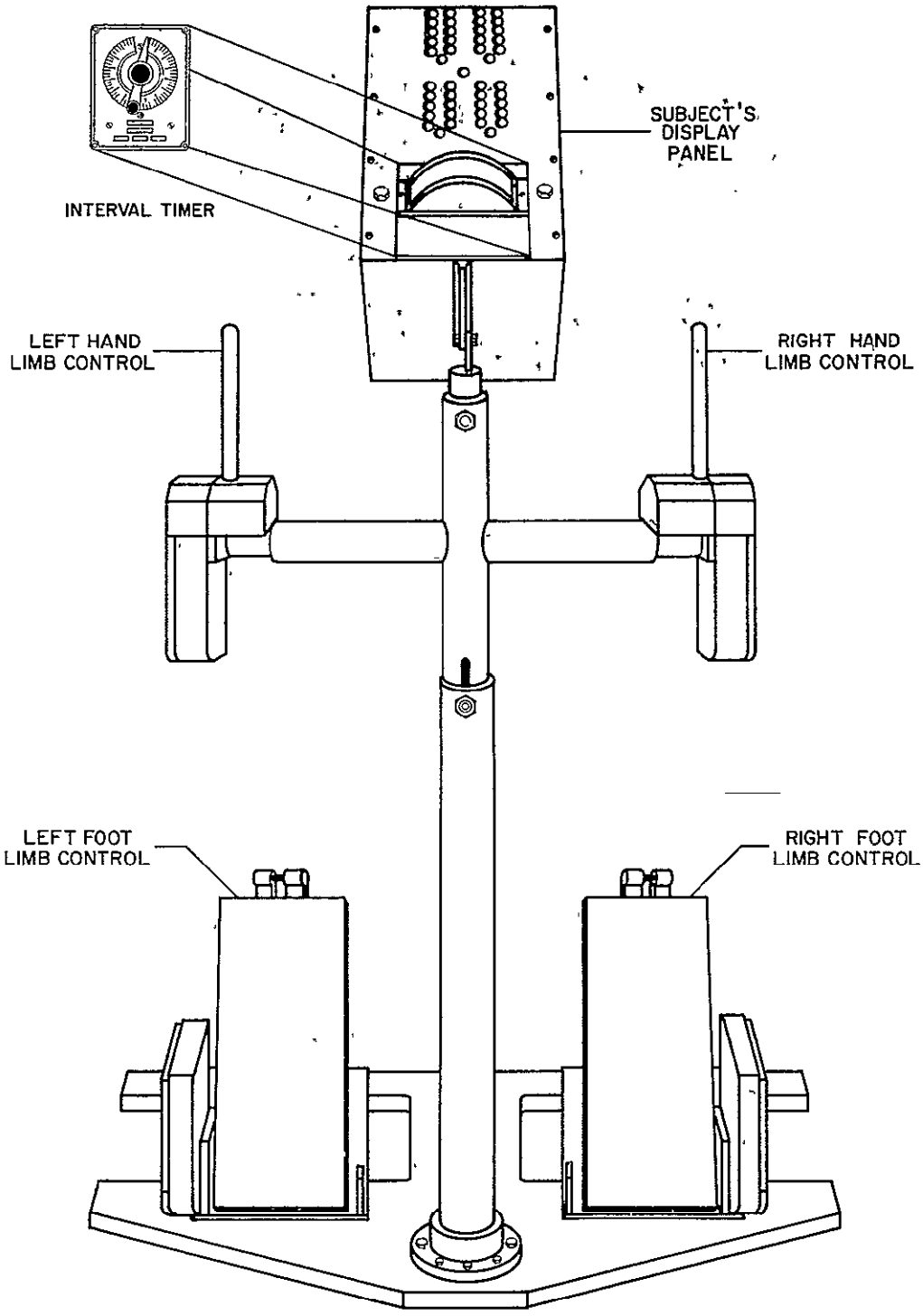

Figure 2.4.- Subject's display panel and limb controls.

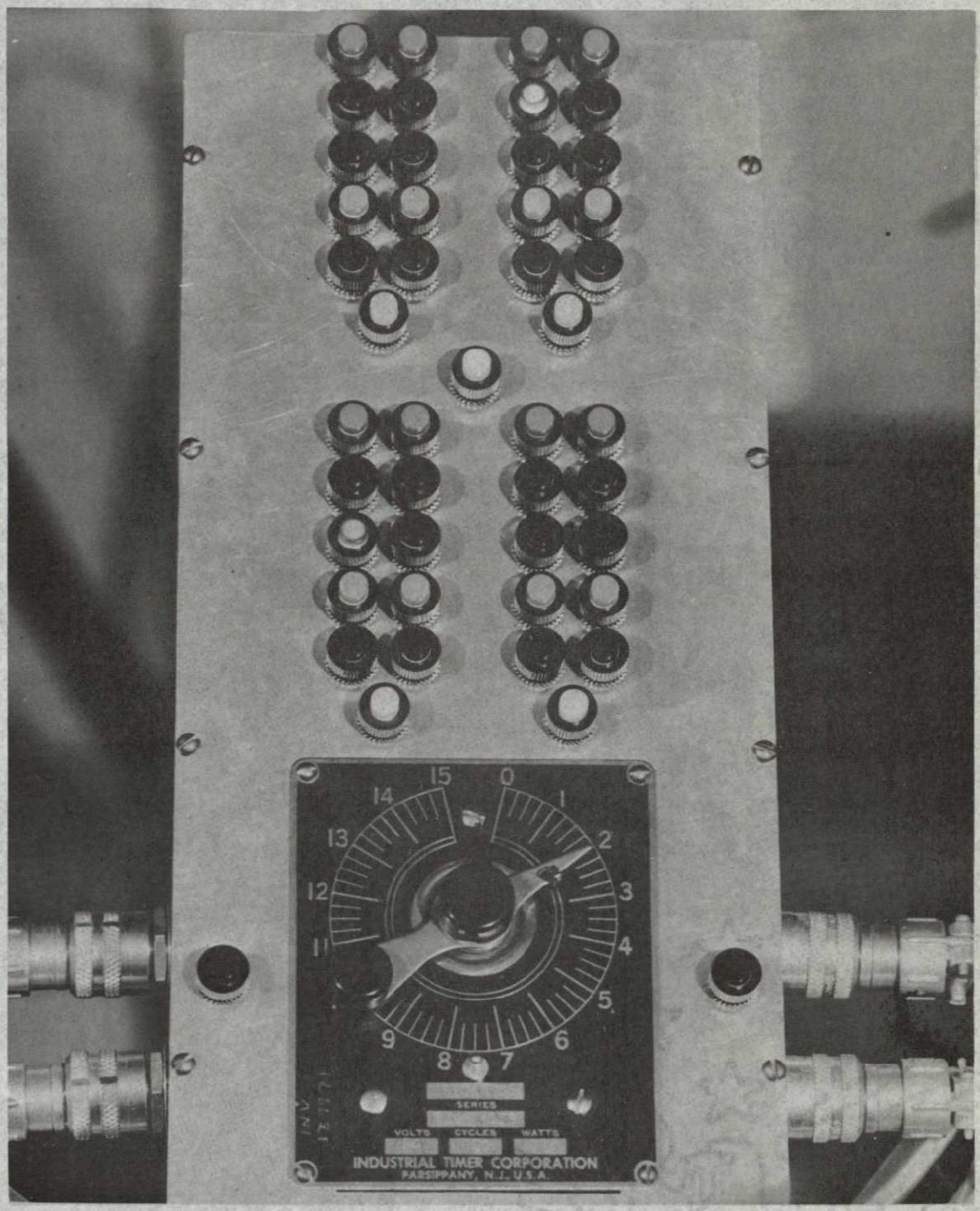

Figure 2.5.- Subject's display panel.

each right hand column are the response lights. The white light in each quadrant located directly below the two columns is an additional stimulus light for that limb and is used to give the subject additional information regarding the correct response he should make. The white light in the center of the four quadrants is an additional stimulus light which gives the subject information regarding the correct response for all four limbs.

The subject's display panel also contains an interval timer with a sweep hand and two red lights located on either side of the timer. When the Complex Coordinator is used in the self-paced mode, the timer activates the two red lights when it reaches its pre-set limit. In this mode of operation, these two lights inform the subject of his rate of performance. In addition to activating the red lights, the signal generated when the timer reaches its pre-set limit can be used to blow a horn or to shock the subject. In the pacing mode, the timer can be set to present problems to the subject at a constant rate.

2.4.3 Limb Controls

The limb controls shown in Figures 2.4 and 2.6 consist of five magnetic Reed switches in series with the response lights of the respective quadrant. The switches are closed one at a time by sweeping a magnet across them. The lever mechanism holding the magnet is spring loaded so that no switch is closed when the control is in neutral position. Dead spaces are designed between switches. When the control is swept through its arc, the switches are closed for 80 percent of the travel and open for 20 percent of the travel. There is provision

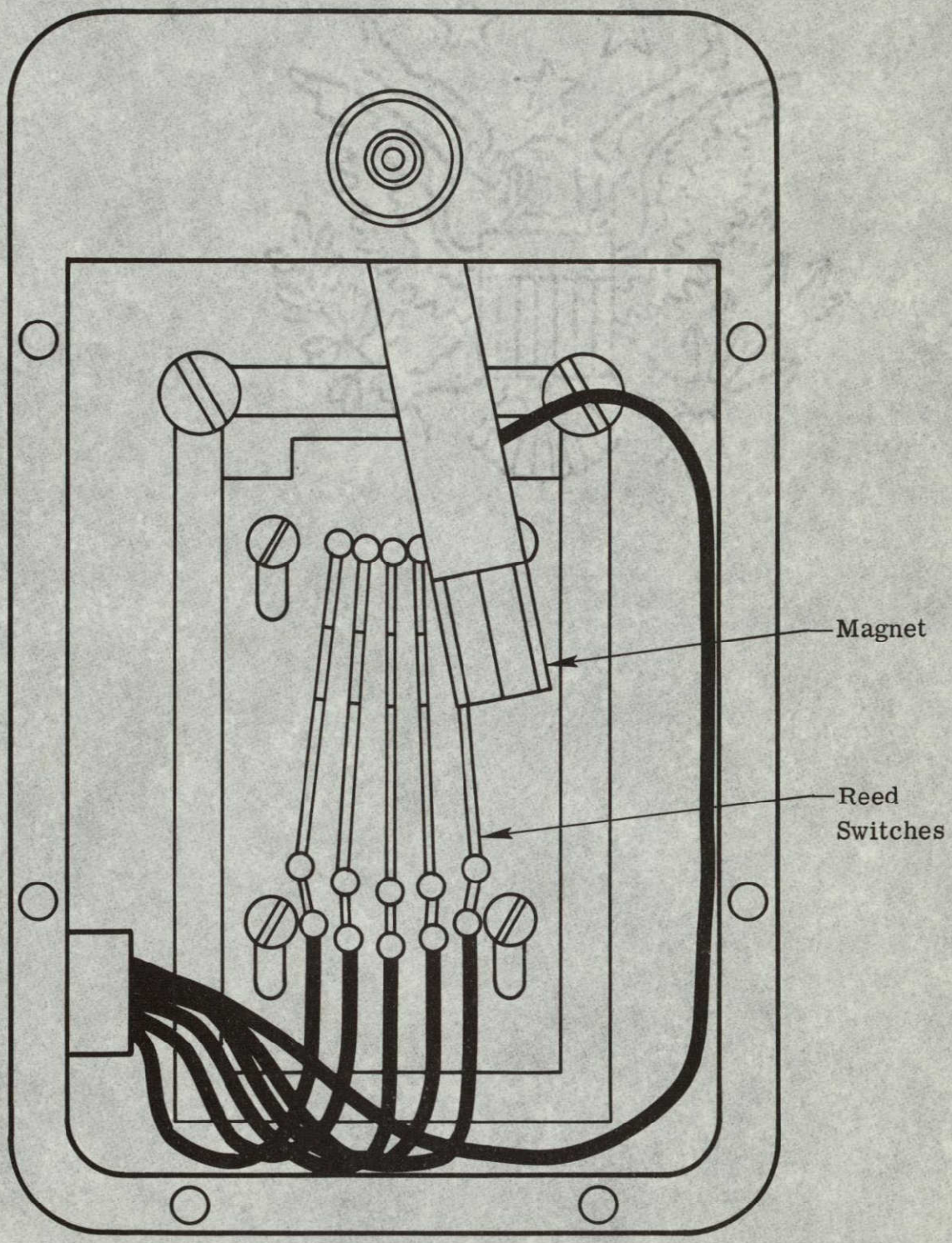

Figure 2.6.- Reed switches and magnet arrangement of limb controls.

for overshoot at each extreme of control travel. There are no detents or noise from the switch closure; therefore, the subject must rely on visual input from the response lights to know when he has made the correct response.

2.4.4 Programer

The programer is shown in Figure 2.7. It contains a row of 57 double pole single throw switches. Forty-five of these switches are connected to the forty-five lights on the subject's display panel. The remainder of the switches are used for counting, resetting, and stepping the program. The drum on which test problems are programed is shown in Figure 2.8. It contains sixty longitudinal grooves equally spaced about its circumference. Pegs or actuators are located in these grooves and actuate the fifty-seven switches which are located tangent to the drum. Each row of pegs represents a stored problem - stimulus lights plus correct response lights. Only fifty rows of pegs are used for a test. In the self-paced mode, the drum is stepped one problem at a time by using a signal that is generated when the subject makes the correct response and holds this response for a predetermined length of time. In the pacing mode, the interval timer generates a signal which is used to step the drum.

2.4.5 Operator's Control Console

A test is administered from the operator's control console shown in Figure 2.9. The subject is seated in a chair at the subject's display panel (Fig. 2.4) and an explanation of the LRC Complex Coordinator is given. Next the operator turns on the power and the

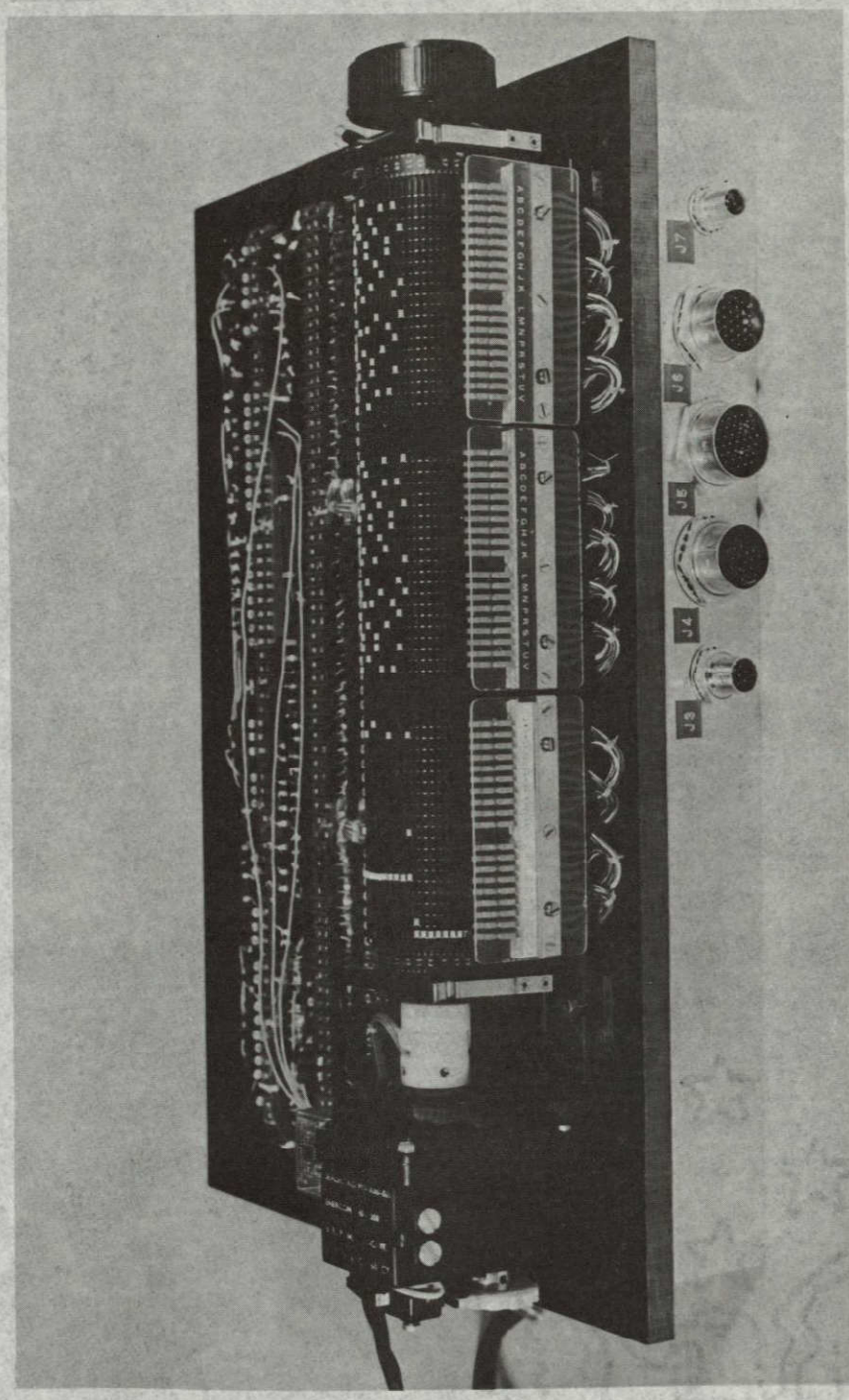

Figure 2.7.- Programer

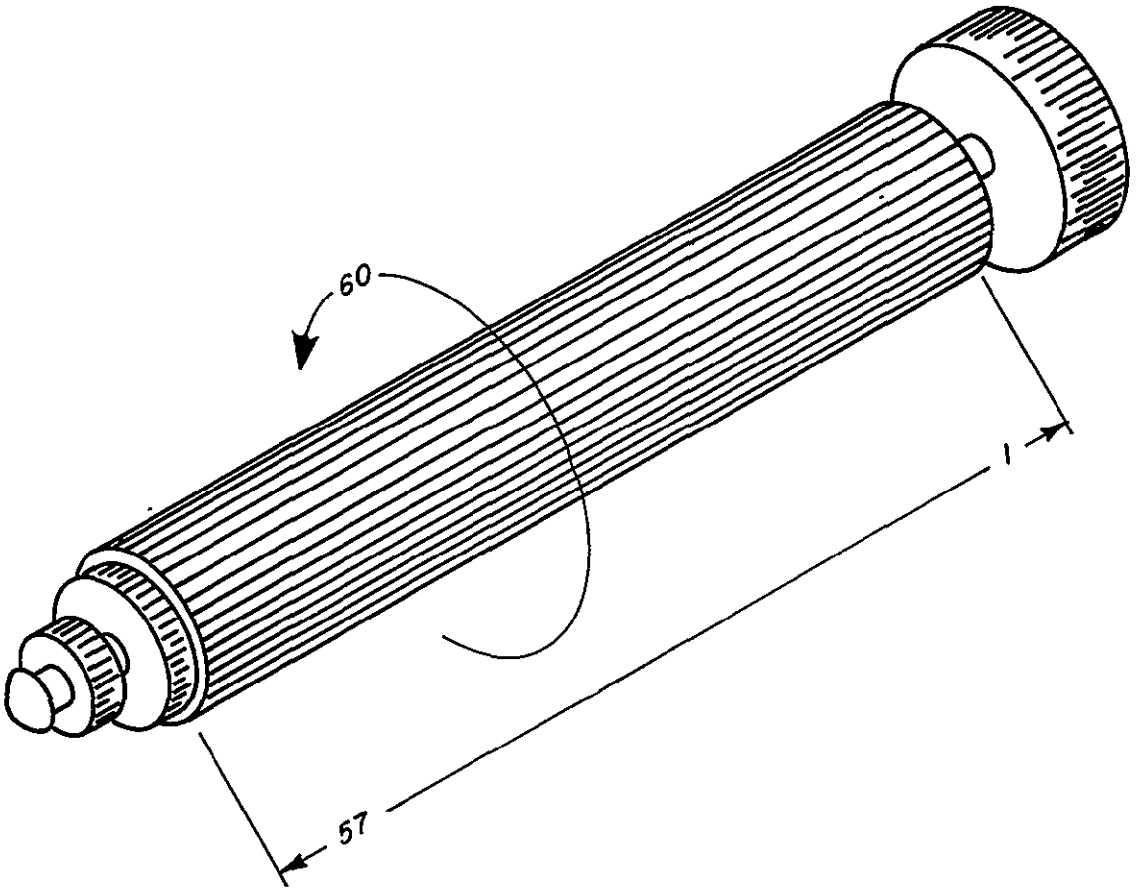

Figure 2.8.- Programer drum shown without test programed. Sixty longitudinal grooves for problems. Fifty-seven positions for switches.

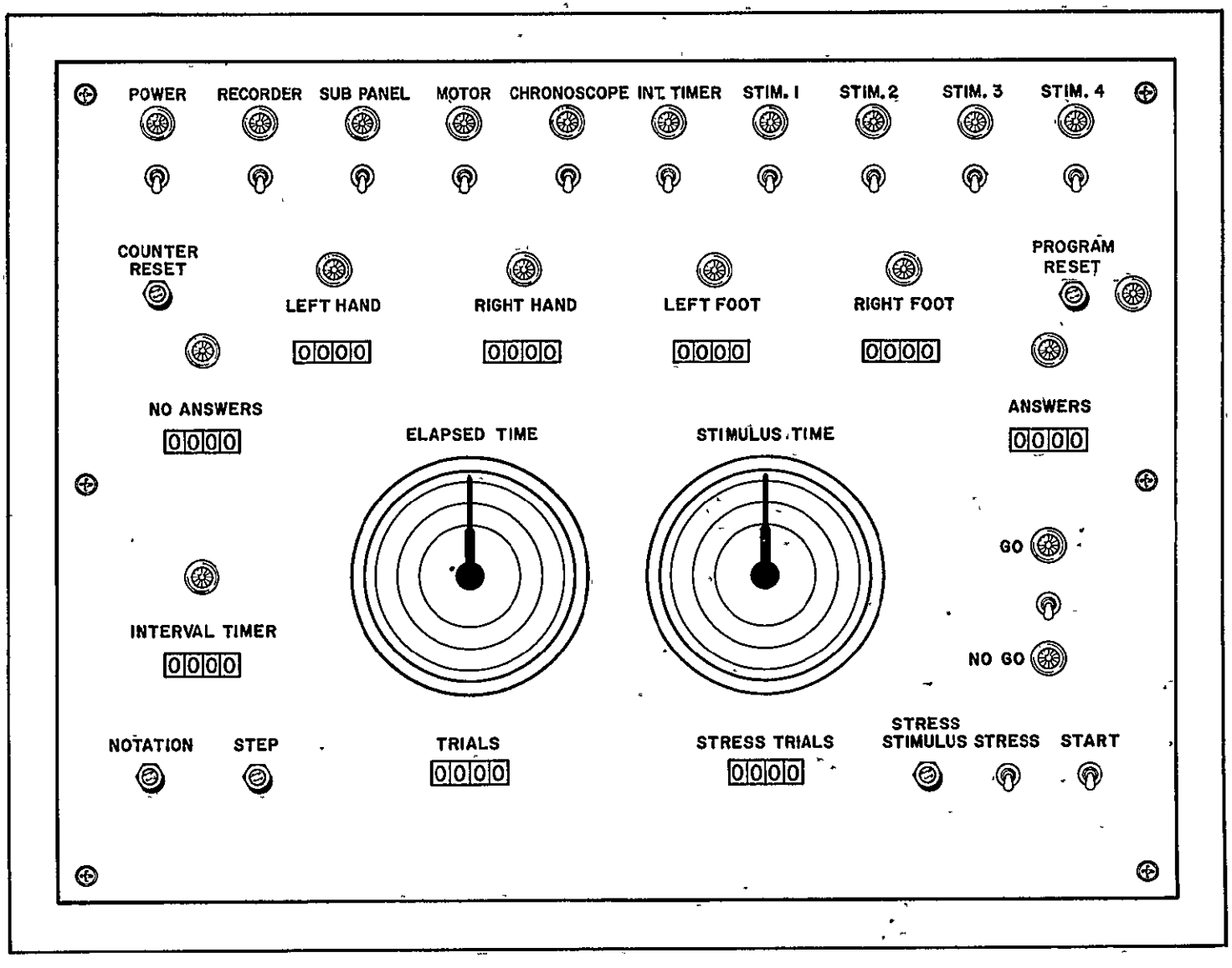

Figure 2.9.- Operator's control console front panel.

subject's panel switches on the operator's control console. This activates the subject's response lights on the subject's display panel and the subject can become familiar with the limb controls.

When the subject has familiarized himself with the limb controls, the test is started. To begin the test, the operator turns on the recorder, motor, chronoscope, interval timer, and stimulus 1 switches. The program reset switch is then activated to reset the program, and the counter reset switch is activated to clear all counters and chronoscopes. When the subject is prepared, the start switch is activated. With the Go - No Go switch in the No Go position, 50 problems will be presented and the program will stop. With the switch in the Go position, multiples of 50 problems can be presented but the switch must be returned to the No Go position before the test is ended.

If it is desired to subject the subject to an acute stress, the stimulus time and the number of problems solved with stress can be recorded by activating the stress switch when the stress begins.

Stimulus 1 switch controls the two red lights on either side of the interval timer located on the subject's display panel. These lights will glow from the time the timer reaches its preset limit until the subject has completed the problem. Stimulus 2, 3, and 4 switches can be used for additional stimuli.

At the end of a test all counters and times are recorded.

1. No Answers - the number of time intervals that the subject has no correct response on any of the four limb controls.

2. Left Hand - the number of times the subject made the correct response with the left hand.

3. Right Hand - the number of times the subject made the correct response with the right hand.

4. Left Foot - the number of times the subject made the correct response with the left foot.

5. Right Foot - the number of times the subject made the correct response with the right foot.

6. Answers - the number of time intervals that the subject had the correct response on all four limb controls simultaneously. Since he is required to hold the correct response on all four limbs for 0.3 seconds before he is presented the next problem, the subject can, by releasing the response too early, cause a higher count than the actual number of problems solved.

7. Interval timer - the number of times that the interval timer reached its pre-set limit before the subject completed the problems.

8. Trials - the number of problems solved.

9. Stress Trials - the number of problems solved under acute stress.

10. Elapsed Time - total time test was administered - reads to 0.01 seconds.

11. Stimulus Time - total time subject performed under stress - reads to 0.01 seconds.

2.4.6 Recorder

A twenty channel event recorder (Fig. 2.3) is used to record the various time sequence of events associated with the presentation and solution of a problem. The time events can be broken down as follows: (1) Time the problem was presented. (2) Time the correct response was made for each limb. (3) Times the interval timer ran down if the subject did not complete the problem in the allotted time. (4) Time the problem was solved. Other derived time events are: (1) Times that a problem is presented but there is no correct response on any of the four limbs. (2) Times that there is a correct response on all four limbs even if the correct response is not held for a sufficient time to solve the problem. Figure 2.10 shows a typical recording with the channels identified.

2.4.7 Programing the Test

Figure 2.11 shows the numbering system used for the lights on the subjects' display panel. These numbers correspond to the programer switches and their position on the drum is shown as the longitudinal numbers on the drum of Figure 2.6. The circumferential numbers on the drum of Figure 2.6 represent the problems of the test.

When the type test desired has been decided upon, a master programing table as shown in Table 2.1 is helpful in setting up the test. This table represents a test which is made up of straight match problems. That is, the subject is asked to respond correctly by

PEN	FUNCTION	PEN	FUNCTION
1	Time Mark	11	Right foot
2	Program drum revolutions	12	Stimulus #1
3	Program drum steps	13	Stimulus #2
4	Error - Interval Timer	14	Stimulus #3
5	Notation	15	Stimulus #4
6	Special Stimulus	16	Interval timer On-Off
7	Problem answered	17	Not used
8	Left hand	18	Not used
9	Right hand	19	No answer
10	Left foot	20	Time mark (1 second intervals)

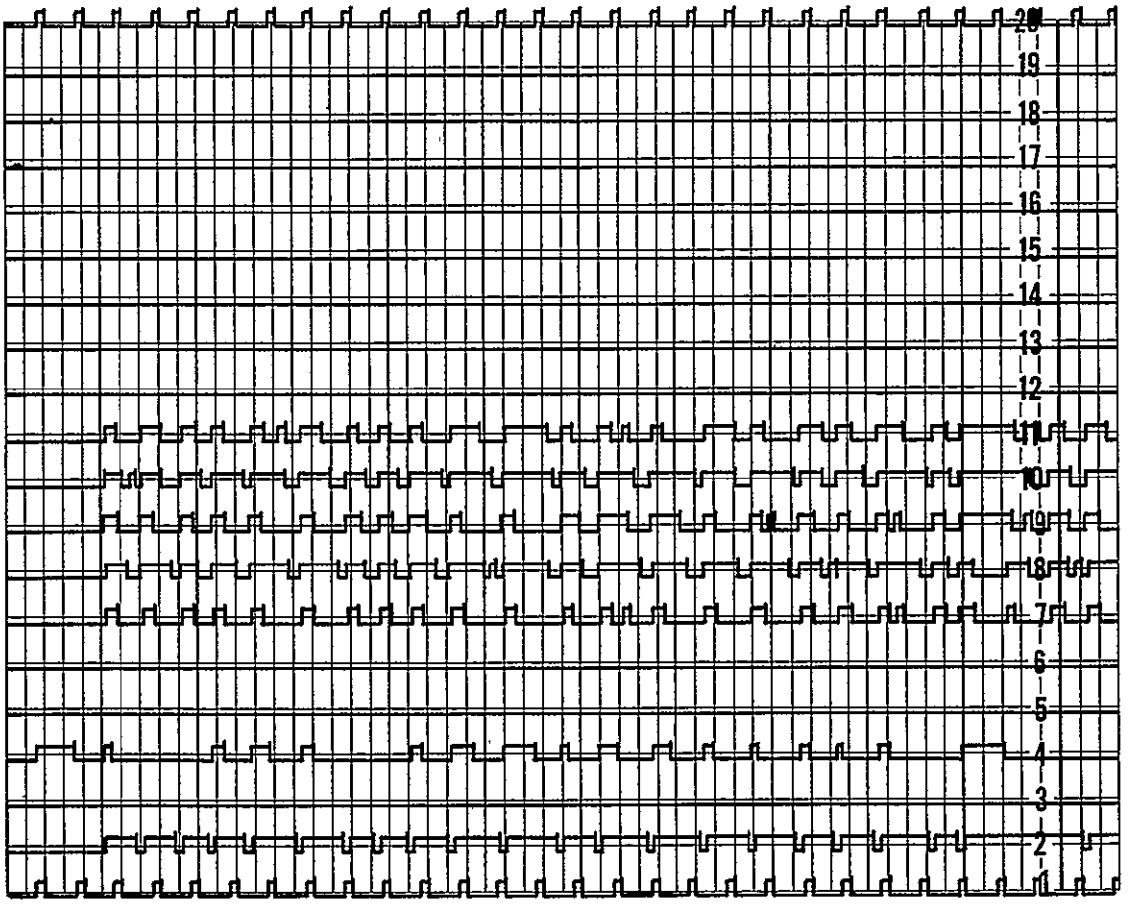

Figure 2.10.- Typical recorder readout at 12 inches per minute.

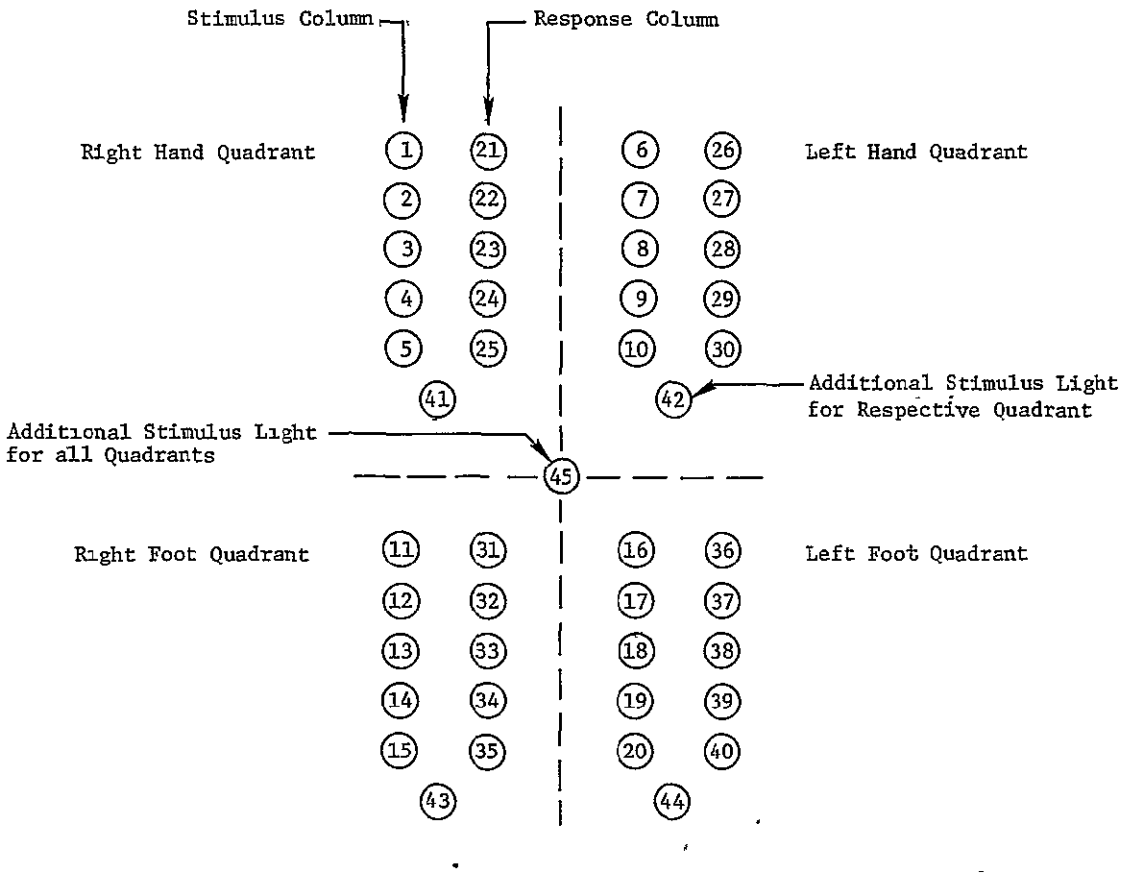

Figure 2.11.- Numbering system for lights on subject's display panel.

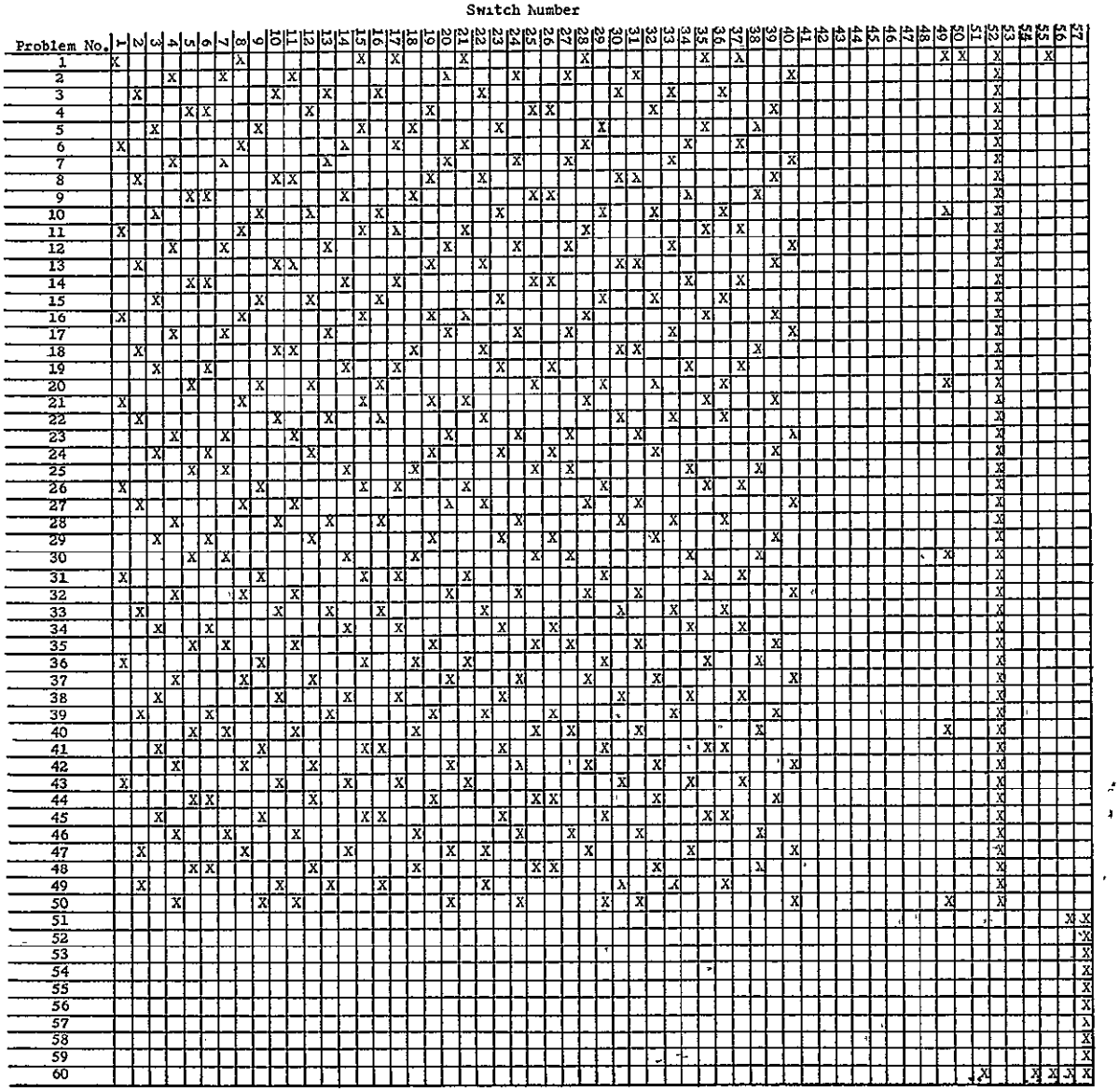

Table 2.1.- Programing table for straight match test (SM)

matching a light in the response column with the same color light that is lit in the stimulus column. None of the white lights numbered 41 through 45 are used for this test. In the test represented in Table 2.1, the problems are presented in a random order. The only restriction is that the same problem or subproblem (stimulus light for any limb) cannot occur two times in sequence. Now that the master programing table is complete, it is a simple task to slide the pegs into position on the drum. Figure 2.12 shows some typical problems (stimulus lights and correct response lights) from this test.

In Table 2.2, a more complex test (MI) is represented. In this case the white lights numbered 41 through 45 are used. When the lights located underneath each quadrant (numbers 41, 42, 43, 44) are activated, the subject makes the correct response by moving down one light in all response columns (Fig. 2.13). When the bottom stimulus light is on, the subject moves back to the top light in the response column. When the center light on the subject's display panel (number 45) is activated, the subject makes the correct response by moving up one light in the response column (Fig. 2.14). When the top stimulus light is on, the subject moves back to the bottom response light. In this test, the subject has to use the information presented with the lights 41 through 45 to decide whether to move up one or down one in the response column.

In Table 2.3, an even more complex test (MII) is represented. This test contains problems like the three previously described plus problems made up by mixing randomly the lights 41 through 45. When lights 41 through 45 all are activated, the subject makes the correct

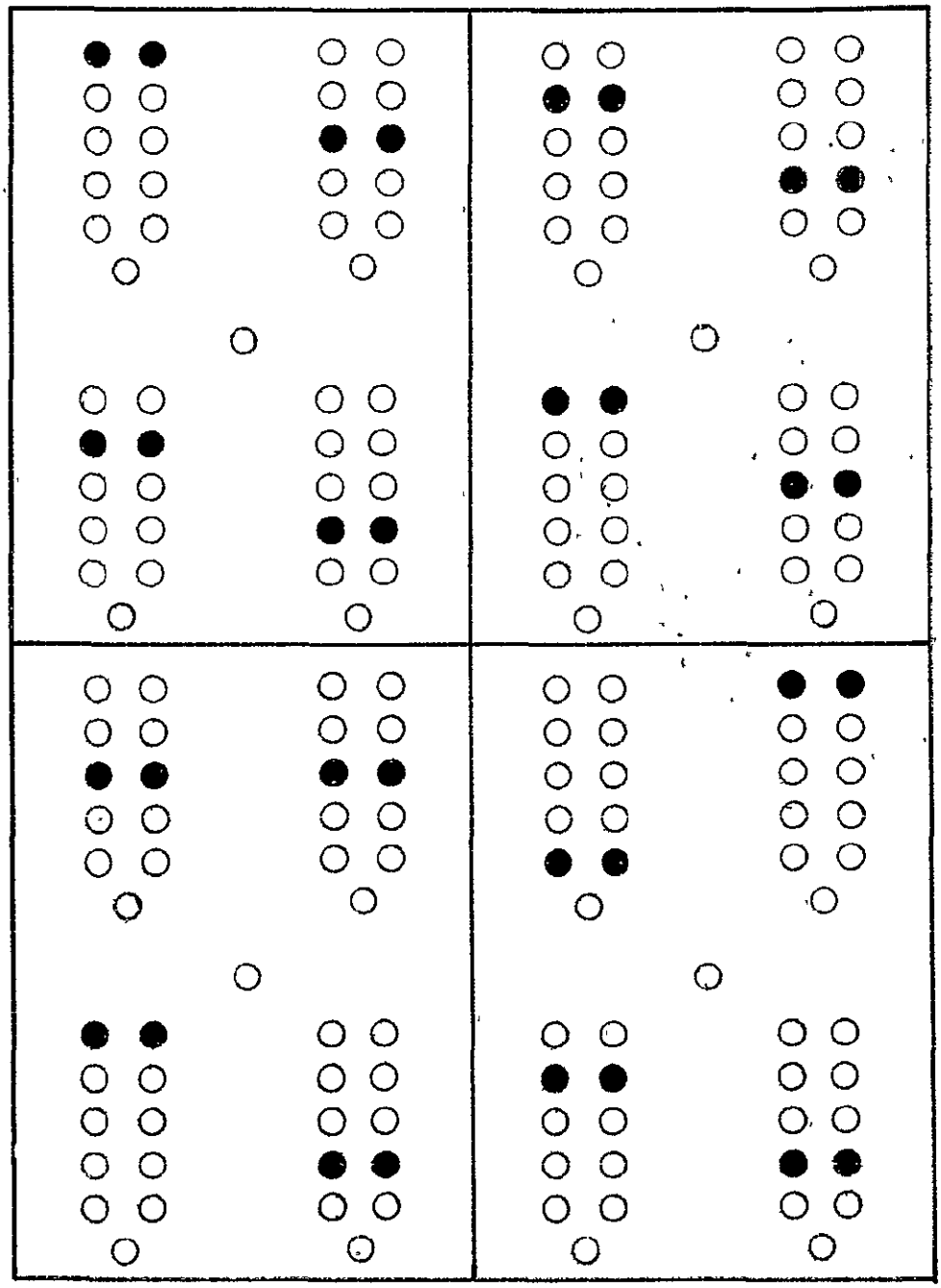

Figure 2.12.- Four typical problems and solutions from the straight match test (SM). The dark circle in the left column of each quadrant depicts the stimulus light and the dark circle in the right column of each quadrant depicts the correct response light. Straight match refers to both position and color (see Fig. 2.5).

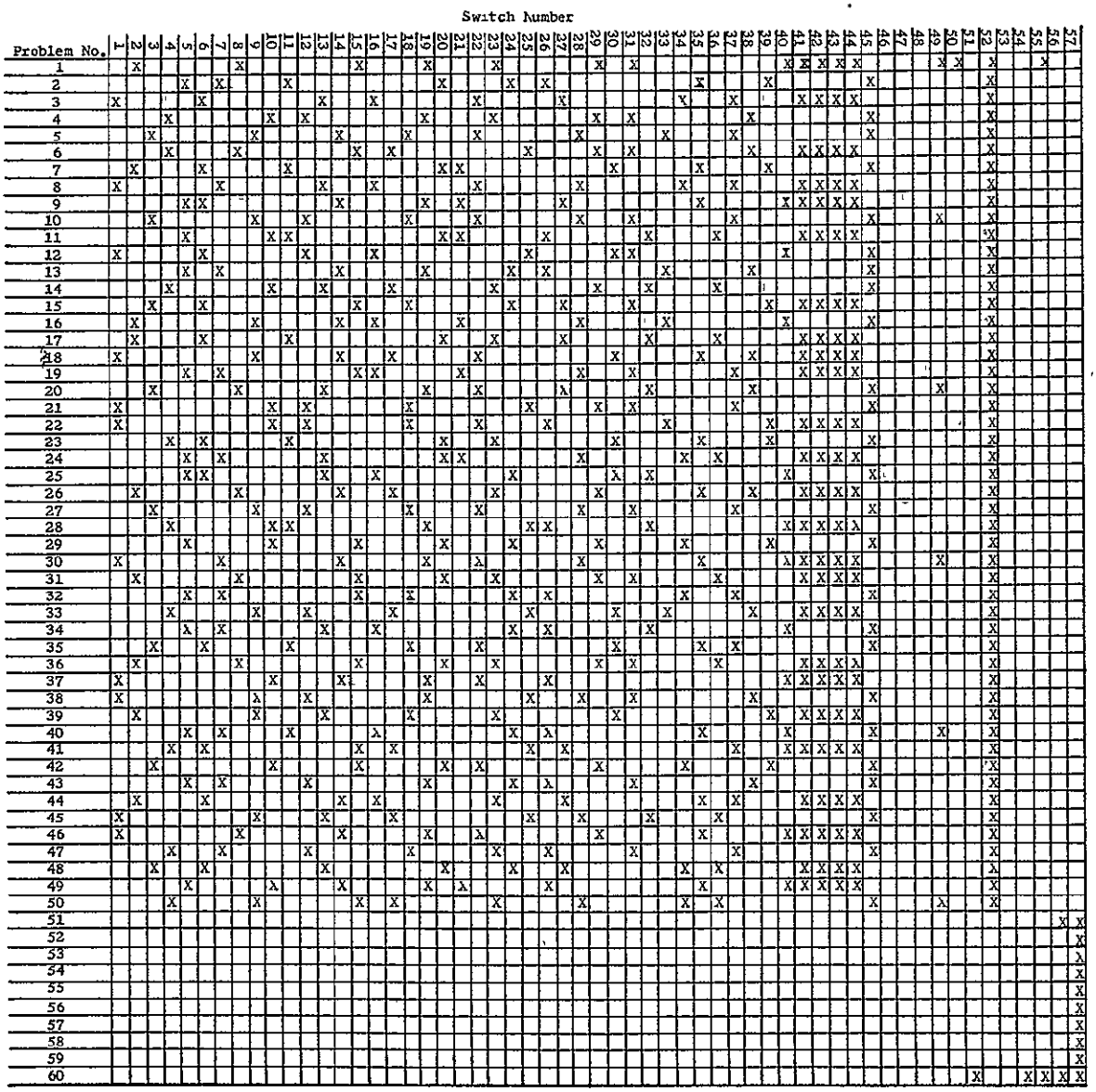

Table 2.2.- Programing table for simple mixed test (MI)

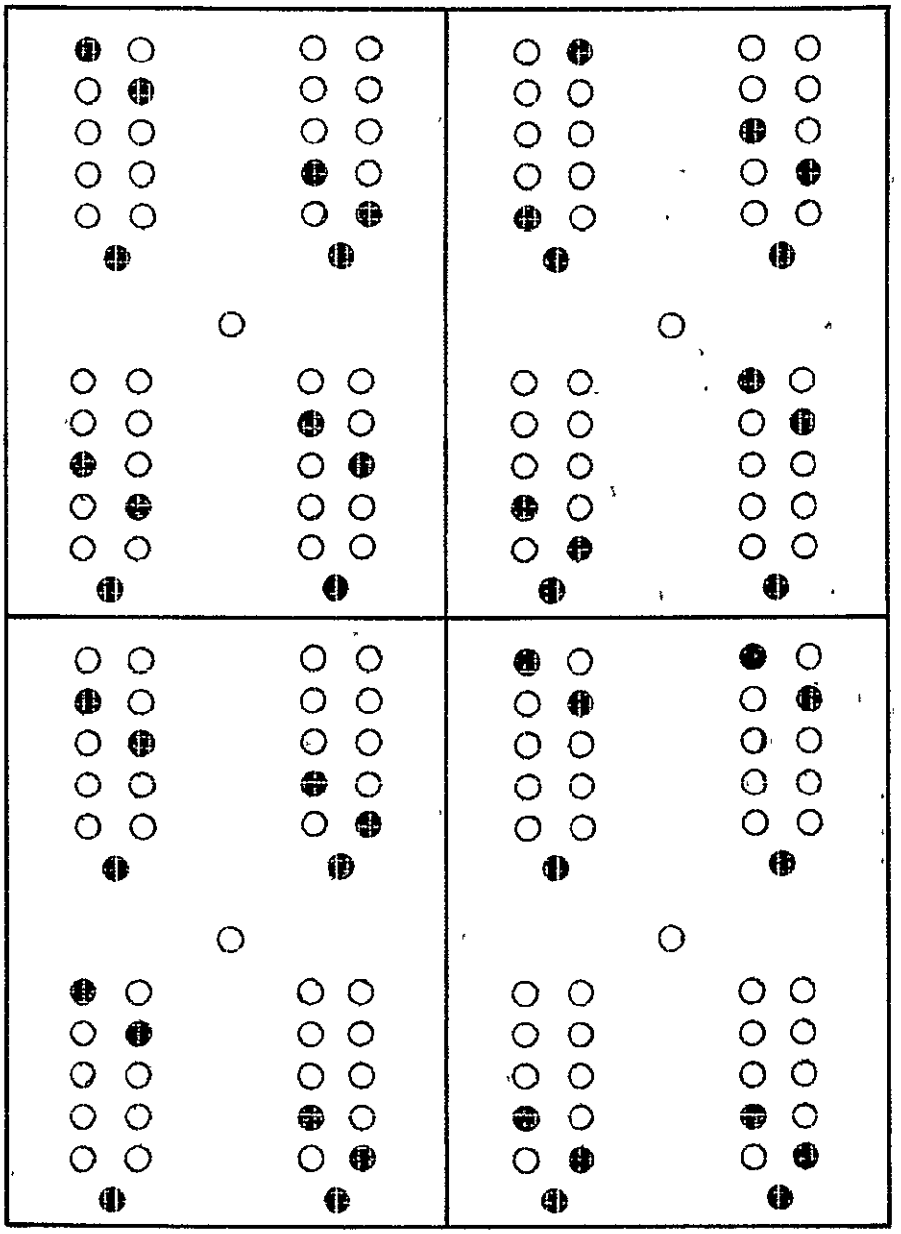

Figure 2.13.- Four typical one-down problems and solutions from the simple mixed test (MI). The dark circle in the left column of each quadrant depicts the stimulus light and the dark circle in the right column of each quadrant depicts the correct response light. The single bottom light in each quadrant informs the subject that the correct response is no longer a straight match (Fig. 2.12) for that quadrant but the correct response is down one light in the response column. There is a discontinuity in some problems; i.e., when the bottom stimulus light is illuminated, the correct response is the top light in the response column.

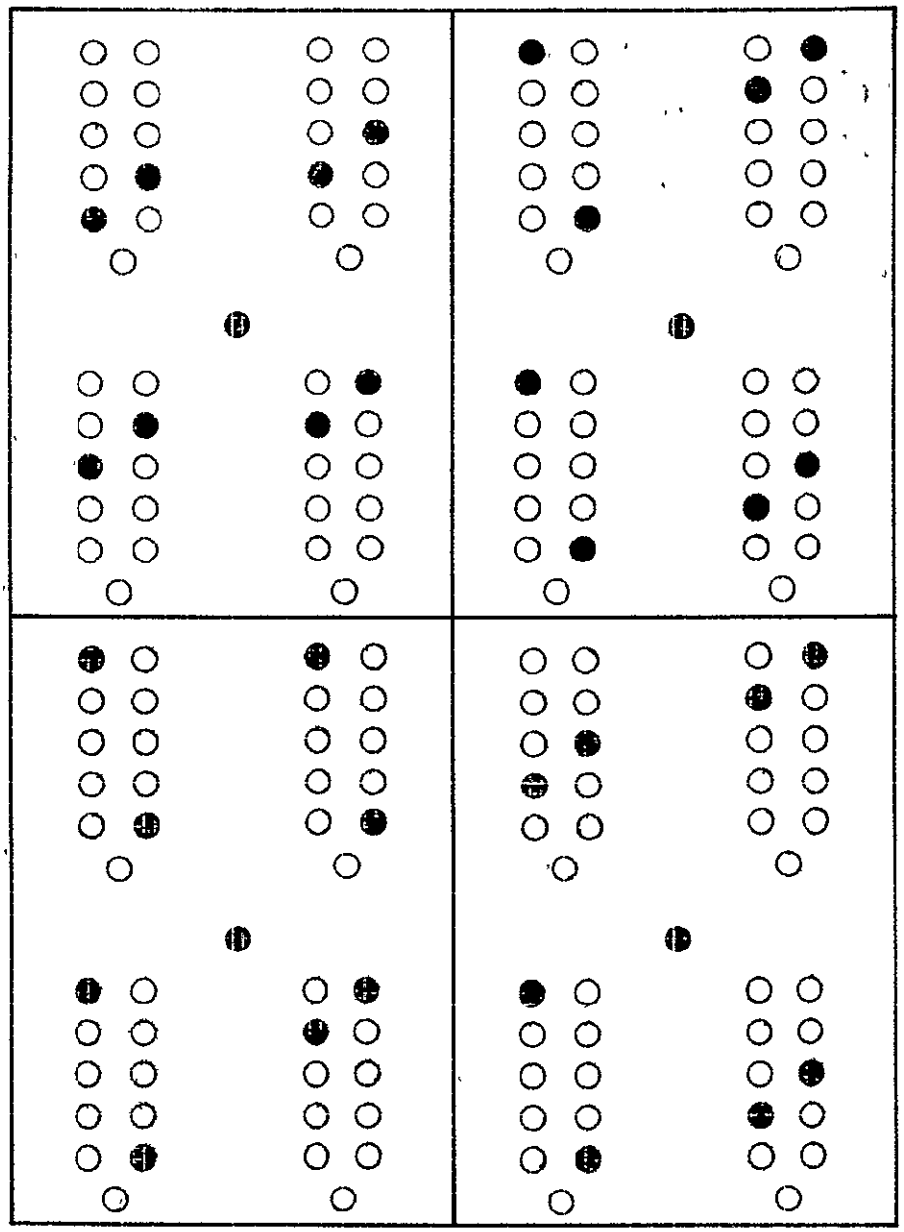

Figure 2.14.- Four typical one-up problems and solutions from the simple mixed test (MI). The dark circle in the left column of each quadrant depicts the stimulus light and the dark circle in the right column of each quadrant depicts the correct response light. The single light in the center of all quadrants informs the subject that the correct response is no longer a straight match (Fig. 2.12) but up one light in the response column of each quadrant. There is a discontinuity in some problems; i.e., when the top stimulus light is illuminated, the correct response is the bottom light in the response column.

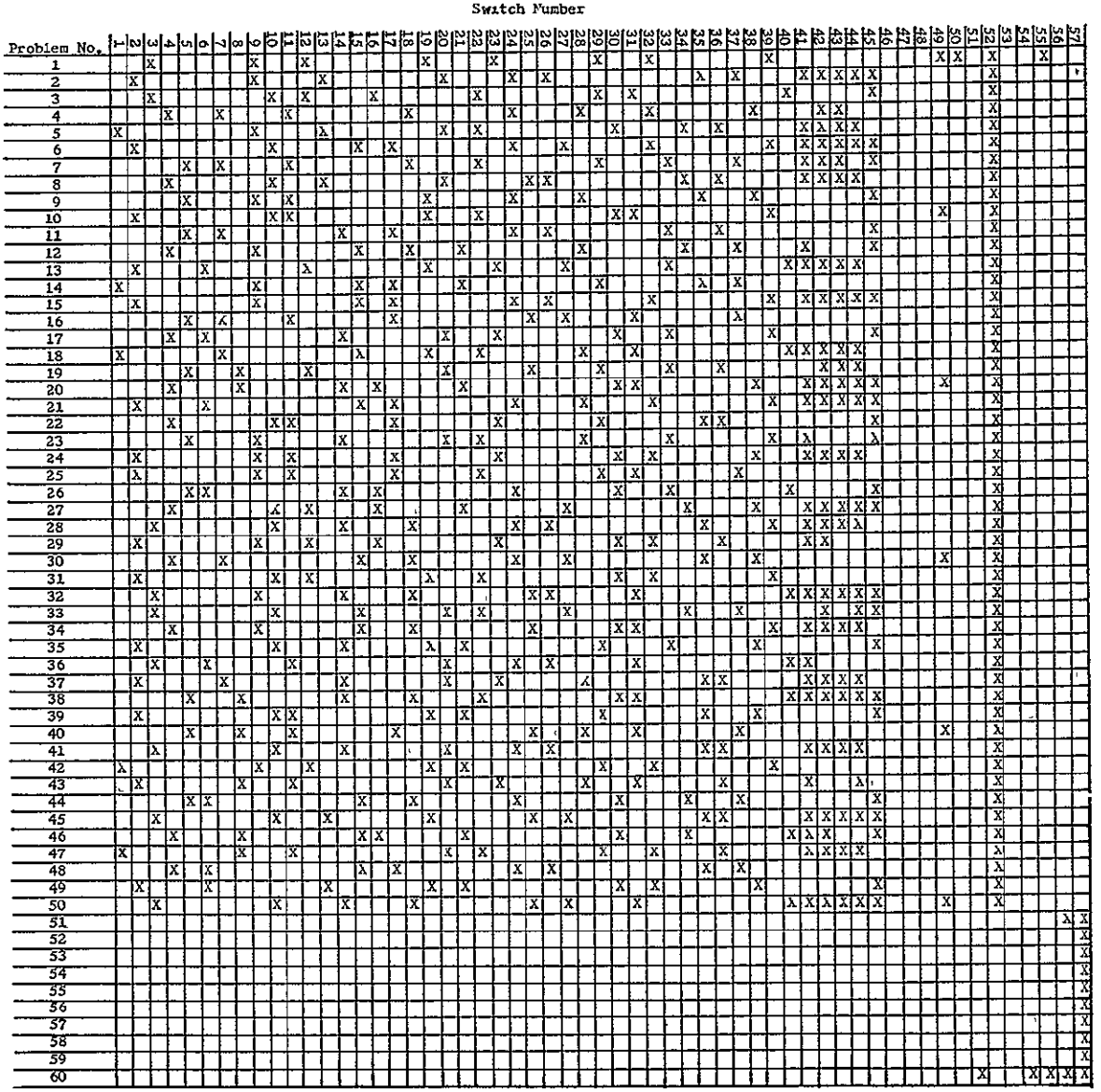

Table 2.3.- Programing table for complex mix test (MII)

response by moving down two lights in the response column. When various combinations of lights 41 through 45 are activated, the correct response can be derived from the type problems described above. Typical problems from this test are shown in Figures 2.15 and 2.16.

2.5 Tests

Three tests were programed for the LRC Complex Coordinator (see 2.4.7). The first test consisted of all straight match problems (SM). In the second test (MI), the subject had to choose one of two possible positions for the correct response for each limb; either up one light in the response column or down one light in the response column. In the third test (MII), the subject had to choose one of four possible positions for the correct response for each limb; straight match, up one, down one, or down two.

The LRC Complex Coordinator was operated in the self-paced mode; that is, the subject had to complete the current problem before another problem was presented. A time delay required the subject to hold all four limb controls on the correct response for 0.3 seconds to complete the problem.

2.6 Training

Each subject was trained to baseline performance on the straight match (SM) test in approximately 20 one-half hour sessions over a two-month period. Then training started on tests MI and then MII. After training began on the MI test, each subject was still required to perform 200 SM problems per session. Near the end of the training sessions each subject was performing 200 problems from each test per

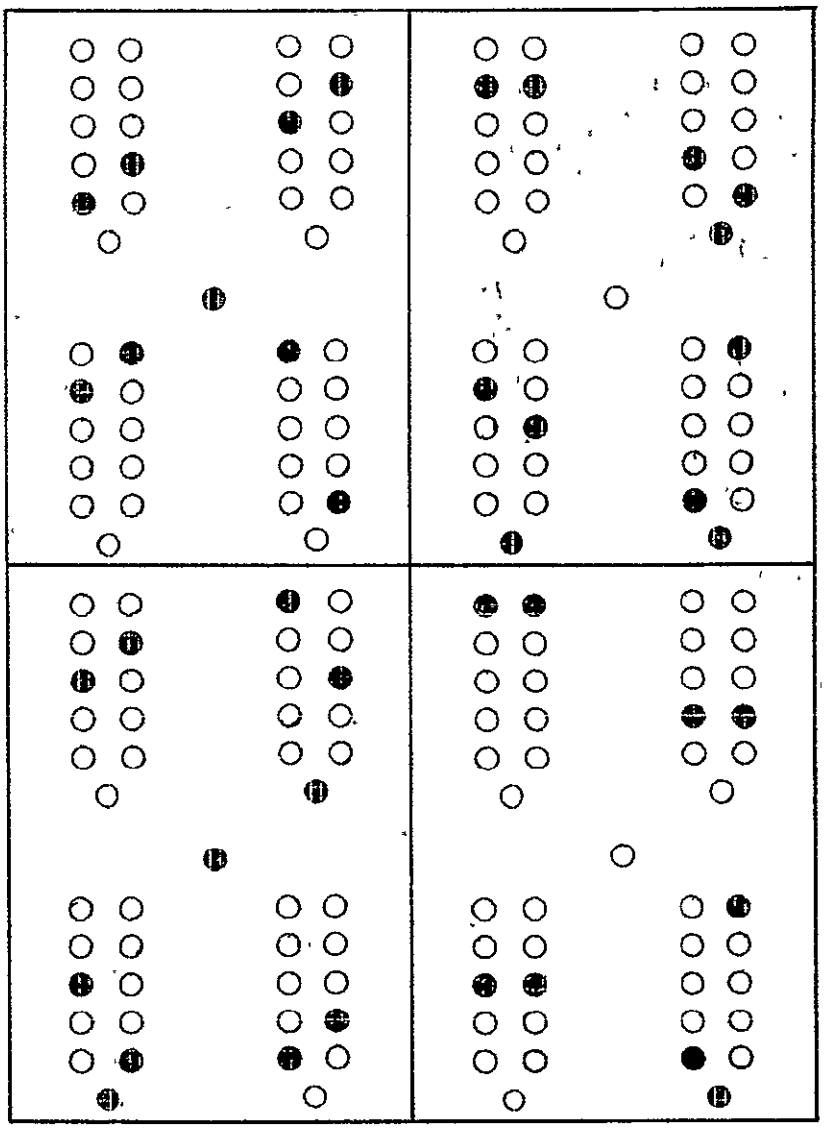

Figure 2.15.- Four typical problems and solutions from the complex mixed test (MII). The correct response for each quadrant of these problems can be derived from the problems described in Figures 2.12, 2.13, and 2.14 except when the light underneath a quadrant is illuminated simultaneously with the light in the center of all quadrants. Then the correct response for that quadrant is down two lights in the response column. There are discontinuities in some problems; i.e., when the bottom stimulus light is illuminated and the correct response is down either one or two lights in the response column, the subject moves to the top or second from top response light, respectively.

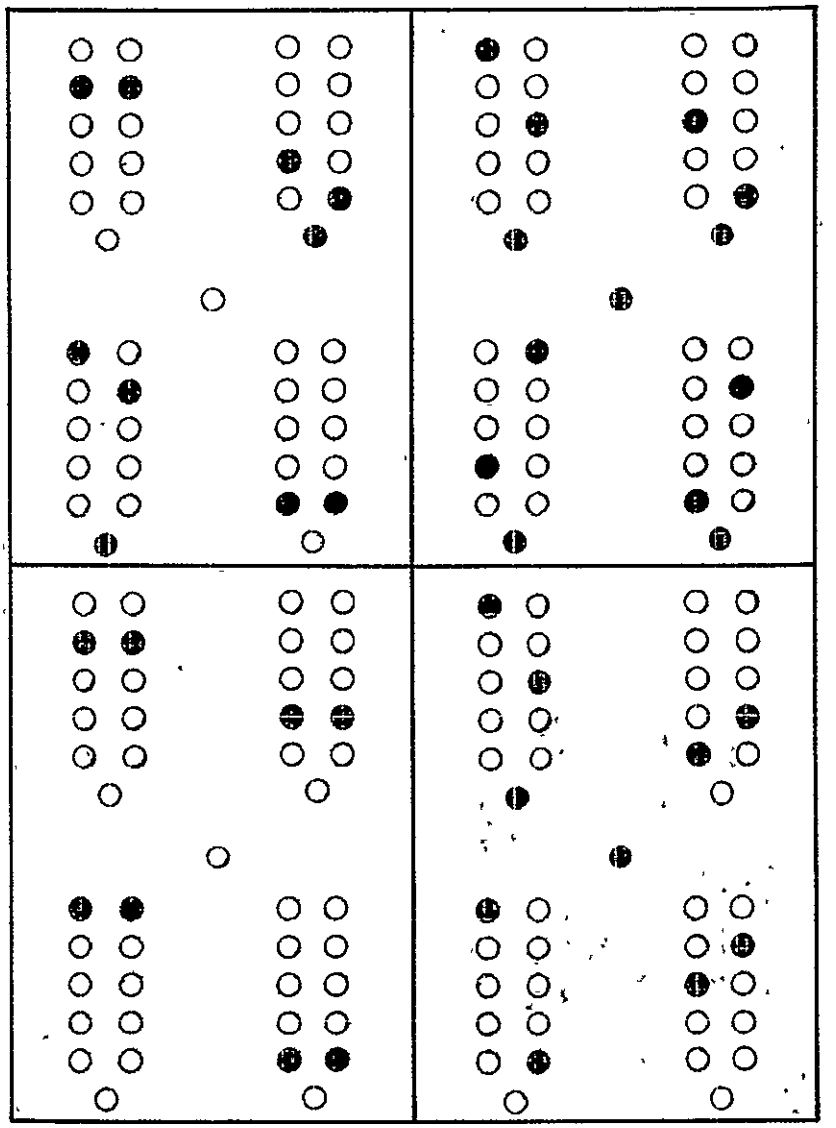

Figure 2.16.- Four typical problems and solutions from the complex mixed test (MII). The correct response for each quadrant of these problems can be derived from the problems described in Figures 2.12, 2.13, and 2.14 except when the light underneath a quadrant is illuminated simultaneously with the light in the center of all quadrants. Then the correct response for that quadrant is down two lights in the response column. There are discontinuities in some problems; i.e., when the bottom stimulus light is illuminated and the correct response is down either one or two lights in the response column, the subject moves to the top or second from top response light, respectively.

training session. The average number of training problems for each test was: SM - 21,875, MI - 2,345, and MII - 1,425. Only one performance criterion - to perform all problems as rapidly as possible - was given to the subject.

2.7 Test Procedure

On a test day the subject reported to the laboratory at 8:00 a.m., filled out a questionnaire (Fig. 2.17),[3] was instrumented to record EKG and respiration, and his blood alcohol concentration was recorded. He was then tested for baseline performance by means of 100 problems at each level of complexity.

On the alcohol test days, following the baseline test, the subject was given an orange juice drink containing ethanol to produce a blood alcohol concentration of 0.010 percent. He was asked to consume each drink as rapidly as he comfortably could. His blood alcohol concentration was monitored. When the blood alcohol concentration approached 0.010 percent, he was tested again with 100 problems at each level of complexity and given a second dose of ethanol solution to produce a blood alcohol concentration of 0.050 percent and tested again at this

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[3]The questionnaire was used to minimize extraneous factors that might influence the results. No tests were performed if the subject had taken drugs within twelve hours prior to a test or if there was a possibility the subject was suffering from a hangover. The time and quantity of food last eaten gave an indication of the dose of alcohol required and the absorption time necessary to achieve a desired blood alcohol concentration.

QUESTIONNAIRE FOR DRUG STUDY

1. Name_____ Date_____ Time_____
2. How many hours sleep did you have last night? _____
3. When did you last eat? _____ If within the past 6 hours, answer 4 below.
4. What did you have to eat? _____

_____

5. Have you had any alcoholic beverages within the past 24 hours? Yes ____ No ____
6. If so, what and how much? _____
7. Have you taken any drugs within the past 24 hours? Yes ____ No____. What? _____
8. How many cups of coffee have you had this morning? _____
9. How do you feel that you will perform today on:
   a. Straight Match average_____below average____above average____.
   b. Simple Mix average_____below average____above average____
   c. Complex Mix average_____below average____above average____
10. If you are a smoker, how many cigarettes have you smoked since you awoke this morning (or pipe)? _____
11. Did you drive to work this morning? Yes ____ No ____
12. Do you feel that you had any after effects from the last test? Yes ____ No ____ If so, what? _____
13. Do you have any after thoughts on factors that may have influenced your last performance? Yes ____ No ____ What? _____

_____

Figure 2.17.- Questionnaire completed by subject prior to test

level. This procedure was repeated again; he drank a third dose of ethanol solution and was tested at a blood alcohol concentration of 0.100 percent.

The blood alcohol concentration profile followed is shown in Figure 2.18. This profile allowed all blood alcohol concentrations to be studied in one test session and could be considered as representative of a social drinking session.

Following the test at the 0.100 percent blood alcohol concentration, the subject was given lunch. In the afternoon, as the blood alcohol concentration decreased, selected points were chosen and the subject again tested. In most cases, the subject was tested seven times throughout the day. At the end of the day the subject was sent home by taxi.

On a control day, the subject was given an orange drink containing the same total volume and the same concentration of orange juice as on the day that he received ethanol. Ethanol was spread on the rim of the glass to disguise the drink. All tests and procedures were the same as for the ethanol test days.

The tests were conducted in a sound proof chamber approximately eight feet wide, twenty feet long, and seven feet high. An observer sat in the chamber with the subject on all tests. The subject was also observed while he was in the chamber by means of closed circuit television. Between tests the subject remained in the laboratory. He was allowed to read, play cards, or study. Only one subject was

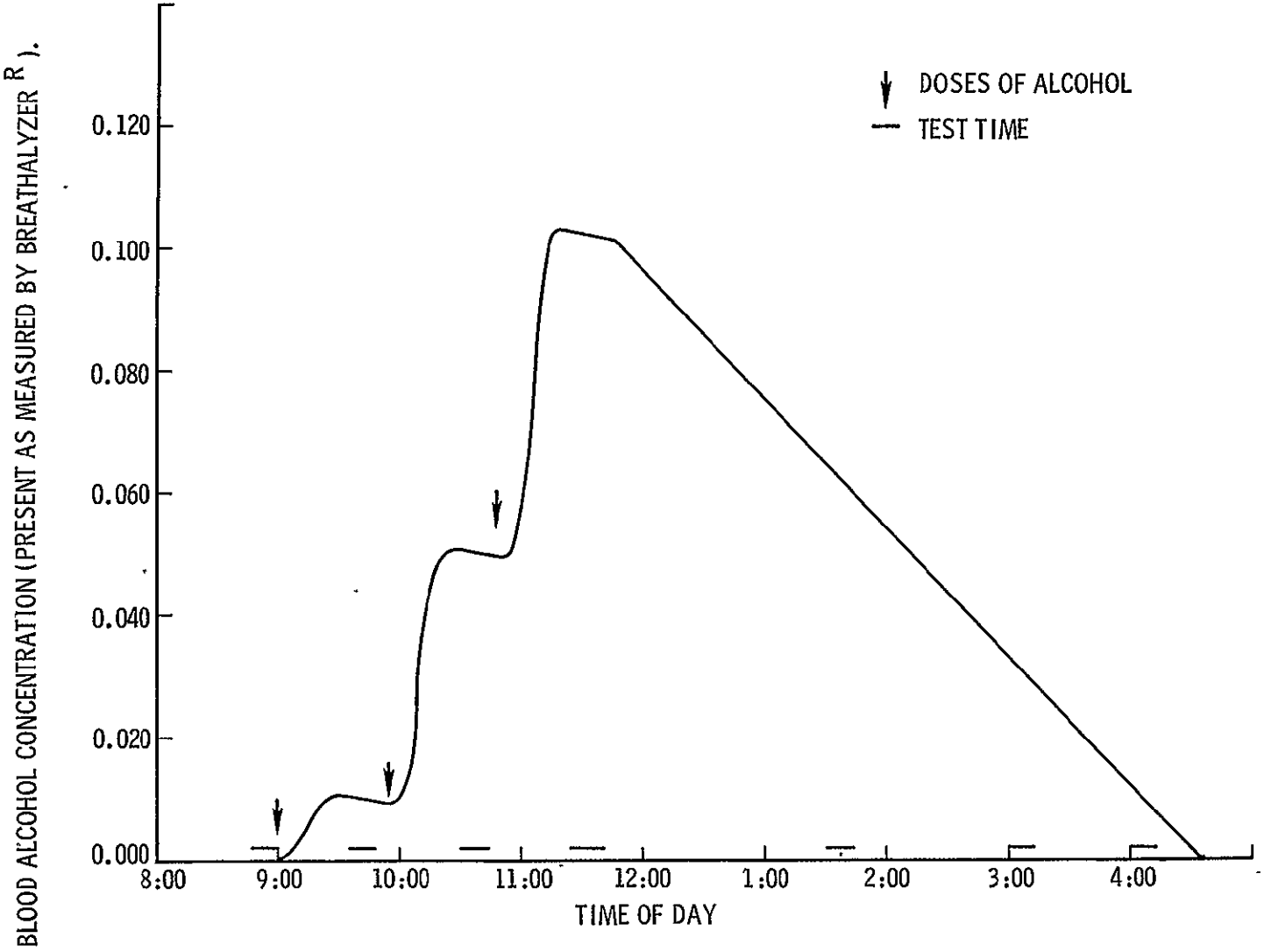

Figure 2.18.- Blood alcohol concentration profile followed.

tested in each session. The results of the tests were not given to the subject until all tests were completed.

2.8 Statistical Methods

The experiment was designed to use the analysis of variance technique for analyzing the data. The replicated randomized block design by Hicks (28) was used. Subjects (ten used in analysis), complexities (3), and alcohol levels (4) were the independent variables. Two replications were performed. An analysis was made of the effects of the various independent variables and interactions on several measures of performance. The analysis was performed on a computer.

CHAPTER 3

RESULTS

3.1 Behavior Without Alcohol

Two measures of performance on the LRC Complex Coordinator were used as behavioral measures. These were the total time (to the nearest 1/100 of a second) to perform 100 problems at each level of complexity and the total number of errors for all four limbs per 100 problems at each level of complexity. The total number of errors was derived from the four counters shown in Figure 2.9 (labeled left hand, right hand, left foot, and right foot). Each counter would have read 100 had the subject been accurate; but, since the limb controls were very sensitive to minor movements, each time the subject passed through the correct response or slipped off the correct response this was counted by a limb control counter.

The subjects were well trained on the straight match test (SM). When they started training on this test each problem was broken down by the subject into four components - a left hand component, a right hand component, a left foot component, and a right foot component and each component performed separately. As the training continued, the method of solution changed to a two part solution - both hands simultaneously and both feet simultaneously. By the time the experiment began, all subjects were performing the straight match test (SM) problems as two part problems. On the control test days, when the subject did not receive alcohol, there was no change in the time required to perform

100 problems or in the number of errors per 100 problems. Had there been an effect due to fatigue, it would have shown up as an increase in the time to perform the problems or as an increase in the number of errors.

The subjects were not trained as well on the simple mixed test (MI) or on the complex mixed test (MII) as on the straight match test (SM). All subjects were treating the problems in these two tests as four part problems. There was no change in the two behavioral measures on the control tests.

Even though the subjects were not told that they did not receive alcohol and the orange juice drink had alcohol spread on the rim of the glass, the thought that they could be receiving alcohol did not influence their test scores. There was no change in the time or errors.

3.2 Behavior With Alcohol

The blood alcohol concentration profile shown in Figure 2.18 was followed. The time at which the peak blood alcohol concentration occurred and the quantity of alcohol required to produce this peak varied from subject to subject. For those subjects who did not eat breakfast on a test day, the time scale was reduced. The absorption time for those subjects who ate breakfast and especially those subjects who ate a large breakfast was long and the time scale was expanded. The Breathalyzer^{R} made it possible to follow the blood alcohol concentrations individually.

3.2.1 Performance on the Straight Match Test (SM)

Since the subjects were well trained on this test and were using a two-part method of solution, it was anticipated that they might change their method of performance at the higher blood alcohol concentrations. This would be expected if the alcohol produced a significant reduction in the visual input or if the alcohol affected the processing of this large quantity of visual information. However, there was no change in the method of solution of the straight match problems.

Figure 3.1 presents the performance data for this test. The total time to perform 100 problems and the total number of errors for all four limbs for 100 problems is presented as a function of blood alcohol concentrations. Both performance measures deteriorated at all concentrations of blood alcohol.

3.2.2 Performance on the Simple Mixed (MI) Test

In this test the subject had to make a decision regarding the correct solution of the problem. The correct solution in all cases was up one light in the response column or down one light in the response column from the straight match problems for all four limbs. Information with which to make this decision was presented to the subject by the white lights on the subject's display panel. With each white light directly underneath each quadrant illuminated, the correct response was down one light in the response column. With the white light in the center of the subject's display panel illuminated, the correct response was up one light in all response columns.

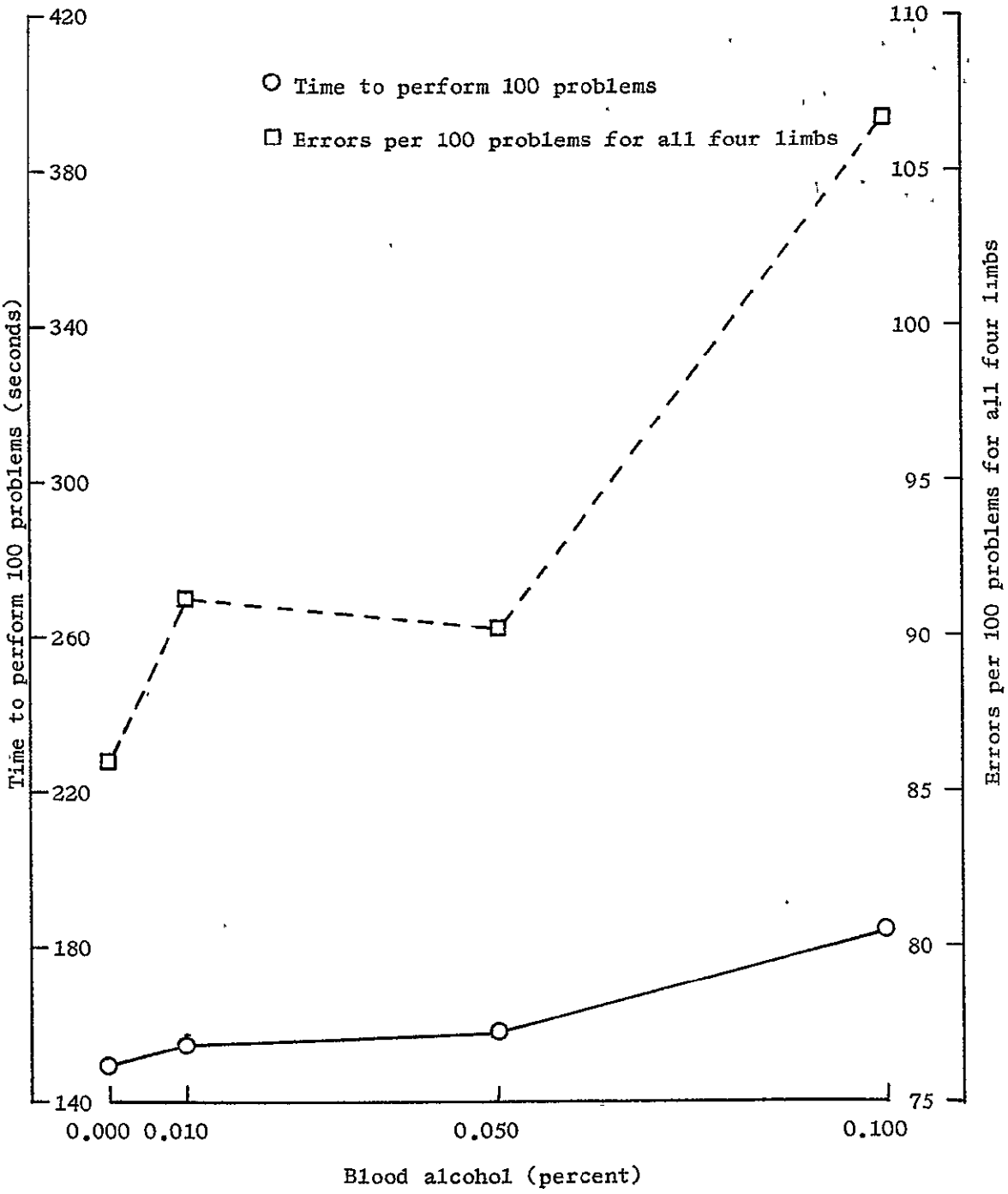

Figure 3.1.- Effect of alcohol on performance (total time and total errors) on straight match test (SM). Mean for ten subjects.

There was no change in the method of solution with blood alcohol concentration. As with the straight match problems, the total time to solve 100 problems and the total number of errors correlated with blood alcohol concentration.

The performance data for this test is shown in Figure 3.2. Again, performance deteriorated with increasing blood alcohol concentration.

3.2.3 Performance on the Complex Mixed Test (MII)

Since this test was made up of problems from tests SM, MI, and additional problems of greater complexity, the subject first had to diagnose the problem type before attempting to solve the problem. If the problem was a straight match problem, it was solved as a two-part problem. If the problem was not a straight match problem, it was solved as a four-part problem. There was no change in the method used by the subjects to solve the problems with increasing blood alcohol concentrations.

The data for this test is shown in Figure 3.3, in which total time to perform 100 problems and total number of errors per 100 problems is plotted as a function of blood alcohol. Performance on this test deteriorated with increasing blood alcohol concentrations. There was a trend toward improvement in performance at the 0.010 percent blood alcohol concentration but this did not prove statistically significant.

3.2.4 Performance as a Function of Blood Alcohol

In Figure 3.4, the percent increase in time to perform 100 problems at each level of complexity is presented as a function of blood alcohol concentration. The trend is toward a decrement in performance with

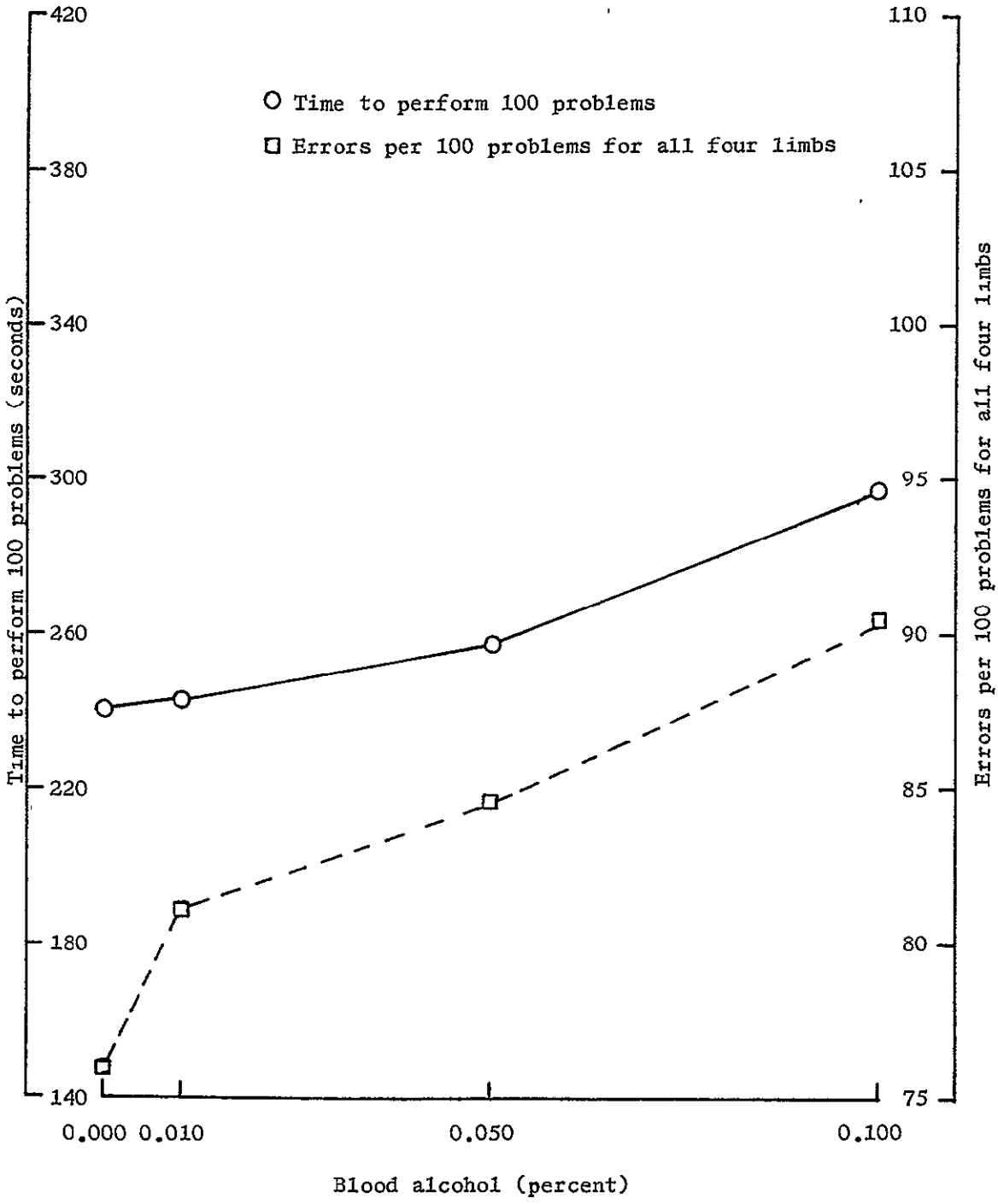

Figure 3.2.- Effect of alcohol on performance (total time and total errors) on simple mixed test (MI). Mean for ten subjects.

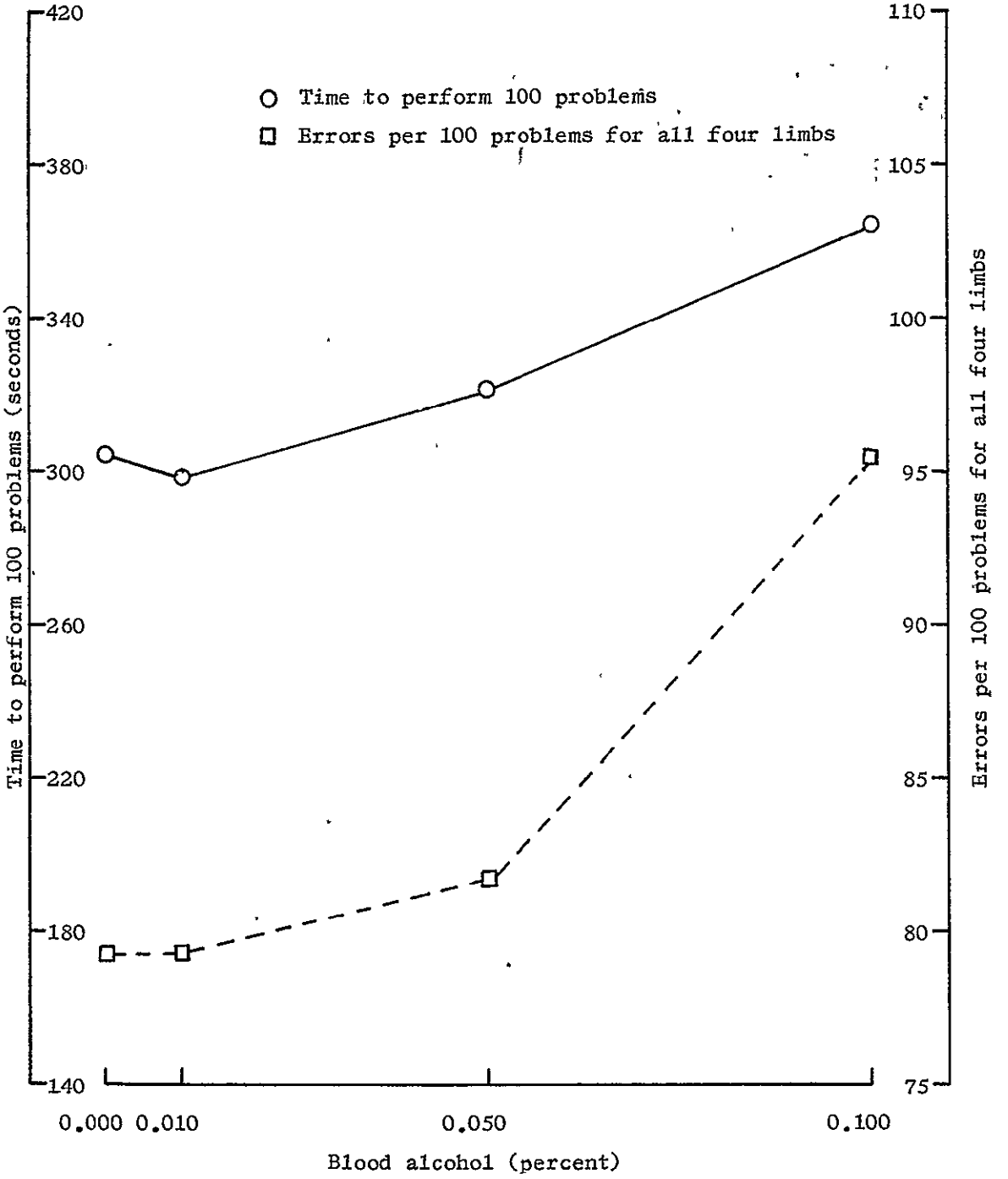

Figure 3.3.- Effect of alcohol on performance (total time and total errors) on complex mixed test (MII). Mean for ten subjects.

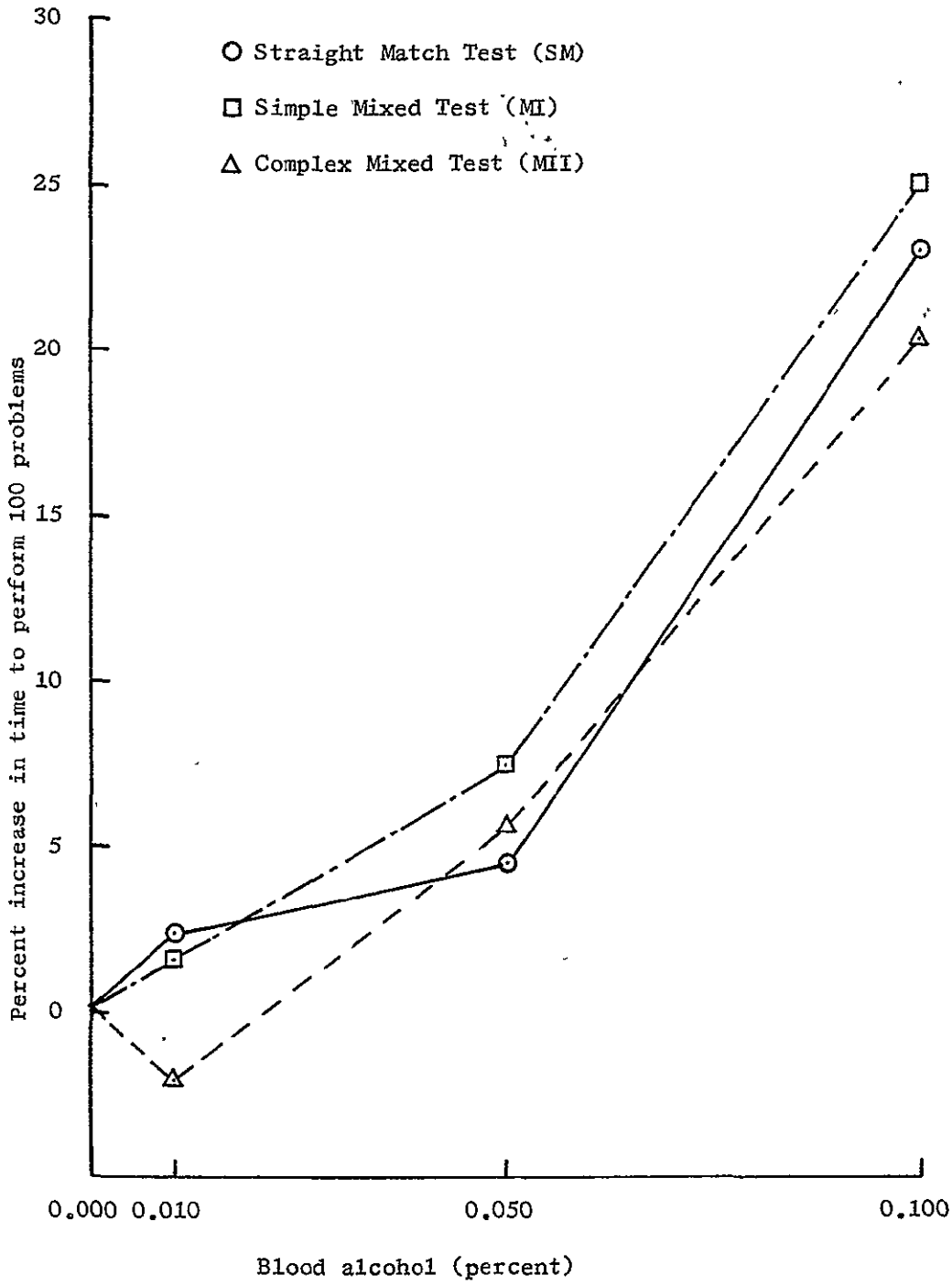

Figure 3.4.- Percent increase in time to perform 100 problems for all levels of complexities. Mean for ten subjects.

increasing blood alcohol concentrations. Performance on all tests deteriorated in a similar manner, possibly indicating that alcohol affected a component common to all three tests.

In Figure 3.5, the percent increase in the number of errors per 100 problems is presented as a function of blood alcohol concentration. Again there appears a similar trend in the decrement of all three tests with increasing blood alcohol concentration.

In order to examine more closely the cognitive component of the complex mixed test (MII), results of the straight match problems were extracted from the MII test and compared to results of the straight match problems from the straight match test. Each 100 problems from MII contained 20 straight match problems distributed randomly. This comparison is shown in Figure 3.6. Each point representing problems from the straight match test is the mean of 100 problems and 10 subjects. Each point representing straight match problems from the MII test is the mean for 40 problems and 10 subjects. The two curves are parallel with a separation of approximately 0.30 seconds. This separation represents the recognition or diagnostic time. Since the two curves follow each other so closely, one cannot say that the cognitive processes that went into making the problem diagnosis were affected over this range of blood alcohol concentrations.

3.2.5 Relationship Between Time and Errors

If the total number of errors for 100 problems is divided by the total time to perform the same 100 problems at each level of complexity and at each blood alcohol concentration, the resulting ratio is a

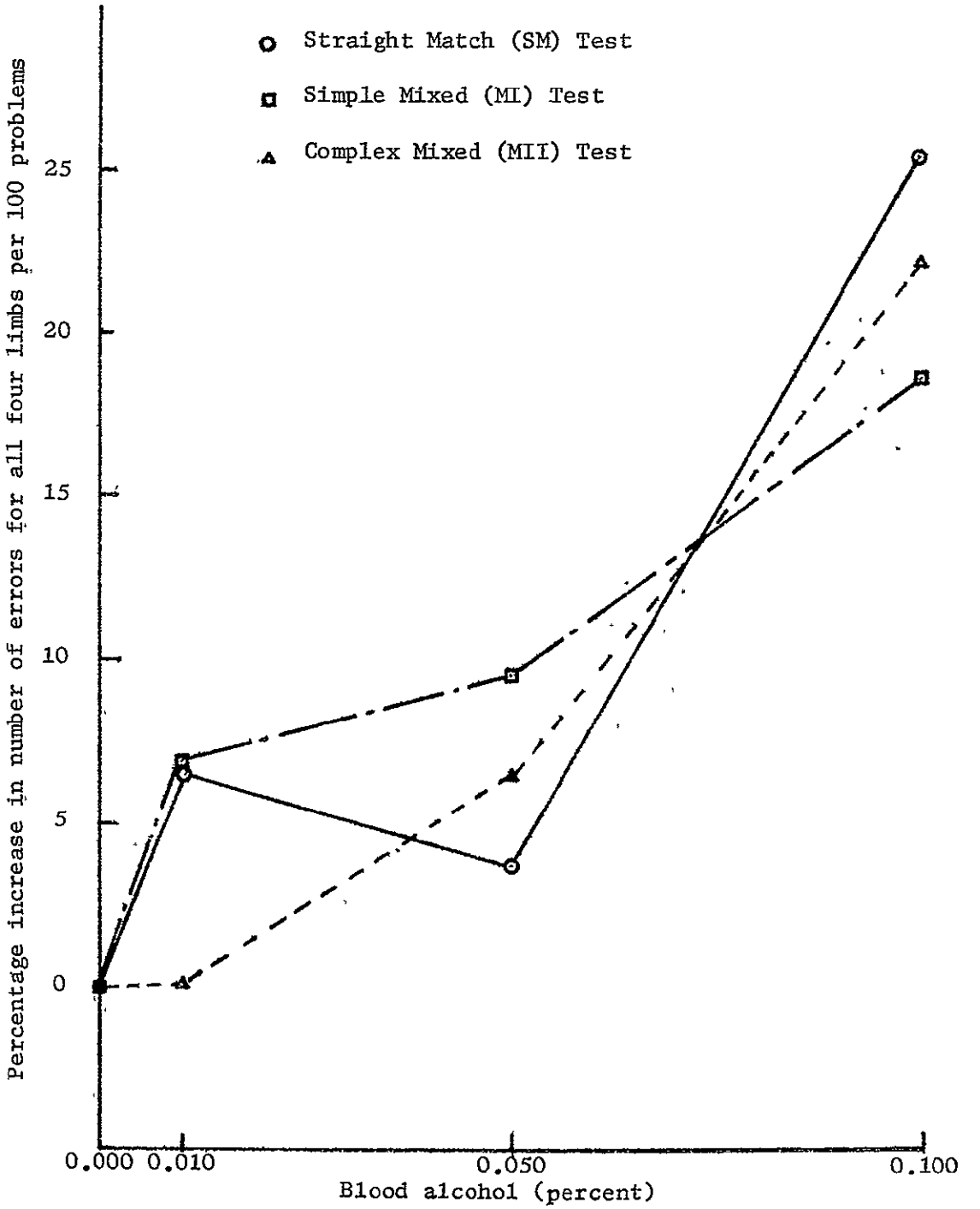

Figure 3.5.- Percent increase in number of errors for all levels of complexities. Mean for ten subjects.

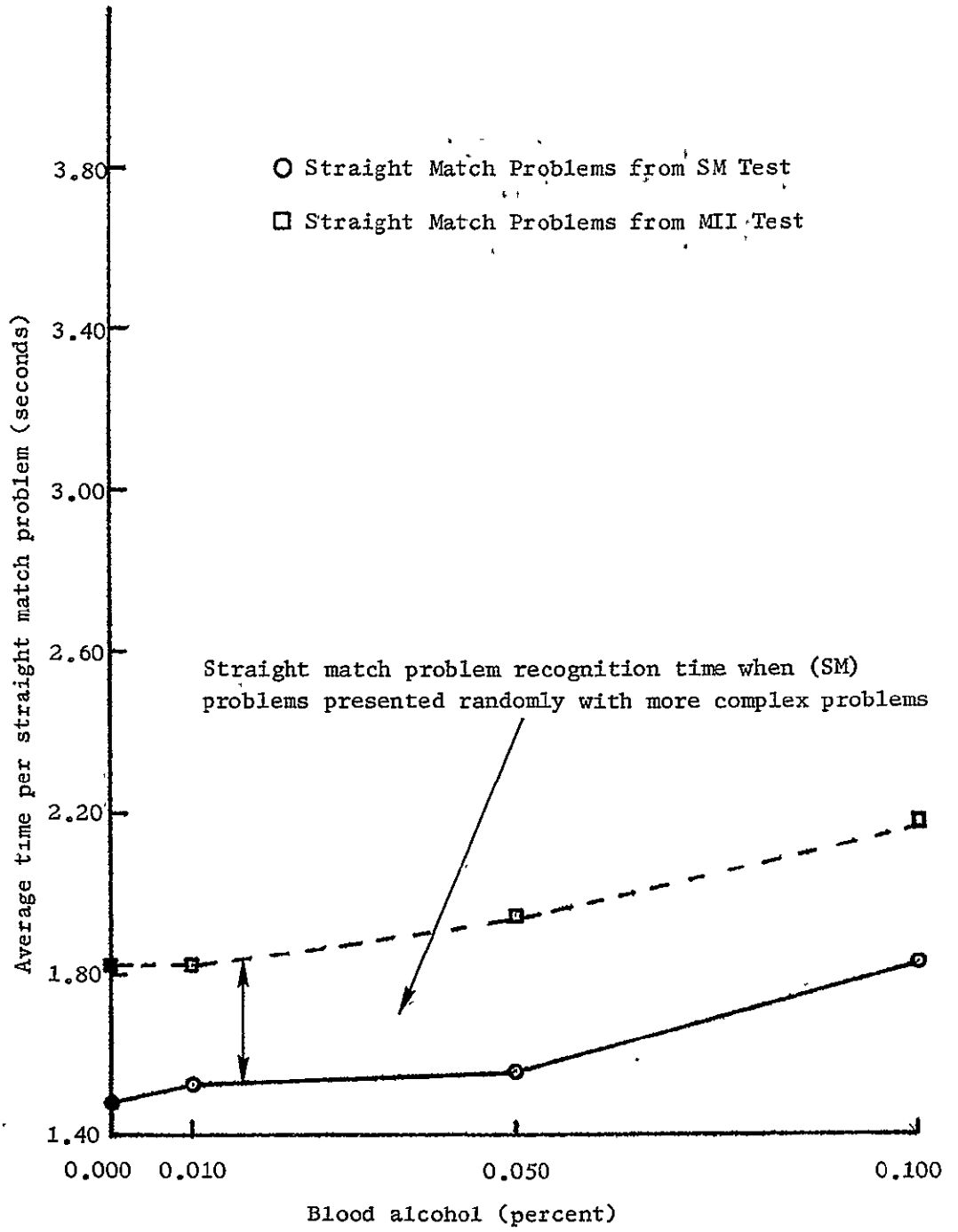

Figure 3.6.- The effect of alcohol on straight match problem recognition. Each O represents 100 problems for ten subjects. Each □ represents 20 problems for the same ten subjects.

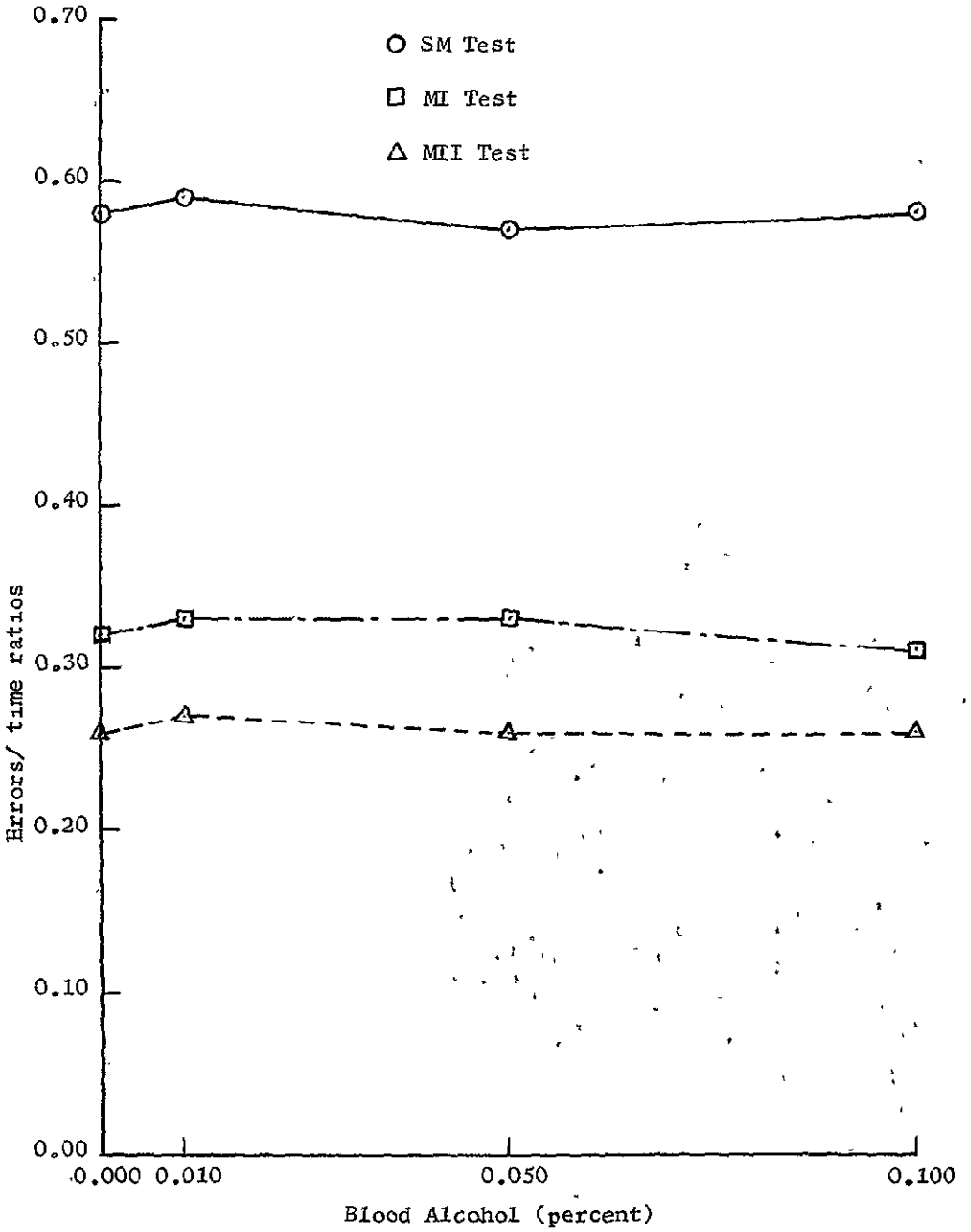

Figure 4.1

Figure 3.7.- Ratio of the total errors for 100 problems to the total time(seconds) to perform 100 problems at each level of complexity. Mean for ten subjects.

SOURCE	d.f.	SS	MS	F
Replications	1	394.75	-	-
Alcohol Levels (A)	3	105,493.97	35,164.66	88.71**
Complexity (B)	2	1,035,682.92	517,841.46	1306.36**
Subjects (C)	9	118,938.92	13,215.44	33.34**
Interaction (AB)	6	8,262.46	1,377.08	3.47*
Interaction (AC)	27	8,515.56	315.39	0.80
Interaction (BC)	18	47,393.38	2,632.97	6.64*
Interaction (ABC)	54	13,578.69	251.46	0.63
Error	119	47,171.12	396.40	-
Total	239	1,385,431.77	-	-

Table 3.1.- Analysis of variance for total time to perform 100 problems with alcohol

**Significant with a confidence of at least 0.999

*Significant with a confidence of about 0.99

subjects, which implied that different people respond differently to the same task. A lack of interaction between alcohol concentrations and subjects implied that the effect the alcohol had on the time to perform the task was uniform over all subjects.

Table 3.2 contains the analysis of variance for the two control days. Again the variable analyzed is the total time to perform 100 problems. The only factor changed in this experiment was that the subjects did not receive alcohol. They were told that they may or may not have alcohol and a few milliliters of alcohol was spread on the rim of the glass. An alcohol effect was not apparent, which indicated that the total time to perform the task was independent of the thought that alcohol had been consumed. Had there been any effect from fatigue, it would have been contained in the analysis for blood alcohol in this case. The pronounced effect due to complexity gives assurance that the complexity, as measured by the total time to complete the task, was varied. In this case, the subject-complexity interaction was stronger.

Table 3.3 contains the analysis of variance for the total number of errors on the two alcohol test days. In this case, the greatest effect was caused by subjects followed by significant effects due to alcohol and complexity, in that order. Again an interaction between subjects and complexities was found. In this analysis, there appeared a slight interaction between alcohol concentrations and subjects. The alcohol-complexity interaction was not significant when total errors were analyzed.

SOURCE	d.f.	SS	MS	F
Replications	1	13,955.28	-	-
Alcohol Levels (A)	3	817.24	272.41	1.48
Complexity (B)	2	1,017,402.79	508,701.40	2761.23**
Subjects (C)	9	103,202.97	11,467.00	62.24**
Interaction (AB)	6	1,504.91	250.82	1.36
Interaction (AC)	27	4,360.77	161.51	0.88
Interaction (BC)	18	28,277.72	1,570.98	8.53**
Interaction (ABC)	54	4,675.84	86.59	0.47
Error	119	21,923.62	184.23	-
Total	239	1,196,121.14	-	-

Table 3.2.- Analysis of variance for total time to perform 100 problems without alcohol

**Significant with a confidence of at least 0.999

SOURCE	d.f.	SS	MS	F
Replications	1	25.35	-	-
Alcohol Levels (A)	3	10,768.42	3,589.47	14.77**
Complexities (B)	2	5,373.43	2,686.72	11.05**
Subjects (C)	9	117,892.32	13,099.15	53.89**
Interaction (AB)	6	950.33	158.39	0.65
Interaction (AC)	27	11,197.92	414.74	1.17*
Interaction (BC)	18	30,457.98	1,692.11	6.96**
Interaction (ABC)	54	7,540.58	139.64	0.57
Error	119	28,927.65	243.09	-
Total	239	213,133.98	-	-

Table 3.3.- Analysis of variance for the total number of errors for 100 problems with alcohol

**Significant with a confidence of at least 0.999

*Slightly significant at the 0.95 level

Table 3.4 contains the analysis of variance for the total number of errors on the two control days. Alcohol concentrations were not significant. There were significant effects caused by subjects and a measurable influence from complexities. The subject-complexity interaction appeared again in this analysis.

3.4 General Conclusions

There was no evidence to support the hypothesis that alcohol at low to medium concentrations in the blood would facilitate behavior having a large motor component but cause a decrement in behavior requiring cognitive processes. Behavior deteriorated at all concentrations of alcohol studied. The cognitive component did not appear to be affected even though performance on the test containing the cognitive component did deteriorate.

SOURCE	d.f.	SS	MS	F
Replications	1	7,194.15	-	-
Alcohol Levels (A)	3	1,526.30	508.77	1.89
Complexities (B)	2	4,911.93	2,455.97	9.13**
Subjects (C)	9	114,148.65	12,683.18	47.14**
Interaction (AB)	6	839.98	140.00	0.52
Interaction (AC)	27	4,830.45	178.91	0.66
Interaction (BC)	18	22,329.83	1,240.55	4.61**
Interaction (ABC)	54	6,740.27	124.82	0.46
Error	119	32,018.86	269.07	-
Total	239	194,540.42	-	-

Table 3.4.- Analysis of variance for the total number of errors for 100 problems without alcohol

**Significant with a confidence of at least 0.999

CHAPTER 4

DISCUSSION

4.1 Comparison With Other Data

In the field of research on the behavioral effects of alcohol on man, it is sometimes difficult, if not impossible, to compare results. This difficulty is caused by the failure of many investigators to report all experimental conditions that are pertinent to the results. The major factor in this difficulty is the difference between dose of alcohol and blood alcohol concentration attained with a specific dose. The blood alcohol concentration attained is related to the dose; but it is also related to the rate of absorption. The rate of absorption is related to the quantity and quality of food in the stomach. In the present study, this problem was overcome by measuring the blood alcohol concentration directly with the Breathalyzer^{R}.

The performance decrement in all three tests was in agreement with other studies in which tasks having a large motor component were used (38, 42, 15, 55, 9). Even though some investigators used psychomotor tasks or driving simulators and were unable to measure decrements (17, 16, 29, 20, 34, 10), this might have been a result of the relative magnitude of the motor component.

The finding that alcohol did not affect the cognitive component of behavior is compatible with the findings of several investigators. Wilkinson and Colquhoun (57) found similar results using the Five Choice test of choice reaction. Primarily, their test was a test of prolonged

attention and concentration, but it involved a degree of motor coordination. When analysis was based upon the scores in the test as a whole, alcohol effects were not significant. From the interactions of alcohol with sleep deprivation and with knowledge of test results, they were able to conclude that alcohol in a moderate dose acts as an arouser and not as a depressant. Landauer, Milner, and Patman (35) reported results which are in agreement with this finding. The three tests which they used (simulated driving task, dot-tracking task, and pursuit rotor task) probably contain a small or minimum motor component.

Higgins et al. (29) were unable to show a decrement in performance with blood alcohol concentrations as high as 115 mg percent. They actually found improvement with time, which may have been a result of training. Their tests of reaction time (time to turn off a buzzer by pressing a key) and motor coordination (the total number of squares in which the subject was able to construct a three line configuration in 60 seconds) probably contained minimum motor components. Ferret, Barbut, and Ducos (16) attributed the improvement in performance they found in seven of twelve subjects with alcohol to the fact that these seven subjects were emotionally unstable types. Frankenhaeuser, Myrsten, and Jarpe (22) found that verbal and inductive test performance was unaffected by alcohol. Their results showed that performance speed was less affected than accuracy.

In the study by Laties and Weiss (36) on timing behavior, the mean number of responses was comparable before and after alcohol and the inter-response time did not change. When they modified the experiment

by asking the subjects to do concurrent subtraction of the number 17 beginning with 1000, the mean number of responses did drop. This may have been a result of the motor component introduced.

The lack of an alcohol-complexity interaction when the total errors were analyzed is also in agreement with the above analysis. There was a slight alcohol-complexity interaction when the total time to complete 100 problems was analyzed. This may have been a result of the performance criteria required of the subject. One performance criteria was given to the subject. It was to perform all problems as rapidly as possible. The results of the tests were not given to the subject until all tests had been completed. Other investigators (56) have required two performance criteria (perform as rapidly as possible but errors will be charged against the subject).

There are a number of sensory factors whose influence cannot be entirely discounted. Alcohol nystagmus and in particular the first phase (PAN I), as described by Goldberg (24), is one. (PAN I appears about one-half hour after alcohol intake. It is a horizontal, spontaneous positional nystagmus with one fast and one slow component. With the head in the right lateral position, the fast component beats to the right, changing its direction with the position of the head.) The subject was seated for approximately 3 to 5 minutes at the test device before the test started and the test itself did not require any head movements which are required to elicit the nystagmus. Therefore, it is doubtful that nystagmus contributed to the results.

4.2 Significance of the Data

Even though observations of complex human behavior cannot be extrapolated directly to the central nervous system, observations can implicate fruitful areas for more intense study. The finding that alcohol affected the motor component of behavior implicates one or more of the following areas of the central nervous system. Breakdown of the visual processing centers could increase the error rate in a motor task having visual input. This could result from an elevation of the visual threshold caused by a drug, a breakdown in the fine positional control of the eyes by the oculomotor system, a change in other inputs to the visual system such as the input from the vestibular apparatus or a change in the output of the visual system to lower centers in the central nervous system. There was no evidence that the visual threshold was increased by alcohol. Other investigators (42) have been unable to measure visual decrements.

The alcohol could have influenced the cerebellum. The cerebellum is primarily a neural mechanism regulating and graduating muscular tension for the proper maintenance of equilibrium and posture and the smooth performance of voluntary movements. Any disturbance in this system could account for the increase in errors in a motor task.

Since the reticular activating system can be considered as an integrating system for the entire central nervous system, alcohol could exert an influence on this system. The influence of alcohol on this system might be to alter the fine motor movements required by a motor task having visual inputs.

Although this experiment did not localize the site of action of alcohol in the central nervous system, the type of behavioral changes observed did implicate one or more of the subsystems involved in motor coordination.

The finding that all tasks deteriorated with alcohol should be a warning to those who would consider driving an automobile and in particular those who would consider flying an aircraft following consumption of small quantities of alcohol. Most of the people who would consider doing these types of activities are probably justified in their claim that they can think just as well with alcohol, but they fail to recognize that their fine motor control and precision of motor response is significantly deteriorated by small blood alcohol concentrations.

4.3 Validity of the Hypothesis

There was no evidence to support the hypothesis. On the contrary, behavior deteriorated at all concentrations of alcohol studied. The reason that behavior deteriorated appeared to be due to the increase in error of the motor component. Since this was a self-paced task, an increase in errors would produce an increase in performance time. The task required very precise positioning and holding all four limbs simultaneously for 0.3 seconds before a problem was solved. This was the component of all tests that appeared sensitive to alcohol.

There was no evidence that cognitive behavior, as measured in this experiment, suffered. The complexity-alcohol interaction that appeared in the total time may have been a result of the performance criterion asked of the subject. That is, in the training sessions as well as the

tests, the subjects were asked to perform all problems as rapidly as possible. This interaction was not significant in the analysis of errors.

4.4 Implications for Future Research

An interesting measure to evaluate in future research with the LRC Complex Coordinator is response latency. That is, the time per problem that it takes the subject to make a correct response with an limb. It is possible that this measure will be sensitive to those stresses which affect either the cognitive components of the test or the conduction velocities of the nervous system.

Another interesting study with this device would be a survey of drug effects on man. From such a study, it would be possible to group drugs which produce similarities in performance. This kind of information possibly could allow one to infer the sites of action of an unknown drug.

In future research using this device, the sensitivity of the measures could be improved by using the test device to select subjects for the test. There was a large component in the analysis of variance which was due to subject variability. In most studies, it would probably be desirable to have several groups of subjects whose abilities varied over a wide range; thus, subjects could be grouped according to ability.

Using the above mentioned refinements, it would be interesting to take a closer look at behavior when the blood alcohol concentration was in the range of 0.010 to 0.050 percent to determine if there is

facilitation in more complex mental processes. There was a suggestion of this at the 0.010 percent level on the most complex task, and Carpenter et al. (11) showed that problem solving efficiency on the "Calculus method" was facilitated with a dose of 0.33 ml of alchol per kg of body weight. Carpenter and Ross (12) found that less proficient subjects showed improvement at low alcohol doses on the Running Matching Memory Task. Performance on the Complex Mixed Test at a blood alcohol concentration of 0.010 percent (Fig. 3.3) was suggestive of their finding but did not prove to be statistically significant.

CHAPTER 5

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CHAPTER 6

APPENDIX

The following tables contain the behavioral measures for the individual subjects. Data are presented for three levels of the cognitive component and two replications with and without alcohol.

REPLICATION NO. I					
COMPLEXITY	BLOOD ALCOHOL CONCENTRATIONS (%)				
	SUBJECT	0.000	0.010	0.050	0.100
SM	1	130.31	135.81	127.21	166.52
	2	139.67	141.82	150.62	166.49
	3	137.39	138.14	163.63	156.32
	4	162.80	160.38	160.13	180.21
	5	161.65	168.63	172.90	212.83
	6*	130.04	130.44	164.16	
	7	144.20	158.59	156.78	184.98
	8	141.84	134.17	151.46	173.83
	9	143.46	159.64	155.72	183.49
	10*	129.35	129.80	135.50	185.37
	11	157.59	160.42	164.72	185.99
	12	150.01	153.12	155.21	181.19
MI	1	259.82	259.21	271.15	310.17
	2	204.05	211.42	222.85	270.48
	3	217.15	224.99	281.68	263.17
	4	257.66	269.89	248.52	323.71
	5	268.10	271.93	279.11	342.73
	6*	205.49	199.89	215.69	
	7	206.90	201.52	194.43	254.88
	8	216.84	216.60	229.71	244.09
	9	232.79	246.49	265.54	294.99
	10*	177.18	180.41	227.18	289.15
	11	266.46	270.94	267.22	301.01
	12	283.00	279.38	302.79	382.25
MII	1	301.70	304.07	343.94	388.49
	2	287.06	307.00	329.10	330.75
	3	300.93	274.25	334.12	356.20
	4	331.91	355.46	355.62	404.10
	5	325.44	314.65	339.27	370.06
	6*	246.60	250.44	299.69	
	7	247.22	246.15	267.92	290.13
	8	261.61	244.82	273.80	295.93
	9	310.86	289.65	282.33	365.91
	10*	239.04	254.51	281.91	336.26
	11	328.48	346.11	340.70	376.43
	12	301.19	339.01	370.69	522.08

Table A.1a.- Total time in seconds to perform 100 problems with alcohol. *Data not included in analysis of variance

REPLICATION NO. II					
COMPLEXITY	BLOOD ALCOHOL CONCENTRATIONS (%)				
	SUBJECT	0.000	0.010	0.050	0.100
SM	1	142.45	140.91	145.01	153.80
	2	130.54	134.06	136.94	176.87
	3	133.61	132.54	128.18	158.58
	4	158.13	154.51	154.87	184.37
	5	170.11	147.21	163.13	203.07
	6*	137.93	133.53	140.96	154.43
	7	152.10	163.00	172.80	213.24
	8	133.94	150.54	144.89	185.88
	9	150.28	173.91	171.20	172.01
	10*				
	11	176.73	184.08	177.75	238.46
	12	161.02	157.97	163.10	178.62
MI	1	252.77	241.83	274.22	274.56
	2	201.57	204.45	221.43	305.29
	3	216.30	205.66	230.43	288.18
	4	237.52	240.57	275.50	312.91
	5	267.01	262.86	283.77	298.72
	6*	195.49	188.40	209.12	208.57
	7	206.04	215.37	208.52	272.51
	8	203.55	213.60	210.82	270.80
	9	239.71	253.21	256.47	307.10
	10*				
	11	282.45	301.61	335.00	340.09
	12	263.40	261.24	278.92	318.08
MII	1	287.76	268.82	288.75	321.43
	2	276.11	275.14	310.39	362.78
	3	273.43	282.29	306.65	335.54
	4	349.11	307.10	336.13	375.29
	5	323.63	304.43	310.72	353.44
	6*	224.38	233.81	271.78	257.51
	7	260.15	246.50	243.16	302.06
	8	250.11	263.52	267.51	327.22
	9	262.84	266.58	300.81	369.72
	10*				
	11	381.54	334.45	450.61	384.47
	12	368.13	336.42	314.98	408.71

Table A.1b.- Total time in seconds to perform 100 problems with alcohol. *Data not included in analysis of variance

REPLICATION NO. I					
COMPLEXITY	BLOOD ALCOHOL CONCENTRATIONS (%)				
	SUBJECT	0.000	0.000	0.000	0.000
SM	1	141.27	125.61	129.51	138.94
	2	142.72	151.86	144.13	134.92
	3	148.28	136.97	133.42	126.00
	4	147.64	147.97	147.20	158.39
	5	165.85	160.19	172.09	159.14
	6*	138.64	145.99	143.34	143.86
	7	145.01	157.56	167.90	161.60
	8	149.69	152.09	141.78	149.25
	9	161.53	172.06	172.24	189.45
	10*	129.21	137.80	131.77	130.22
	11	172.45	169.62	160.38	163.42
	12	158.54	150.86	163.02	157.60
MI	1	224.52	241.66	247.70	268.47
	2	232.24	217.38	209.67	215.22
	3	235.67	238.05	233.34	239.56
	4	229.69	232.90	239.41	235.29
	5	308.03	294.03	288.52	270.70
	6*	217.32	213.13	220.21	236.35
	7	243.96	234.48	220.35	227.11
	8	255.79	243.57	254.91	258.80
	9	292.18	315.11	286.59	280.09
	10*	220.78	201.82	197.18	193.04
	11	276.12	274.01	257.07	271.07
	12	308.94	295.63	297.17	317.01
MII	1	298.47	307.13	288.39	293.87
	2	320.39	303.14	290.34	273.54
	3	326.93	329.15	320.80	299.75
	4	295.84	303.70	303.57	311.58
	5	393.06	349.49	356.69	349.64
	6*	287.95	275.23	285.28	295.75
	7	283.06	286.04	291.22	266.36
	8	302.92	337.12	302.19	307.90
	9	345.55	341.08	337.22	326.41
	10*	317.28	282.68	303.59	281.78
	11	368.31	362.38	350.51	362.68
	12	348.18	326.54	349.79	348.71

Table A.2a.- Total time in seconds to perform 100 problems without alcohol. *Data not included in analysis of variance

REPLICATION NO. II					
COMPLEXITY	BLOOD ALCOHOL CONCENTRATIONS (%)				
	SUBJECT	0.000	0.000	0.000	0.000
SM	1	135.15	123.01	133.62	126.34
	2	138.73	133.11	131.55	134.11
	3	141.73	144.29	137.45	127.29
	4	148.18	144.62	150.32	147.71
	5	155.07	156.81	169.65	162.93
	6*	136.91	135.59	140.13	140.62
	7	156.73	164.48	161.07	148.53
	8	136.33	142.37	137.11	145.92
	9	156.53	164.88	158.11	158.61
	10*	120.15	142.11	133.92	126.43
	11	160.23	166.71	160.26	172.60
	12	149.39	149.84	154.67	156.93
MI	1	213.29	236.83	202.53	233.12
	2	209.43	205.26	204.33	202.35
	3	235.52	214.02	223.08	219.08
	4	220.40	221.36	234.95	217.39
	5	273.12	266.71	298.06	281.20
	6*	213.36	228.67	203.46	225.69
	7	228.88	230.96	227.18	219.53
	8	224.65	221.28	230.09	234.21
	9	255.52	260.49	264.83	250.94
	10*	193.79	207.13	202.87	198.56
	11	263.01	250.12	259.81	286.26
	12	290.94	306.90	313.19	291.13
MII	1	286.78	281.74	274.34	282.73
	2	314.37	270.19	270.66	268.37
	3	268.25	254.01	259.60	250.95
	4	282.28	290.86	289.44	283.13
	5	319.40	332.90	305.35	323.11
	6*	262.42	264.64	254.54	265.79
	7	272.43	254.42	269.14	246.77
	8	283.02	278.03	267.10	290.42
	9	312.23	319.03	313.33	291.20
	10*	273.95	257.43	253.99	282.06
	11	337.08	337.34	322.82	303.86
	12	338.72	380.33	360.05	344.40

Table A.2b.- Total time in seconds to perform 100 problems without alcohol. *Data not included in analysis of variance

REPLICATION NO. I					
COMPLEXITY	BLOOD ALCOHOL CONCENTRATION (%)				
	SUBJECT	0.000	0.010	0.050	0.100
SM	1	115	139	152	127
	2	72	81	62	77
	3	78	65	88	85
	4	84	78	91	125
	5	87	100	86	108
	6*	61	69	98	73
	7	101	120	130	133
	8	72	81	101	98
	9	68	91	76	91
	10*	82	72	83	137
	11	72	98	74	97
	12	42	62	62	114
MI	1	134	152	164	131
	2	58	68	36	63
	3	84	98	112	111
	4	111	112	91	150
	5	74	59	56	65
	6*	80	82	86	84
	7	91	80	88	101
	8	73	93	100	91
	9	50	60	74	68
	10*	71	73	108	125
	11	50	73	82	88
	12	38	43	47	90
MII	1	100	109	123	123
	2	64	49	51	53
	3	105	100	134	165
	4	64	67	79	105
	5	77	64	84	69
	6*	62	73	82	84
	7	92	82	93	97
	8	76	67	90	107
	9	70	75	45	89
	10*	49	70	112	121
	11	69	96	64	87
	12	49	62	50	83

Table A.3a.- Total number of errors for 100 problems with alcohol.
*Data not included in analysis of variance

REPLICATION NO. II					
COMPLEXITY	BLOOD ALCOHOL CONCENTRATION (%)				
	SUBJECT	0.000	0.010	0.050	0.100
SM	1	169	173	169	200
	2	68	72	53	75
	3	73	68	66	95
	4	117	93	92	138
	5	107	65	65	99
	6*	78	66	74	56
	7	89	107	113	130
	8	66	78	65	107
	9	80	116	83	71
	10*	66	83	60	62
	11	98	88	125	137
	12	67	61	35	52
MI	1	132	115	144	126
	2	48	47	44	46
	3	89	82	109	93
	4	99	132	129	105
	5	74	55	67	50
	6*	73	61	89	69
	7	80	97	73	87
	8	82	73	81	110
	9	72	74	59	91
	10*	83	81	72	74
	11	69	101	93	104
	12	34	34	38	57
MII	1	104	95	103	109
	2	67	58	47	39
	3	105	128	156	138
	4	87	97	85	95
	5	67	58	47	60
	6*	42	74	73	83
	7	104	102	87	81
	8	75	69	82	120
	9	52	55	70	108
	10*	65	77	67	62
	11	82	91	142	105
	12	55	42	32	79

Table A.3b.- Total number of errors for 100 problems with alcohol.
*Data not included in analysis of variance

REPLICATION NO. I					
COMPLEXITY	BLOOD ALCOHOL CONCENTRATION (%)				
	SUBJECT	0.000	0.000	0.000	0.000
SM	1	113	101	128	129
	2	69	89	91	74
	3	63	52	60	64
	4	92	75	78	80
	5	69	60	75	70
	6*	73	68	70	74
	7	192	129	158	169
	8	72	74	71	83
	9	89	96	96	100
	10*	44	53	41	48
	11	95	102	81	82
	12	51	56	64	55
MI	1	109	109	113	129
	2	98	70	57	73
	3	85	80	80	72
	4	100	73	86	80
	5	83	59	56	41
	6*	93	90	99	97
	7	190	191	188	118
	8	64	67	91	85
	9	102	104	96	101
	10*	60	66	63	59
	11	74	82	67	77
	12	54	45	40	32
MII	1	101	90	70	98
	2	78	74	56	51
	3	112	119	104	105
	4	62	55	55	57
	5	70	70	84	85
	6*	87	86	80	93
	7	104	115	107	102
	8	96	107	87	96
	9	83	67	81	70
	10*	72	56	63	65
	11	74	75	79	67
	12	45	34	45	42

Table A.4a.- Total number of errors for 100 problems without alcohol.
*Data not included in analysis of variance

REPLICATION NO. II					
COMPLEXITY	BLOOD ALCOHOL CONCENTRATION (%)				
	SUBJECT	0.000	0.000	0.000	0.000
SM	1	152	98	125	127
	2	91	69	77	85
	3	107	80	76	66
	4	76	80	82	77
	5	71	59	80	70
	6*	56	66	66	73
	7	106	122	115	76
	8	66	84	63	77
	9	77	90	80	97
	10*	55	72	70	52
	11	74	94	67	74
	12	54	49	46	39
MI	1	69	97	90	121
	2	40	42	51	30
	3	102	96	105	97
	4	88	79	82	62
	5	63	55	58	40
	6*	64	67	72	80
	7	121	104	100	95
	8	72	71	85	84
	9	57	61	76	56
	10*	60	78	77	83
	11	62	45	59	80
	12	38	33	27	24
MII	1	90	111	99	90
	2	51	45	54	44
	3	105	117	114	94
	4	53	58	50	45
	5	69	63	42	57
	6*	72	55	67	64
	7	112	96	101	83
	8	71	80	60	85
	9	55	72	58	56
	10*	63	65	55	53
	11	80	79	64	48
	12	38	43	35	25

Table A.4b.- Total number of errors for 100 problems without alcohol.
*Data not included in analysis of variance