AN EVALUATION OF THE PREDICTIVE PROPERTIES OF MEASURES OF VARIABILITY OF PERFORMANCE ON THREE PSYCHOMOTOR TASKS

by
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CHAPTER I

INTRODUCTION AND STATEMENT OF THE PROBLEM

Origin and Significance of the Problem

Anyone who has attempted to measure the level of performance of an individual on a motor or verbal task is aware that he performs at a different level of skill each time an observation is made. His level of performance will vary to a greater extent the finer the unit of measurement taken, and only the coarsest measures will be the same on two different occasions. Those who have had any experience designing tests recognize this variability at least implicitly and prefer to use measures that will give reasonably consistent results on a second occasion under similar circumstances. To obtain a sufficiently high coefficient of reliability, measures must be gross, the average of a number of observations, or based on a large sample of behavior.

Although the existence of variability of performance is recognized by most individuals, its importance may not be realized. In his discussion of behavioral oscillation, Hull (14, Ch.17) first demonstrates the existence of variability or oscillation of responses and then goes on to point out its significance. He states:

> It must be confessed that behavioral oscillation does impose a grave handicap on all the social sciences; generally speaking, it precludes the possibility of deductively predicting the exact momentary behavior of single organisms (14, p.316).

He points out that by means of statistical devices we can compensate to a large extent for this handicap, but he concludes:

> Finally, it may be said that the principle of behavioral oscillation is to a large extent responsible for the relatively backward condition of the social, as compared with the physical, sciences (14, p.317).

Since this variability is always present and is of the importance indicated the question arises as to what extent it can be used in prediction. Is variability related to the level of performance? Are some individuals characteristically highly variable while others show little variability? Current tests of verbal and motor skills are designed to eliminate or reduce the influence of variability, but few experimenters have made an attempt to measure it and evaluate its usefulness in describing or predicting behavior. Where scores based on the average of several measures are used, the variability of the scores about the mean is usually disregarded as a part of the description of the behavior observed. If variability can be shown to be a useful measure in addition to the conventional measures of performance, the present tests of performance can be of greater value.

In the fields of educational measurement, guidance, and selection and placement there is a never ending search for new and better tests and methods of testing, or for improvements of the present tests. All these tests are based on measures of performance of one sort or another, but extremely few utilize a measure of the variability of that performance. If variability can be satisfactorily measured and is practical for use as a predictor, then the present tests and testing methods can be improved to the extent of the usefulness of the measure of variability. The economic implications of such a finding are those of any improved method of guiding individuals into the proper vocational fields, of selecting those that will be the most likely to succeed, and of evaluating training progress.

Our manufacturing industries have been aware of the existence of variability in completed products and only recently have statistical techniques been used to measure the variability present. The field of quality control is concerned with the measurement of this variability, and the determination by sampling techniques as to whether it is exceeding the allowable limits. When variability is greater than the allowable limits, the source -- machine or individual -- must be located and corrections made. The measurement of individual variability is similar to the industrial quality control situation in methods and application. An individual whose output varies considerably in quality would be undesirable in a situation where production tolerances are small. If that individual can be eliminated prior to training or reassigned if already employed, one source of variability in the manufacturing process will be reduced. Industrial quality control has proved to be of value in manufacturing. Human quality control could be of value in any situation where skilled performance is required. Such considerations represent an important aspect of the technical field called Human Engineering.

One situation where highly skilled performance is required is in piloting an airplane. A pilot is expected to exhibit a high level of proficiency at all times, for a deviation from this level could result in tragedy. If an individual may be characterized as highly variable, it would be undesirable to begin training him as an aviator, for he would be a continual hazard to himself, his instructor, and the equipment. If an individual in training demonstrates inconsistency in the level of his performance, he may never reach the necessary proficiency or he will take longer to train. A measure of variability, then, would be important in evaluating training progress and could possibly be used as a predictor of final proficiency or desirability for further training. To carry the illustration to a third level, it might be possible to use a measure of the variability a pilot exhibits as an indication of his proficiency, for even though a pilot may be able to meet the requirements of the present flight examinations he will exhibit a certain amount of variability. If this can be measured and if there are significant individual differences, it may be an important factor in predicting his desirability as an operational aviator; and may be related to his likelihood of being involved in accidents. The relationship of variability of performance to flight proficiency is unknown, but if the variability can be measured and, better, predicted, its significance will be limited only by its importance in determining flight proficiency.

It is beyond the scope of this study to determine the importance of variability in a flight situation. The aim is, however, to investigate the basic problem of whether variability can be measured and used to describe individuals in a relatively simple situation. If measures of variability of performance are not useful in describing or predicting behavior, then the past disregard of them has been justified. It may well be that they are not useful, but on the basis of evidence available prior to this investigation no such conclusion can be reached.

Historical Background

In psychology, interest in the variability of behavior has arisen from two general sources. The earliest interest came about through attempts to measure the sensory thresholds, for it was found that an individual's ability to perceive very faint stimuli varied from moment to moment. This was referred to as the phenomenon of oscillation. In psychophysical measurements this oscillation is expected and there are well developed techniques to take it into account. An awareness of the seriousness of behavioral oscillations in addition to sensory oscillations came about through attempts to make successive measurements of intelligence, for it was found that these measures were never exactly the same. The problem then, is one of original measurement and one of reliability of measurements taken successively.

Under the heading of "Oscillations in Efficiency" Spearman (25, Ch.19) discusses the above origins of the problem, and summarizes the early attempts to isolate the sources of variability and to measure oscillation of sensation or behavior. The questions he raises are applicable today, for there were no satisfactory answers then, and there are none now. Referring to the phenomenon of oscillation, two of the questions he asks are:

> How, if at all, does this phenomenon vary quantitatively or qualitatively from one person to another? . . . . does the oscillation constitute a general factor in operations of every kind, so that he who is most liable to it in one will tend to be so in all others (25, p.323)?

He states that the available information is meager, but from the results obtained on a battery of eight simple paper and pencil tests he attempts to answer these questions, and comes to the general conclusion that oscillation is a universal factor that does vary from individual to individual. He considers the significance of this factor to be of "unknown magnitude" and points out:

> To make further scientific advance, the first progressive step must be to perfect the technique of measuring. As at present constituted, the tests cannot be made reliable except at the price of excessive time (25, p.328).

When the technique of measurement has been perfected, Spearman points out that there can follow an investigation of the variation of oscillation under different conditions for the same individual and of the relationship of oscillation to other factors. He gives an example that is immediately applicable to the present problem in which he shows a simple sine wave with the peaks of the curve labeled "a" and the troughs, "b". The curve is to "represent the course of the cognitive efficiency of any individual whose oscillations are of great amplitude". Spearman then states with reference to the individual represented by the curve:

> Suppose, first, that he devotes himself to inventing aeroplanes. In that case, his success will depend on his highest points, a, a, a; as for his depths, b, b, b, no great harm will be done if here he be reduced to the point of paralysis. But suppose, instead, that his vocation is to __fly__ aeroplanes, and that just when some sudden peril arises he happens to be down at one of the b's (25, p.328)!

Although written in 1927, the above illustration presents quite concisely the practical background for the present experiment.

Many studies of "variability" have been reported in the psychological and educational literature, but almost without exception these studies deal with variability between individuals. The effect of practice on variability has received much attention, and although most of the emphasis is placed on inter-individual variability, the intra-individual variability could not be ignored. It is a common assumption that in learning a motor skill, improved performance results from the reduction or elimination of useless or inadequate movements and performance becomes more routine and uniform. It would appear to follow then, that performance would become less variable as learning occurred. This has not been supported by the evidence however, for as Woodworth (28 p. 173) points out, whether variability increases or decreases with practice depends on the type of measure taken and the task used. He cites data from Ruger (21) and Batson (3) to show that for a given task, the measurement of time per unit of output will show a decrease in variability with practice, whereas the measurement of output per unit of time will show an increase in variability. Relative variability ($\frac{100\,\sigma}{X}$) shows a decrease in both instances. The results also depend on the task, for in a ball-tossing experiment measuring output per unit of time, the absolute and also the relative variability increase with practice. In maze running measured by the number of errors per trial, variability is reduced to zero as errors are completely eliminated. Woodworth points out that variation still exists, but the measure used does not reveal it.

There has been much experimentation to determine the effect of practice on inter-individual variability, but the results are in disagreement. Kincaid (18), Peterson and Barlow (21), and Reed (23) summarize the relevant literature. Anastasi (2), however, points out the reasons for the controversy and shows how it may be reconciled. She states:

> Much of the controversy and confusion seems to have arisen from the attempt to go beyond the concretely established facts and discuss a sort of disembodied abstract "variability" which is expected to be independent of the particular situation in which it has been measured (2, p.151).

The dependence of variability on the situation in which it is measured is shown by the following outline of her discussion.

A. Type of practice
   1. Amount limit: variability will decrease with practice. The less skilled individual is given an advantage in that he can spend more time in practice.

   2. Time limit: variability will increase with practice. The less skilled individual is at a disadvantage since he accomplishes less in the time allowed.

B. Type of score
   1. Output per unit of time: variability will increase.
   2. Time per unit of output: variability will decrease.

C. Treatment of data
   1. Absolute variability: variability tends to increase.
   2. Relative variability: variability decreases.

It will not be the primary aim of the present experiment to investigate the effect of practice on between-individual variability, although it will yield information in that regard. The interest will be in the variability exhibited within the individual. To avoid the error pointed out by Anastasi, the term variability will not be used independently of the situations in which it will be measured, but only in relation to them. The attempt to characterize individuals along a dimension of variability will be in a relative rather than in an absolute manner. Variability on one task may show entirely different characteristics from variability on another as a function of the task or the method of measurement, but this will not invalidate comparisons of an individual's relative position from task to task.

There have been recent studies of intra-individual variability, but most of these studies have been of differences between traits or abilities rather than of discrepancies between responses from trial to trial on the same task. Preston (22) was concerned with the relation of trait variability to age and practice while Tilton (26) investigated the relation between IQ and trait differences. Gray (6 ,7) used variability of scores on the subtests of a verbal test and investigated its relationship to intelligence and emotionality. She concluded that there were individual differences in this type of variability but there were no consistent relationships to the factors she investigated.

Three studies were found that reported experimentation involving the measurement of variability within individuals and within the same trait or task. The first of the pertinent studies was reported in 1925 by Hollingworth (11). In his experiment he took measures of six individuals for a total of 42 trials of performance on three motor tasks, two verbal tasks, and pulse rate. From the data obtained two measures of variability were computed. The one measure he chose to call the "stability index", and was based on the correlation of scores for the first and last half-hour of each experimental period for each individual. This correlation was computed for each task and the median for five tasks (excluding pulse rate) was termed the "stability index" for that individual. An additional measure was based on the mean deviation of each trial from the individual's median score, divided by the median score. This was called the "Coefficient of Variability".

Hollingworth found that the two measures of variability of performance were closely related, although inversely. He found that high stability indices and low variability coefficients were "positively associated" with superior average performance and capacity for gain through repetition. He found too that the less variable individuals were more resistant to the effects of alcohol. He concludes:

> These interesting indications suggest the desirability of a more elaborate investigation of such relationships, on a larger array and range of individuals (11, p.208).

A second study by Woodrow (27) in 1932 is closely related. He also investigated the variability within an individual within one task. He states his aim and points out the possible significance of the results as follows:

> It is such variation from sitting to sitting, or from day to day, here designated by the term 'quotidian variation' that is to be considered. A method of measuring

> this characteristic, yielding what may be termed an index or ratio of quotidian variation will be described, and illustrative results obtained by its use will be presented. It is believed that this index may be of significance in the description of individuals - possibly even in clinical psychology - since under the same test conditions individuals differ greatly in the degree of instability of behavior from day to day. It is probable that a more important use for this index lies in the fact that a recognition of the conditions revealed by it should be conducive of greater efforts in psychological experimentation to control the internal condition of the subject, whether by more adequate instruction or otherwise, and should lead to an actual determination of whether the condition of the subject has been controlled to the point where significant differences do not occur under supposedly constant conditions. Efforts along these lines should result in improving the verifiability of the conclusions drawn from a psychological experiment, a verifiability which has been noticeably uncertain in many instances in the past (27, p. 246).

The index of quotidian variation that Woodrow uses is the ratio of the experimentally obtained standard deviation of the daily average scores, to the average standard deviation of each day's scores; divided by the square root of the number of scores taken each day. He shows, that under constant external conditions, if the successive measurements are all of the same universe or category that ratio will not differ significantly from 1. If the data are corrected for practice effects, any significant deviation indicates that the measurements are not of the same universe, and the conditions are not constant as assumed.

Woodrow applied this analysis to the data given by Thorndike in a line drawing experiment, and to his own experiment using two subjects in a synchronous tapping experiment. He also analysed data for eight subjects in reproducing empty time intervals, and in every case the index of quotidian variation differed significantly from 1. The magnitude of the index varied with the individual. He concludes:

> The results cited above indicate that in the average psychological experiment pertinent conditions, probably for the most part conditions within the subject, are not adequately

> controlled. Under conditions such as ordinarily prevail the processes which go on in the subject and lead to the measured responses change to such a degree that the measurements made on one day may not belong to the same population or category as those made on a different day, even though all conditions that are controlled by the experimenter remain constant(27, p.256).

Woodrow's study demonstrates the existence of variability that is "probably for the most part" due to conditions within the subject, but he does not attempt to make use of his index of variation. Both studies indicate the possibilities for the measurement of variability and the desirability for further experimentation.

The third study of within-individual variability on the same task was carried out by Chance (4). In her experiment she twice administered both a personality test and an interest test to a large group of university students. By analysis of the test results and interviews with forty of the individuals tested, she concluded that intra-individual variability was present and the degree to which it appeared was related to tendency to report neurotic traits, adjustment problems, etc. Since variability was related to certain items it was possible to predict the degree to which variability might be expected. It was found that variability was specific to the personality test and showed no relation to variability on the interest test.

The problem that Chance was interested in was the influence of intra-individual variability on measures of reliability and in the sources of that variability. The influence on reliability is the second source of interest in the problem of measuring variability, for it is important for a better understanding of the discrepancy between scores on successive administrations of a test. Since different measures of reliability will give different results, one problem is to isolate the errors of the measuring instrument from the variability within the individual. Recent techniques of analysis of variance are applicable to this problem and provide methods of handling the data that were not available to the earlier investigators of intra-individual variability. Methods of estimating reliability by these techniques are presented by Hoyt (13), Jackson (15,16), Alexander (1) and summarized by Johnson (17). Tests for homogeniety of variability as originally postulated by Neyman and Pearson and reviewed by Johnson (17, pp.82-86), will be used to determine whether the variability within-individuals differs significantly from one individual to another.

No studies have been found that would indicate that an attempt to measure variability or an attempt to use a measure of variability would be unproductive. In his discussion of behavioral oscillation, Hull (14) points out the existence and significance of oscillation as referred to above, but in addition he suggests some of its characteristics which may have an influence on the measurement of variability. There are many possible sources of variability of performance, and of those the physiological aspect is only one. In regard to this source he states:

> Now, nearly all movements are mediated by the coordination of sizeable muscle groups. If the contraction of one muscle of such a group should vary in its intensity, that of the others remaining constant, the joint movement produced by the group as a whole will inevitably deviate in one respect or dimension from what it otherwise would have been. Since the contraction of each muscle is mediate by distinct habits, the contraction of all the muscles of a group will oscillate independently. Thus coordinated movement as such may be said to have as many dimensions of variation as there are muscles involved in its production (14, p.315).

The implication of this statement, as applied to the problem under consideration, is that as the dimensions of variation become more numerous when the task increases in complexity, the reliability of a measure of the variation will decrease. Unless individuals differ significantly throughout the range of the possible dimensions of variation, and this difference is characteristic of each individual, measures of variability will not be reliable.

With the above consideration in view, if variability of performance on one task can be measured reliably, the question may be raised as to whether this variability will be related to variability on any other task. Of possible bearing on this question, Hull states with regard to simple learning that:

> . . . . evidence derived from trial and error learning situations demonstrates in a convincing manner that the oscillation associated with each habit tendency is largely, if not totally, uncorrelated with that of the others, i.e., that the oscillations of different effective habit tendencies are essentially asynchronous (14, p.318).

If this were true on the level of complex skills, one would not expect variability in one skill to be related to variability in another. It would not be possible under those circumstance to classify each individual along a general dimension of variability of motor performance. Experimental evidence indicative of the specificity of variability on a personality and on an interest inventory is reported by Chance (4) as summarized above.

The available experimental evidence leads to no definite conclusions with regard to the predictive properties of measures of within-individual variability, but it does indicate that there are individual differences in variability and that further research in the area might be profitable. In the previous research either the number of subjects used was small, or the number of trials given was inadequate for complete evaluation. It would appear desirable to examine within-individual variability on a larger number of subjects over a longer period of time. Variability should be investigated at different levels of learning and proficiency, for all the available types of measures of performance, for different time intervals of measure, and on tasks of differing levels of complexity.

It is not possible to explore all the possible relationships or to generalize beyond the experimental situation, but the aim of this investigation is to examine what appear to be the most important relationships involving the measurement of intra-individual variability. The results yield information with regard to the extent and characteristics of intra-individual variability of performance, and the effect of practice on variability. Conclusions are drawn concerning the existence of individual differences and the relationships of variability to other measures of performance.

Statement of the Problem

General statement and definitions. The purpose of the experiment is to make an evaluation of measures of intra-individual variability of performance as predictors of performance, variability, and training time on the same and other tasks. This is accomplished by testing the specific hypotheses stated below. The measures used are intra-day and inter-day variability of performance on a battery of three progressively more complex psychomotor tasks. The terms used in this investigation are defined in the following manner:

> Level of performance: conventional scoring of total time on target, or the number of correct matchings per unit of time.
>
> Intra-individual variability: standard deviation of an individual's performance scores from his own mean performance on a single test.
>
> Intra-day variability: standard deviation of performance scores within one day and on one task from the mean for that day.

Inter-day variability: standard deviation of performance scores on one task from the mean for all days.

Specific aims. To accomplish the general purpose of the investigation, specific aims have been formulated. These aims, for each task, are:

1. To determine if final performance can be predicted from initial performance.

2. To determine if there are individual differences in variability of performance.

3. To determine if intra-individual variability late in practice can be predicted from intra-individual variability early in practice.

4. To determine if, at any stage of learning, intra-individual variability is related to level of performance.

5. To determine if inter-day and intra-day measures of intra-individual variability are related.

6. To determine if time of training to reach a performance criterion can be predicted from intra-individual variability early in practice.

7. To determine if measures of initial variability are of value in addition to measures of initial performance in predicting final performance.

In addition to the relationships within each task, specific aims have also been formulated for the relationships among the three tasks. Therefore the aims of the investigation also are:

8. To determine if performance on one task can be predicted from performance on the other two tasks.

9. To determine if variability on one task can be predicted from variability on the other two tasks.

10. To determine if measures of variability on the two less complex tasks are of value in addition to measures of performance in predicting final level of performance on the most complex task.

Hypotheses to be tested. In order to investigate the aims as stated above, they are restated below as hypotheses, which are as follows:

1. Initial performance is related to final performance on the same task.

2. There are individual differences in variability of performance.

3. Intra-individual variability early in practice is related to intra-individual variability late in practice on the same task.

4. Intra-individual variability is related to level of performance on the same task.

5. Inter-day and intra-day measures of intra-individual variability on the same task are related.

6. Measures of intra-individual variability early in practice are related to time of training to reach a performance criterion on the same task.

7. The multiple correlation of a measure of initial performance and a measure of initial intra-individual variability with the final level of performance on the same task is higher than the correlation of initial and final performance alone.

8. Measures of performance on one task are related to measures of performance on the other two tasks.

9. Measures of intra-individual variability on one task are related to measures of intra-individual variability on the other two tasks.

10. Using final level of performance on the most complex task as a criterion, the multiple correlation of measures of intra-individual variability on the two less complex tasks is higher than the multiple correlation with measures of performance alone.

For the purpose of statistical analysis the above hypotheses will be tested as null hypotheses, but conclusions will be drawn in terms of the positive statements.

CHAPTER II

METHODS AND APPARATUS

Experimental Design

In order to test the hypotheses set forth, measurements of performance of 30 individuals were made on three tasks, over a period of 15 days practice. The measures of variability used will be the standard deviations of performance scores about the individual's own mean for the day and for the entire training period. Acceptance or rejection of the hypotheses will be on the basis of product-moment correlations and multiple correlations between the variables measured. Significances of differences will be tested by means of the L_1 test of homogeneity of variability (17, p.82), and the analysis of variance technique.

The major variables involved in pursuing the aims of the experiment are as follows:

1. Tasks used (in order of complexity):[1]
   S.A.M. Rotary Pursuit Test
   S.A.M. Two-Hand Coordination Test
   S.A.M. Complex Coordination Test

For the purpose of the experiment the most complex task is defined as the one involving the most muscle groups. By this definition the task involving a rotary motion of one hand and arm in following a moving target is the least complex (Rotary Pursuit Test), and that involving the coordinated movement of one hand and arm and both feet in response to visual patterns is the most complex (Complex Coordination Test). The Two-Hand Coordination Test, involving the coordinated movement of two hands in following a moving target is considered to be at some unassigned point between the least complex and most complex task.

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[1]These tasks are described below.

2. Order of practice: with three tasks it is possible to practice them in six different orders. To be able to evaluate any possible effects of the order of practice, the number of individuals who practiced in each order was counter-balanced.

3. Amount of practice: Results of a pilot experiment indicated that subjects could be expected to reach a high level of skill in a 15 day period.

4. Time interval of measure: The following intervals will be available for analysis:

   Rotary Pursuit Test
      One trial (20 seconds)
      Trial series (five trials)
      Daily (15 trials the first day, 20 trials all other days)

   Two-Hand Coordination Test
      30 second
      Trial (one minute)
      Trial series (four trials)
      Daily (eight trials)

   Complex Coordination Test
      30 second
      Trial (one minute)
      Trial series (four trials)
      Daily (eight trials Day 1, 16 trials all other days)

   The measurements made will be:

1. Measures of performance:
   Time on each target area: for Rotary Pursuit and Two-Hand Coordination Tests.
   Number of patterns matched: for Complex Coordination Test.
   For the purposes of this experiment only the time on the 1/2" diameter center of the target will be analysed.

2. Measures of variability:
   Intra-individual variability of performance
      Intra-day
      Inter-day

Apparatus

The U.S. Air Force provided one test unit of each type used. The units are the standard ones used in the Air Force selection batteries.

modified for the purposes of this experiment. The operation of each task will be described briefly and the modifications and control units explained. The instructions to subjects, as shown in Appendix C, give additional information with regard to the operation of the tasks. More detailed descriptions and illustrations may be found in reference (19) edited by Melton.

The School of Aviation Medicine Rotary Pursuit Test

Description. This task involves a rotary motion of one hand and arm in following a rotating target. A photograph of the test unit is shown on the left in Plate 1. A brass target is set flush with the surface of the black bakelite turntable. The object is to maintain contact between the target and the point of a hinged stylus as the turntable rotates at 60 rpm. Performance is measured by the time that the stylus is in direct contact with the target, and is measured in units of .001 minutes.

Modifications. The Rotary Pursuit Test was modified in the following manner to make possible an evaluation of scores in terms of distance from the center of the target. The standard 3/4" target was replaced by a brass target composed of three insulated areas of an over-all diameter of 1 1/2", and with its center 3 3/16" from the center of the turntable. The center, or first, area of the target is circular, 1/2" in diameter. The second area is a ring having an outside diameter of 1" and fitted around the first area. The third area is a ring having an outside diameter of 1 1/2" and fitted around the second ring. Each area is separated from the other by a red plastic insulation 1/32" thick, and all are embedded in a balanced bakelite turntable. The entire target was rubbed down with a fine stone to eliminate surface irregularities. Each

Plate 1. S.A.M. Rotary Pursuit Test and S.A.M. Two Hand Coordination Test

area is wired to an insulated collector ring built into the turntable mounting bracket, and brushes mounted on the task unit housing carry the current to the scoring console. So that the contact area of the stylus would be small, the same at any angle, and less subject to wear, the stylus was modified by soldering a 1/8" ball bearing onto the end of the stylus.

Control Unit. The control console for the Rotary Pursuit Test and the Two-Hand Coordination Test is shown in Plate 2. This unit was constructed for the purposes of this experiment, containing electronic relays, timers, counters, and the cycling mechanisms for the automatic timing of the test and rest periods. The wiring diagram for the Rotary Pursuit Test scoring and cycling mechanism is shown in Figure I of Appendix A. The operational description is also given in Appendix A. A wiring diagram of the electronic relays is shown in Figure II of Appendix A. The cycling unit was taken from a standard Air Force control unit, and although modified to some extent, its basic operation remained the same. A single trial occupies a total time of 30 seconds: 1.5 seconds motor warm up, 20 seconds scoring, 8.5 seconds rest. The total operating time of the cycling mechanism for five trials is 2.5 minutes.

The School of Aviation Medicine Two-Hand Coordination Test (Model D)

Description. The object of this task is to follow a moving target over an irregular pattern with a contact point that is moved by means of two crank handles. The coordinated movement of both hands is required. A photograph of the task is shown on the right in Plate 1, and in more detail in Plate 3. The crank handle for the left hand is attached to a lead screw which drives the entire carriage, including the right hand crank handle, from left to right across the apparatus. The crank handle

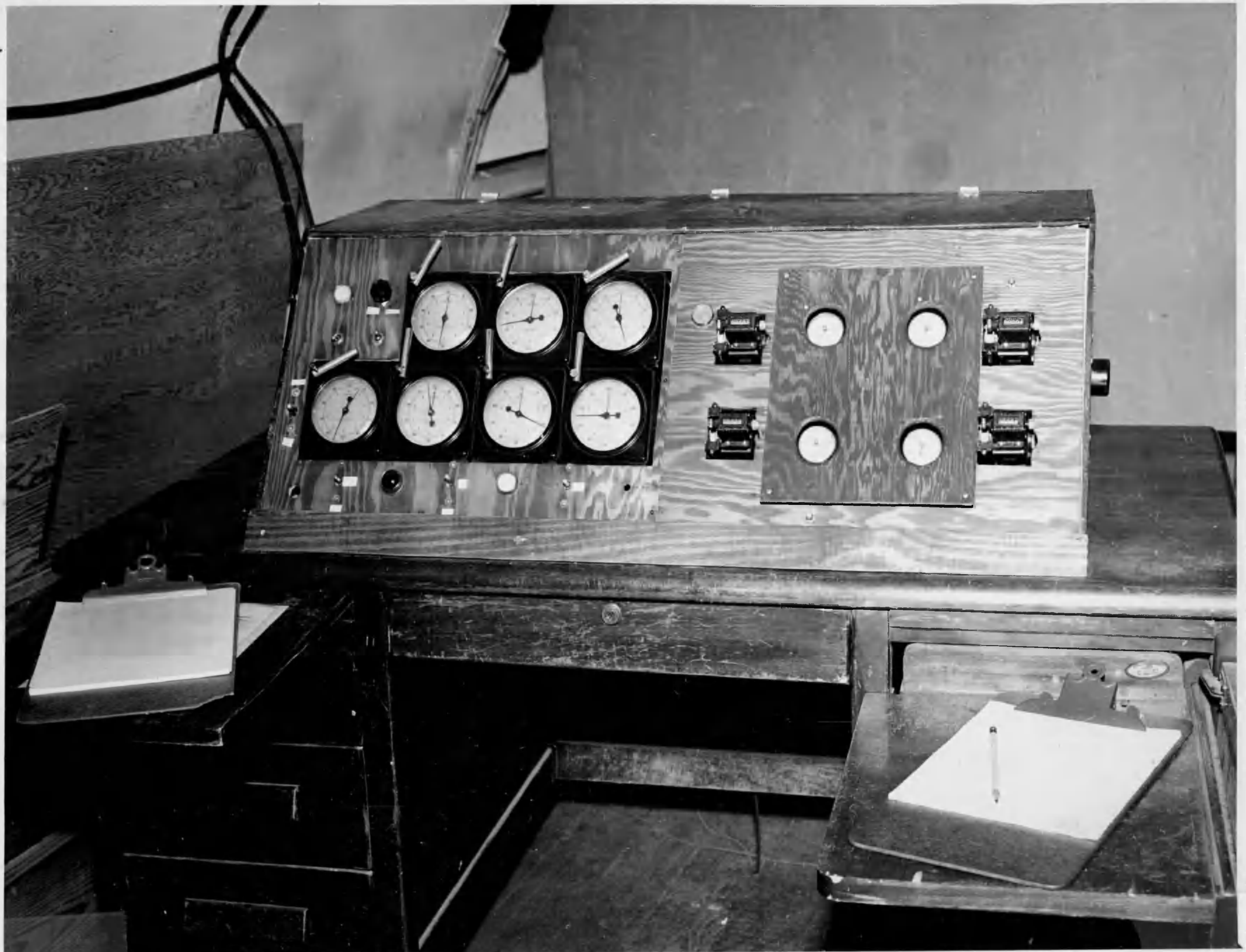

Plate 2. Control Unit for S.A.M. Rotary Pursuit Test and S.A.M. Two Hand Coordination Test

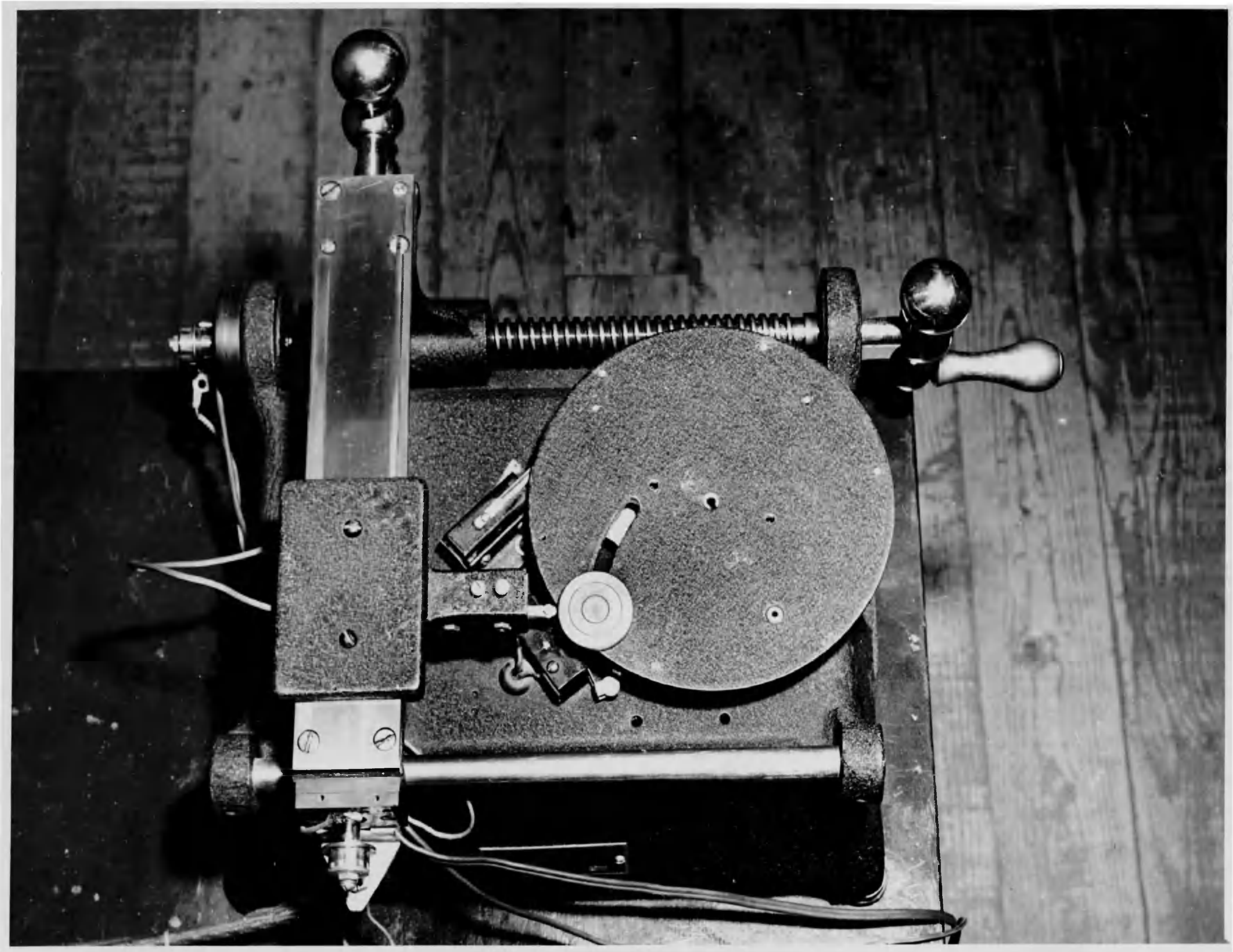

Plate 3. S.A.M. Two Hand Coordination Test

for the right hand is fastened to a second lead screw at right angles to the first, and moves the contact button with its mounting plate toward or away from the front of the unit. Rotating both handles at the same time moves the contact button to any position over the turntable; but since both lead screws have left hand thread the direction of rotation of the handle is the reverse of what normally would be expected. When the task is in operation the turntable disc rotates at a constant speed of 1 rpm. As the disc rotates it carried with it a brass target which is mounted on a shaft projecting up through a curved slot in the top of the disc. Irregular movements of the target within the slot are produced by two identical irregularly shaped cams mounted beneath the disc. The bottom cam is stationary, while the upper cam rotates in a counter-clockwise direction at 1/4 rpm. This cam arrangement produces four different patterns of movement of the target which are repeated every four trials.

Modifications. The following modifications were made in order to evaluate scores in terms of distance from the center of the target. The standard 7/8" target was removed and replaced by a target identical to the laminated target used in the Rotary Pursuit Test. The wires to each target area are bound to the target arm under the turntable, and lead down a hollow center shaft to collector rings below the worm drive gear. Insulated brushes mounted on the task unit housing make contact with the collector rings and are wired to the scoring console. The target is completely insulated from the mounting arm and the task unit housing. On the standard task, contact with the target closed a microswitch which in turn operated the scoring mechanism. This was modified so that current flowed through the contact to the target. A plastic block was substituted for the microswitch and the original spring contact arm and contact were fastened to the block. The contact arm was then connected to a flexible wire that led to a terminal strip on the underside of the task unit housing.

Control Unit. The Two-Hand Coordination Test is controlled from the same console as the Rotary Pursuit Test. The same target scoring mechanism is used but with a separate, special cycling mechanism and additional counters. A single trial occupies a total time of 75 seconds: two seconds warning, 60 seconds scoring, 13 seconds rest. The total operating time of the cycling mechanism, for four trials, is five minutes. A wiring diagram of the control unit is shown in Figure III of Appendix A. An operational description is also given in Appendix A.

The School of Aviation Medicine Complex Coordination Test (Model E)

Description. The object of this task is to coordinate the movement of stick and rudder controls in order to match patterns of visual stimuli. A photograph of the test unit is shown in Plate 4. The stimulus patterns consist of combinations of red lights presented before the subject on an upright panel, one light appearing in each of three double banks of lights. The banks of lights each consist of a row of 13 red and 13 green lights, each bank corresponding to one of the components of control movement. The green lights in each bank are manipulated by the airplane type controls, the upper curved row corresponding to aileron movement, the center vertical row to elevator, and the lower horizontal row to rudder movement. Each light of the stimulus pattern of three red lights is to be matched by a green light; and when all three are matched and held for a period of 0.5 seconds, a new stimulus pattern is automatically presented. The score is the number of patterns matched during

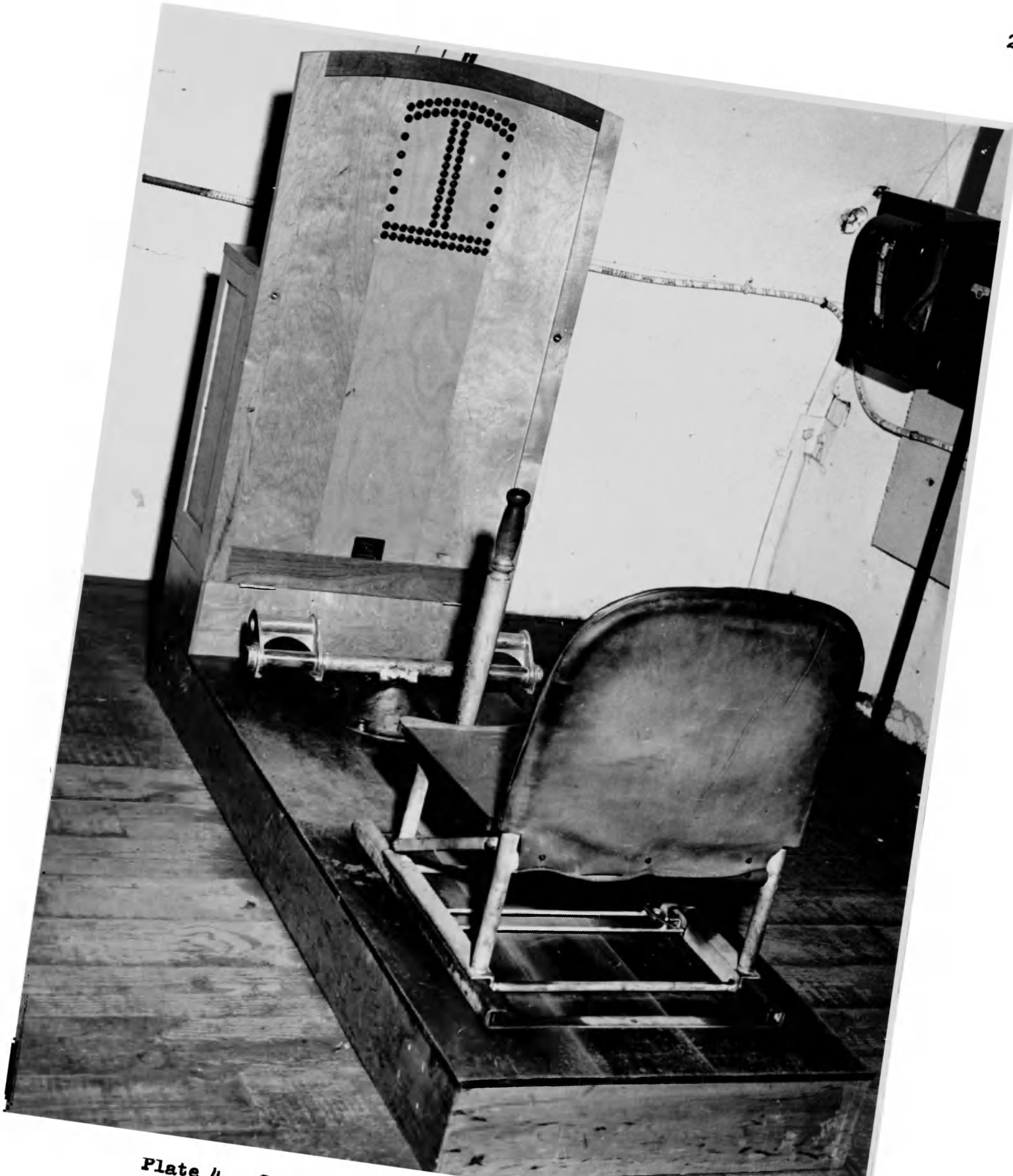

Plate 4. S.A.M. Complex Coordination Test

the trial period. The selector mechanism is constructed to present a total of 40 patterns of red lights. Of these 40, there are 13 basic patterns which are repeated three times, and then followed by basic pattern number 11.

Control Unit. The control console for the Complex Coordination Test is shown in Plate 5. This unit was also constructed for the purposes of the experiment and contains the scoring units and a cycling mechanism for alternating banks of counters. The circuit for the control unit is shown in Figure IV in Appendix A, and the operational description is also given in Appendix A. The number of settings or patterns completed is counted by a magnetic counter operated by a microswitch attached to the switching mechanism of the task unit.

Types of Scores

The types of scores used in the analysis of results differ to some extent for each task, and are described below. Other scores were obtained, but the analysis of the results will be limited to the scores described. The target scores on both the Rotary Pursuit Test and the Two-Hand Coordination Test represent the amount of time on the particular area of the target in units of .001 minute. The scores obtained on each task are:

1. Rotary Pursuit Test. The basic scoring period is 20 seconds, termed one "trial". The score obtained in this interval is the time that the stylus was in contact with the 1/2" diameter, center area of the target (Area 1).

2. Two-Hand Coordination Test. The basic scoring period is 30 seconds, termed the "30 second" score. The score obtained in this interval is the time that the contact point was in contact with the 1/2" diameter, center area of the target (Area 1).

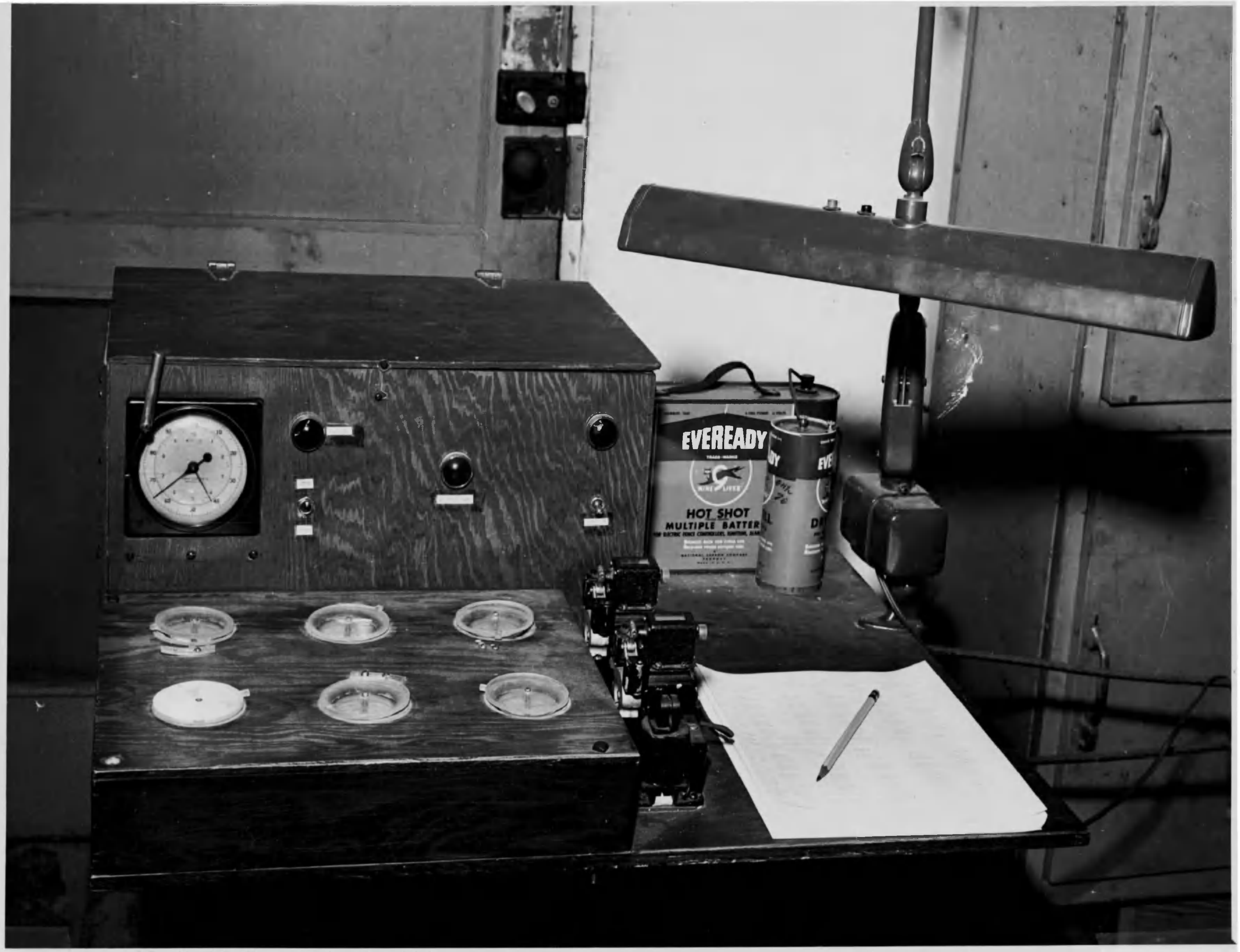

Plate 5. Control Unit for S.A.M. Complex Coordination Test

3. Complex Coordination Test. The basic scoring period is 30 seconds, termed the "30 second" score. The score obtained in this interval is the number of patterns that were matched.

The basic scores are the ones actually recorded from the scoring mechanism. All scores for intervals longer than the basic periods are obtained by summation of the basic scores. Sample scoring sheets with the scores for one individual on one day are shown in Appendix B.

Experimental Environment

The experiment was conducted in a 20' by 16' section of a Hobbs Type Hutment. The test units were set up along one side of the length of the room, with the Rotary Pursuit and Two-Hand Coordination Tests mounted on a desk 30 1/4" high as shown in Plate 1, and the Complex Coordination Test in the position shown in Plate 4. The control units were located on the other side of the room, opposite the tasks they controlled. The room was illuminated by three fluorescent fixtures each having two 40 watt fluorescent tubes. The level of illumination was high throughout the room except over the Complex Coordination Test where it was considered desirable to have the illumination slightly lower. Daylight was excluded so that the level of illumination was constant throughout the experiment. The scoring mechanism was soundproofed to as great an extent as possible and distractions were kept at a minimum. Only the subject and the experimenter were in the experimental room, and no one was allowed to enter during the experimental hour.

Procedure

A pilot investigation was conducted in which three subjects practiced five days a week for 23 days, and four subjects practiced seven days a week for 20 to 27 days. From the results of this investigation the following procedure was adopted.

Each subject practiced on all three tasks each day and in an order assigned prior to the experiment. The possible orders were numbered from one to six and assigned to subjects in the order in which the numbers appeared in a table of random numbers (5, p.340). The orders were assigned so that each would be represented the same number of times in each group of subjects, and counterbalanced for the entire number of subjects used. Because of subjects whose data could not be used, complete counterbalancing was not possible. The numbers of the subjects who practiced under each order are shown in Table I.

TABLE I

ORDER OF PRACTICE ON TASKS

X = Rotary Pursuit Test
Y = Two-Hand Coordination Test
Z = Complex Coordination Test

Order Number	Sequence of Practice	Subjects
1	X Y Z	1, 10, 19, 28, 23
2	X Z Y	8, 4, 21, 27
3	Y Z X	9, 11, 13, 18, 25
4	Y X Z	5, 2, 14, 17, 22, 30
5	Z Y X	3, 12, 15, 16, 24
6	Z X Y	6, 7, 20, 29, 26

The number of trials given on each task on Day 1 and Days 2 through 15 are shown in Table II. The number of trials given the first day conformed to the Air Force procedure and fitted conveniently into a 50 minute experimental period. Additional trials were possible after the first day since only brief instructions were necessary. In the pilot

TABLE II

NUMBER OF TRIALS GIVEN ON EACH TASK

	Rotary Pursuit	Two-Hand Coordinator	Complex Coordinator
Day 1	15	8	8 (+ 2 practice)
Days 2-15	20	8	16

experiment subjects quickly reached a high level of skill on the Two-Hand Coordination Test, so the additional trials were given on the Rotary Pursuit Test and the Complex Coordination Test. Two minutes rest was given between practice periods on the different tasks, and 30 to 60 seconds rest between trial series on the same task. Details of the administration of the experiment may be found in the Instructions to Subjects in Appendix C.

Each subject practiced for a total of 15 days. Because of university holidays and semester changes, Wednesday was chosen as the first practice day. Subjects did not practice on Saturdays or Sundays. Practice days were as follows:

Days 1 - 3: Wednesday through Friday of first week
Days 4 - 8: Monday through Friday of second week
Days 9 - 13: Monday through Friday of third week
Days 14 - 15: Monday and Tuesday of fourth week.

The individuals used as subjects were male volunteers from the general student body at the University of Maryland. The average age was 20.8 years with a range from 17 to 30 years. None had previous experience on the tasks used. All subjects had visual acuity of at least 20/20 corrected in each eye and had normal color vision, as determined by a Snellen wall chart and the Ishihara Tests for Color-Blindness. Thirty-seven students began the experiment but the analysis of results will be based on 30 subjects for whom the data are complete. The subjects were run in three groups chronologically and designated as follows:

Group A:	January 4 – January 24, 1950.	N = 12
Group B:	February 15 – March 7, 1950.	N = 8
Group C:	March 15 – April 4, 1950.	N = 10.

The tests were administered by five experimenters who were graduate students or senior majors in psychology. In order to assure as standard a procedure as possible, all instructions were read to subjects and experimenters administered the tasks to each other as checks on standardization. All had practice in administration prior to the experiment.

Subjects were informed of their highest scores at regular intervals during practice and were permitted to see any of their scores. On the Rotary Pursuit and Two-Hand Coordination Tests they were told their best score of the preceding series of trials during the rest period. Early in practice, scores were given for the sum of the three target areas; but later in practice, Area 1 scores were given. On the Complex Coordination Test, during the rest period, the subjects were told the total number of patterns they matched during the preceding interval. The individual was not given his own scores for previous days or any scores made by other individuals.

It was the intent of the experiment to maintain a low and stable level of motivation. Subjects were informed that at the conclusion of the experiment they would be paid at the rate of fifty cents for each practice period. They were told that they were participating in a learning experiment and that the aim was to find out how well they could do in the practice period given. They were reminded of this aim on the second day and at the beginning of the second and third weeks of practice. There were no intentional reminders at any other time unless questions were asked, in which case the same information was repeated. The complete instructions as read to the subjects are given in Appendix C. Scores were presented only as described above. No statements that could be interpreted as evaluations of performance were made, nor were the subjects aware of any other individual's performance. Subjects were requested not to discuss the experiment with anyone else engaged in it.

Every effort was made to maintain constant conditions throughout the experiment and to eliminate all possible sources of error. Administration of the tests was standardized and the experimental situation maintained as constant as possible. Timing of all trials and most of the rest periods was automatic. The apparatus and scoring mechanisms were checked frequently during each day. In spite of these precautions there was one source of error that could not be immediately corrected. This error was in the scoring mechanism of the Rotary Pursuit and Two-Hand Coordination Tests.[1] The possible effect on the experiment is that scoring conditions were not precisely constant from group to group. As to whether the conditions differed sufficiently to affect the results is a question that is considered below in the discussion of the results.

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[1]It was discovered that the spring tension of the relays contained in the electronic scoring relays decreased with use and permitted an overscoring to occur as the stylus passed from one area of the target to another. It was necessary, then, to make an adjustment in the spring tension of the relays in order to eliminate the possibility of scores higher than the theoretical maximum of .333 min. on the Rotary Pursuit, and .500 min. on the Two-Hand Coordinator. The first adjustment was made after the third day of practice of Group B, and on several occasions thereafter. Prior to this adjustment of the relays the scores for the sum of Areas 1, 2, and 3 did exceed the theoretical maximum by as much as .043 min. on the Rotary Pursuit and .015 min. on the Two-Hand Coordination Test. Increasing the spring tension operated to reduce the level of the scores for the total of the three areas. The effect on the Area 1 score would be expected to be of a lesser magnitude but its precise amount cannot be determined.

A second source of error was in the timing of the scoring intervals for the Two-Hand Coordination Test.[1] The significance of this error for the experiment is that any measure of variability will include at least a small amount of machine variability. The machine variability is insignificant early in training, but when the individual reaches a level of skill such that he scores only in the center area of the target, the machine variability may be greater than the individual's variability. As a result the comparison, between-individuals, of scores and of the variability of scores that approach the maximum is of limited value. Except for evaluations late in training, the error is not significant for its magnitude is small and it is randomly distributed between trials and between subjects. Its influence is considered below in the discussion of the results for the Two-Hand Coordination Test.

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[1]The timing of each trial is determined by the speed of the rotating disc. The apparatus is designed for the disc to rotate at the speed of one rpm, but the actual time for one revolution varied from .990 min. to .997 min. This speed could not be regulated, so no correction could be made. Because each trial was slightly less than one minute the maximum possible score that could be obtained for each trial varied from .990 to .997 min., depending on the speed of rotation of the disc.

CHAPTER III

ANALYSIS OF RESULTS FOR THE S.A.M. ROTARY PURSUIT TEST

The analysis of the data is presented separately for each task, and the relationships of measures within that task are presented under that task heading. Relationships of measures among tasks are presented after the analyses of the three tasks. To reduce confusion the following system of notation will be adhered to throughout the report:

Let X be any score on the Rotary Pursuit Test
Let Y be any score on the Two-Hand Coordination Test
Let Z be any score on the Complex Coordination Test.

Subscripts will be used to refer to specific scores as follows:

i : a score for any individual
j : a score on any day
h : half-minute score (30 seconds)
t : trial score
s : trial series score.

A bar placed over the letter indicates a mean score as for example, $\bar{X}_t$ = a mean trial score on the Rotary Pursuit Test. Additional symbols are added and are explained as the need for them arises. All target scores referred to are time in contact with the 1/2" diameter, center area of the target. All standard deviations referred to are maximum likelihood estimates, indicated as σ.[1]

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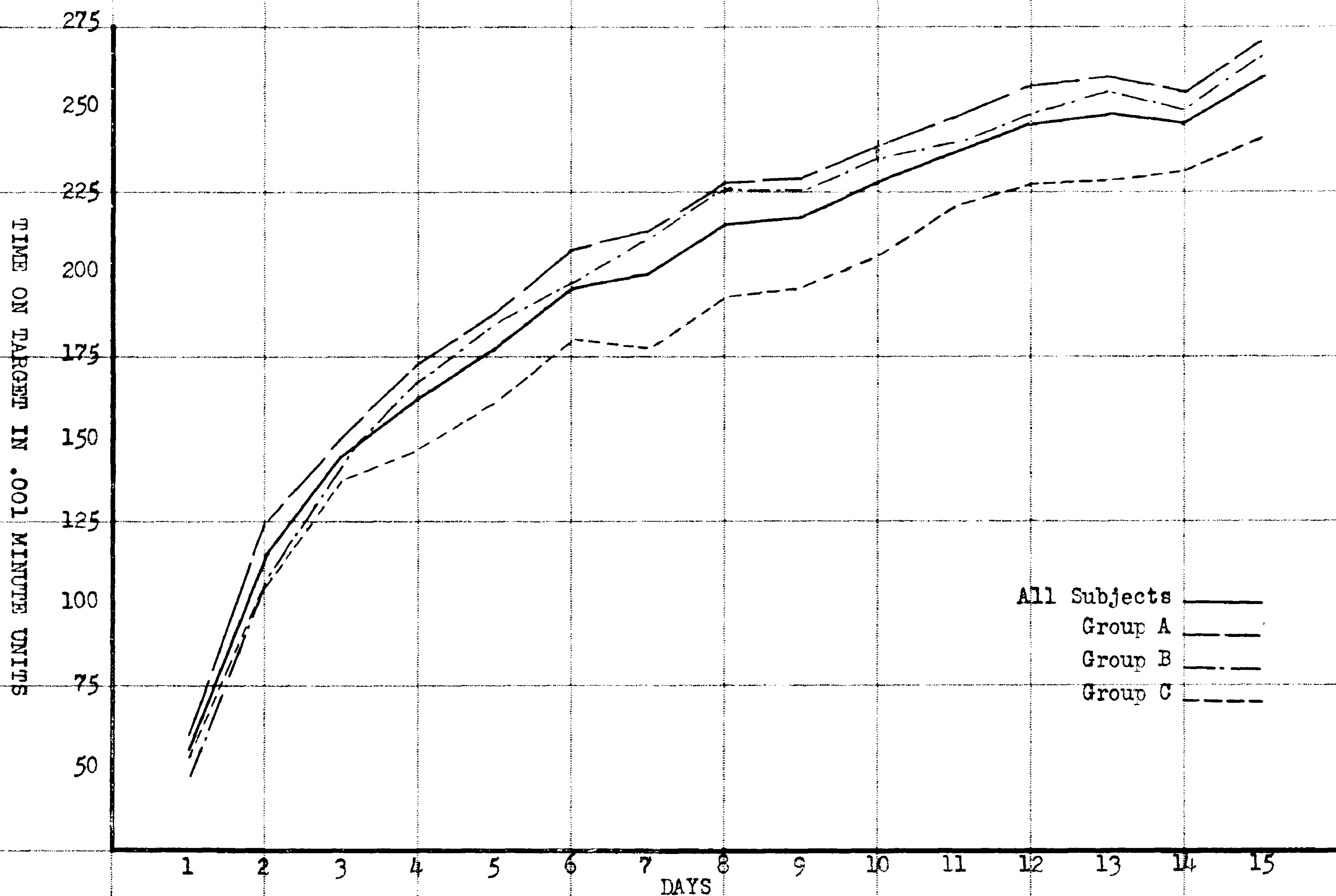
[1] The standard deviation of a sample is always an under-estimation of the standard deviation of the parameter unless the sample mean is equal to the mean of the parameter. A more precise estimate of the parametric value may be obtained by multiplying the sample standard deviation by $\sqrt{\frac{N}{N-1}}$, or from raw scores by the formula $\sigma = \sqrt{\frac{N \Sigma X^2 - (\Sigma X)^2}{N(N-1)}}$. Derivation of this formula is given in Peters and Van Voorhis (20, pp.70-71).

Level of Performance: Rotary Pursuit Test

The mean trial scores for each day and for each subject on the 1/2" diameter target are shown in Table I of Appendix D. These scores were computed by dividing the total score for all trials each day by the number of trials. They are referred to by the symbol $\bar{X}_t$. A graph of the means of the $\bar{X}_t$ scores for each group by days is shown in Figure 1. From inspection of the graph it can be seen that the mean score was still increasing at the end of the practice period, but the rate of increase was considerably less for the last eight days than for the first seven. An "end spurt" is apparent but would be normally expected for the subjects were aware that the fifteenth day was their last. The effect of lack of practice over the weekend was not apparent the first weekend, but over the second, groups A and B showed no improvement and over the third, their level of performance dropped. Group C showed less effect of no practice over the weekend. Inspection of the graph indicates that in this situation the higher the level of skill the greater may be the decrement in performance as a result of a break in the regular practice routine.

To test the hypothesis that the groups did not differ significantly among themselves in performance, the analysis of variance technique was applied to the $\bar{X}_t$ scores. The summary table for the analysis is shown in Table III. The evaluation of the between groups variance against the residual variance yields a highly significant value for F, indicating that the groups differ significantly. Group C deviates from the mean to the greatest extent, so an analysis was made to test the hypothesis that Groups A and B do not differ significantly. The summary of the analysis is shown in Table IV. When evaluated against residual (F_1) or both



ROTARY PURSUIT TEST: MEAN TRIAL SCORES

FIGURE 1

TABLE III[1]

ANALYSIS OF VARIANCE FOR GROUP DIFFERENCES, ROTARY PURSUIT TEST DAILY MEAN TRIAL SCORES ($\bar{X}_t$). N = 30

Source	Sum of Squares	df	Variance	F
Total	1884886.80	449		
Between Days	1406721.00	14	100480.07	99.15**
Between Groups	59538.49	2	29769.24	29.37**
Interaction	8178.50	28	292.07	-
Residual	410448.81	405	1013.45	

TABLE IV

ANALYSIS OF VARIANCE FOR GROUP DIFFERENCES, ROTARY PURSUIT TEST DAILY MEAN TRIAL SCORES ($\bar{X}_t$), GROUPS A AND B. N = 20

Source	Sum of Squares	df	Variance	F_1	F_2
Total	1297031.21	299			
Between Days	1012037.20	14	72288.37	69.54**	72.85**
Between Groups	3173.39	1	3173.39	3.05	3.20
Interaction	1144.11	14	81.72	-	
Residual	280676.51	270	1039.54		

residual and interaction variance (F_2), Groups A and B do not differ significantly. It may be concluded that Group C contributes most to the variance among groups, and is the group producing the heterogeneity of the between groups variance as shown in Table III.

[1]In this table and throughout the report, a single asterisk will indicate that a value of F is significant between the 1% and 5% levels of confidence. A double asterisk will indicate significance at less than the 1% level.

The source of the differences in the groups cannot be experimentally determined, but there are two possibilities. No effort was made to equate the groups at the beginning of training, for subjects were chosen only on the basis of availability for scheduling purposes if they qualified under the standards set up for the experiment. As one possible explanation for the group differences there may have been a biasing factor operating in the method of selection; but what would appear to be the more obvious explanation of the differences is in the adjustments that had to be made of the scoring apparatus. These adjustments of the electronic relays did not affect the shape of the curves to any extent but would be expected to depress the level of the scores. The scoring relays were not adjusted at any time during the Group A experimental period but were adjusted on several occasions during the Groups B and C experimental periods. In spite of this the three curves follow essentially the same patterns and in no case does a deviation from a smooth curve coincide with a point at which a scoring adjustment was made. Although adjustments were made during the Group B experimental period as well as the Group C period, no effect on the performance of Group B may be noted. Scoring adjustments cannot be eliminated as a source of the group differences, but because the difference cannot be attributed only to them, Group C will be used in the analysis along with the other groups.

To evaluate the effect on level of performance of the order in which the tasks were practiced, the analysis of variance technique was used. The fewest individuals who practiced in one order was four, so four individuals were selected at random from each of the other groups. The sum of each individual's daily mean trial scores for all 15 days of practice ($\sum_{J=1}^{15} \bar{X}_t$) was used as the measure of performance. The summary table for

TABLE V

ANALYSIS OF VARIANCE OF ROTARY PURSUIT TEST, TOTAL MEAN DAILY TRIAL SCORES. N = 24

Source	Sum of Squares	df	Variance	F
Total	3986417	23		
Between Orders	896745	5	179349	1.04
Within Orders	3089672	18	171648	

this analysis is shown in Table V. From the analysis it may be concluded that the order in which the tasks were practiced had no effect on the level of performance on the Rotary Pursuit Test.

To test the null form of Hypothesis 1 regarding the relation of initial performance to final performance, Pearson product-moment correlations of the daily mean trial scores ($\overline{X}_t$) were computed between Days 1 and 2, and each with all the other days. The intercorrelations of consecutive days were computed to determine the consistency with which the test measured performance from day to day. The correlations are shown in Table VI.

Using Guilford's tables of significant values of r (8, p.548), a correlation of .463 with an N of 30 is significant at the 1% level of confidence. It may be concluded then, that initial and final performance is significantly related, but that the relationship is relatively low in comparison with the correlations between consecutive days. The high correlations between consecutive days show that the test is a consistent measure of performance from day to day. Although the relationship remains positive, the correlations between Days 1 and 2 and all other days decrease as the days become more remote. From this it must be concluded that the practice in this situation has a differential effect upon individual

TABLE VI

INTERDAY CORRELATIONS OF ROTARY PURSUIT TEST
DAILY TRIAL SCORES ($\overline{X}_t$). N = 30

Days	Days 2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	.82	.79	.64	.59	.58	.54	.54	.57	.56	.63	.55	.49	.53	.50
2		.94	.79	.78	.70	.68	.66	.66	.64	.69	.63	.59	.62	.63
3			.87										.68	.71
4				.96									.84	.88
5					.94								.86	.90
6						.93							.89	.92
7							.94						.87	.90
8								.94					.85	.90
9									.92				.88	.90
10										.92			.90	.90
11											.95		.89	.90
12												.89	.87	.92
13													.88	.91
14														.95
15														

performance, although in general the individuals who are above average in the beginning must remain above average throughout training.

For later evaluation of measures of variability representative measures of performance will be desirable. The possible measures considered would be those that indicate the level of performance early, midway, and late in practice as well as the average level of performance. The relations between performance on selected practice days and the mean level of performance for all 15 days, as well as the gain[1] from Day 1 to Day 15 are shown in Table VII. Because the mean for the 15 days is based in part on the performance on each day it would be expected to be correlated with each of them to at least some extent. Because Day 7 is highly correlated with Day 15, evaluation against both would be unnecessary. The mean performance over the whole training period is also highly related to Day 15. Scores for Days 1, 2, 15, and gain appear to be somewhat different measures so they will be used as representative of performance.

TABLE VII

INTERCORRELATIONS OF SELECTED MEASURES OF PERFORMANCE ($\overline{X}_t$) ON THE ROTARY PURSUIT TEST. N = 30

	Day 2	Day 7	Day 15	Mean, Days 1-15	Gain, Days 1-15
Day 1	.82	.54	.50	-	-.20
Day 2		.68	.63	-	.09
Day 7			.90	-	-
Day 15				.94	.75
Mean, Days 1-15					.56

The interday correlations of consecutive days shown in Table VI indicate that the Rotary Pursuit Test measures performance consistently from day to day. An estimate of the reliability of the test may be derived from an analysis of the variance of the $\overline{X}_t$ scores. The summary table for the analysis is shown in Table VIII.

[1]Computed by subtracting the Day 1 mean score from the Day 15 mean score.

TABLE VIII

ANALYSIS OF VARIANCE FOR BETWEEN INDIVIDUAL DIFFERENCES, ROTARY PURSUIT TEST DAILY MEAN TRIAL SCORES ($\bar{X}_t$).
N = 30

Source	Sum of Squares	df	Variance	F
Total	1884886.80	449		
Between Individuals	395399.22	29	13634.46	66.88**
Between Days	1406721.00	14	100480.07	492.89**
Residual	82766.58	406	203.86	

The differences between days are highly significant as would be expected in a learning situation, and there are also significant differences between individuals in level of performance. The reliability of the test may be estimated by means of an adaptation of the Hoyt technique (13). The reliability is computed as follows:

$$r = \frac{\text{Between Ind. Var.} - \text{Residual Var.}}{\text{Between Ind. Var.}}$$

Applied to the data of Table VIII, this ratio yields a coefficient of .985. It may be concluded then, that the measures of performance obtained are highly reliable.

Homogeneity of Trial Score Variability

As each day's practice consisted of 15 or 20 trials, it is possible to consider each day as an individual sample of behavior and test to determine whether the variability within the different samples is homogeneous. That is, have the samples been drawn from normal populations having a common standard deviation? The test used is that of the criterion L_1 (17, p.82) the ratio of a weighted geometric mean to a weighted arithmetic mean of the mean squares from which the variances were estimated. The mean squares are weighted with the number of observations. It is possible to test the homogeneity of variability between individuals at any point in the training period, giving L_1 ratios as shown in Table IX.

The probability levels shown are based on Mayer's tables of the L_1 distribution (17,p.366). Rejection of the hypothesis of homogeneity is indicated when the obtained values are equal to or less than the tabled values of L_1 at the respective 1% or 5% level.

TABLE IX

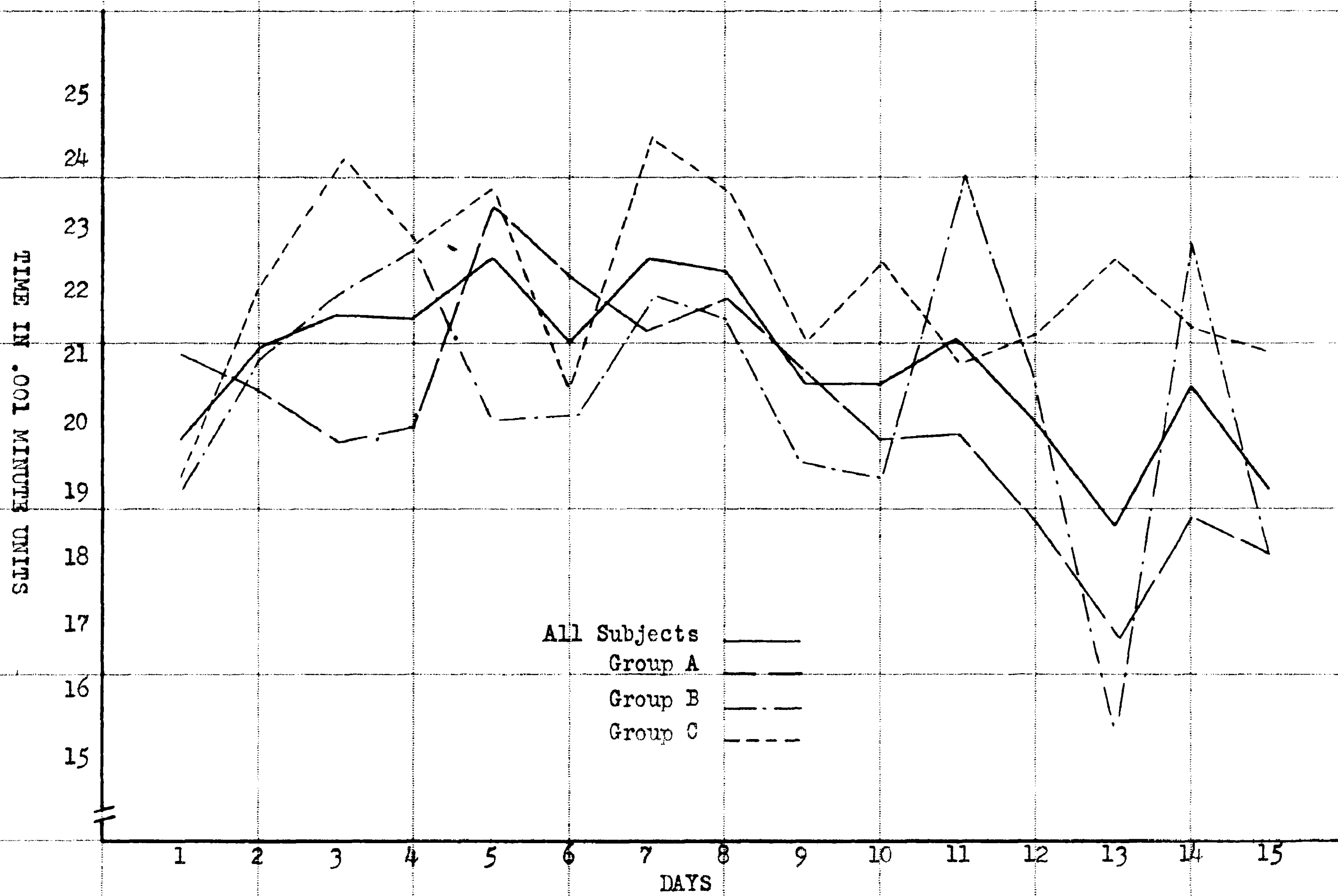
L_1 RATIOS. TEST FOR HOMOGENEITY OF VARIABILITY OF ROTARY PURSUIT TEST TRIAL SCORES ($\bar{X}_t$). N = 30

Day	L_1 Ratio	Prob. Level	Day	L_1 Ratio	Prob. Level
1	.863	< 1%	9	.926	< 5%
2	.890	< 1%	10	.886	< 1%
3	.911	< 1%	11	.894	< 1%
4	.962	> 5%	12	.897	< 1%
5	.927	< 5%	13	.844	< 1%
6	.945	> 5%	14	.855	< 1%
7	.895	< 1%	15	.832	< 1%
8	.887	< 1%			

For Day 1, the significant values of L_1 at the 1% and 5% levels respectively are .886 and .901. For Days 2-15, the 1% and 5% values of L_1 are .915 and .927. From the analysis it may be concluded that, except for Days 4 and 6, there are significant individual differences in variability of $\bar{X}_t$ scores throughout the training period. The existence of individual differences is fundamental to the design of the experiment. In general, the magnitude of the L_1 ratio varies directly with the magnitude of the standard deviations of the trial scores as will be shown below. In other words, the variability tends to be more homogeneous as the individuals are more variable. It would be desirable to have a measure of variability that would clearly differentiate between individuals every day of the training period, but that Days 4 and 6 do not, will not seriously affect the analysis. However, a measure of variability on those days will not be expected to be meaningful.

Intra-Individual Variability: Intra-Day

The criterion of L_1 indicates that there are individual differences in the variability of the trial scores for each day. The extent of that variability for each individual may be measured by the standard deviation of the trial scores about the individual's own mean for that day. The maximum likelihood estimates of the standard deviations of the trial scores for each individual, for each day, are shown in Table II in Appendix D. This measure will be indicated by the symbol $_{\sigma}t$. A graph of the mean $_{\sigma}t$ for all subjects is shown in Figure 2. Inspection of the graph shows no consistent relationship between variability and the day of the week. It may be seen that the mean intra-individual standard deviation shows an increase for the first half of the training period, and then decreases. This type of measurement of scores does not precisely fit Woodworth's (28, p.173) classification referred to above, but because all individuals were given the same length of practice period it can be best classified as output per unit of time. Variability obtained under this type of measurement would be expected to increase with practice. The graph of the mean for all subjects shows that in this situation variability increases only for the first half of practice, and then decreases. That the results do not completely agree with a prediction based on Woodworth's



ROTARY PURSUIT TEST: MEAN STANDARD DEVIATIONS OF TRIAL SCORES

FIGURE 2

statement may be because the classification is not proper and/or because the subjects were approaching their physiological limit. The upper level of performance is limited by the task, which would also tend to reduce variability, but with the practice given none of the subjects reached that limit at any time. As will be demonstrated later, individual differences in the trend of variability are marked, for some showed an increase in variability throughout training, whereas others showed a considerable decrease.

To test the hypothesis that order of practice on the tasks had no effect on variability of performance, the 15 day sum of the daily standard deviations of trial scores ($\sum_{J=1}^{15} \sigma_t$) were analysed as shown in Table X. The same 24 subjects were used as in the evaluation of the effect of order or practice on level of performance.

TABLE X

ANALYSIS OF VARIANCE OF ROTARY PURSUIT TEST
TOTAL STANDARD DEVIATIONS OF DAILY TRIAL SCORES. N = 24

Source	Sum of Squares	df	Variance	F
Total	27269	23		
Between Orders	4465	5	893	-
Within Orders	22804	18	1267	

The analysis supports the hypothesis that there are no differences in variability attributable to order of practice.

To test the null form of Hypothesis 3 and to determine the consistency of each individual's variability from day to day, product-moment correlations of variability scores (σ_t) were computed between Day 1 and all other days and between consecutive days. These correlations are

TABLE XI

INTER-DAY CORRELATIONS OF ROTARY PURSUIT TEST
STANDARD DEVIATIONS OF DAILY TRIAL SCORES. N = 30

	Day													
Day	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	.33	.18	-.23	.10	-.17	-.25	-.14	-.11	.06	-.20	-.26	-.06	-.15	-.18
2		.24												
3			.04											
4				-.07										
5					.35									
6						.29								
7							.36							
8								.60						
9									.43					
10										.27				
11											.23			
12												.38		
13													.23	
14														.54

presented in Table XI.

Using Guilford's tables of the significant values of r (8, p.549), with 28 degrees of freedom a correlation of .361 is significant at the 5% level of confidence, and a coefficient of .463 is significantly different from zero at the 1% level of confidence. By these standards none of the correlations of Day 1 with other days differs significantly from zero at the 1% or the 5% level of confidence, five of the consecutive day correlations differ significantly from zero at the 5% level and two differ at the 1% level of confidence. Inspection of the data shown in Table II of Appendix D shows that there are marked individual differences in the trend of variability with practice. Some individuals show a marked decrease, others remain at the same level, and a few show an increase in variability with practice. With such individual differences in trend one could not expect to predict final variability from the level of initial variability. It may be concluded that intra-individual variability early in practice, as measured by the standard deviations of the daily trial scores, is not significantly related to intra-individual variability later in practice. This measure of variability is not consistent from day to day and the relations among the consecutive days are chance relationships 50% of the time.

An estimate of the reliability of the intra-individual variability as measured by the standard deviations of the daily trial scores (σ_t) may be computed by the Hoyt analysis of variance technique. The summary of the analysis is shown in Table XII.

TABLE XII

ANALYSIS OF VARIANCE FOR BETWEEN INDIVIDUAL DIFFERENCES, ROTARY PURSUIT TEST STANDARD DEVIATIONS OF TRIAL SCORES.
N = 30

Source	Sum of Squares	df	Variance	F
Total	11401.64	449		
Between Individuals	2477.28	29	85.42	4.20**
Between Days	674.96	14	48.21	2.37**
Residual	8249.40	406	20.32	

$$r = \frac{85.42 - 20.32}{85.42} = .762$$

From the analysis it may be concluded that there are significant individual differences in variability. The significance of the difference between days indicates that there is a trend in the average variability, as is shown in Figure 2. The estimate of reliability of .762 is considerably lower than that for the performance scores. The measure of variability, then, is much less reliable than the measure of performance on the same task. The low estimate of reliability, along with the low or zero inter-day correlations, indicates that this measure of variability is of doubtful value for describing or predicting behavior levels.

To test the hypothesis that the differences in variability between groups are not significant, the analysis of variance technique was again applied. The summary of the analysis is shown in Table XIII.

TABLE XIII

ANALYSIS OF VARIANCE FOR BETWEEN GROUP DIFFERENCES, ROTARY PURSUIT TEST STANDARD DEVIATIONS OF TRIAL SCORES. N = 30

Source	Sum of Squares	df	Variance	F
Total	11401.64	449		
Between Days	674.96	14	48.21	2.01*
Between Groups	327.63	2	163.81	6.82**
Interaction	669.16	28	23.89	-
Residual	9729.89	405	24.02	

The analysis shows that there are significant differences between groups. To determine which group contributes most to the between groups variance, a similar analysis of Groups A and B is shown in Table XIV. The between groups variance is much less than the residual variance, indicating that groups A and B are not significantly different. As in the case of the

TABLE XIV

ANALYSIS OF VARIANCE FOR BETWEEN GROUP DIFFERENCES, ROTARY PURSUIT TEST STANDARD DEVIATIONS OF TRIAL SCORES, GROUPS A AND B. N = 20

Source	Sum of Squares	df	Variance	F
Total	7770.19	299		
Between Days	707.81	14	50.56	2.03*
Between Groups	7.88	1	7.88	-
Interaction	332.28	14	23.73	-
Residual	6722.22	270	24.90	

performance scores, Group C must be the heterogeneous group, but in this case the mean variability of Group C for all 15 days is higher than the mean variability for the other groups. Again there is no way of ascertaining the cause of this difference, but these results would seem to indicate that the scoring adjustment was not primarily responsible. If adjustment of the scoring relays were responsible for depressing the performance scores the variability would also be reduced. As this was not the case, the indication is that an unknown factor operating in the selection of the groups may have been primarily responsible for the heterogeneity of Group C.

Because the groups do differ in variability, each was analysed separately and a Hoyt reliability coefficient computed. The coefficients obtained for each group are:

Group A	r = .81
Group B	r = .68
Group C	r = .43
All subjects	r = .76

Although the reliability of the variability differs in the three groups, combining them yields a coefficient only slightly lower than that of the most reliable group. This result is not unexpected for the range of scores is increased.

In an effort to obtain a more consistent estimate of the individual's variability, the daily standard deviations of the trial scores (σ_t) were grouped and means of the grouped measures computed. Grouping was by calendar weeks so that days grouped were as follows:

1 through 3
4 through 8
9 through 13
14 and 15.

The inter-period product-moment correlations of the grouped measures of variability and the correlations with each individual's mean variability for the 15 day training period ($\bar{\sigma}_t$) are shown in Table XV.

TABLE XV

INTER-CORRELATIONS OF GROUPED MEASURES OF VARIABILITY, ROTARY PURSUIT TEST. N = 30

	Days			
Days	4-8	9-13	14-15	$\bar{\sigma}_t$
1-3	-.26	-.26	-.16	.03
4-8		.78	.63	.86
9-13			.72	.90
14-15				.82

The intercorrelations of grouped measures of variability support the previous conclusion that variability early in practice is not related to variability later in practice, but it is apparent that mean variability over a period of several days is a more consistent measure than variability from one day to another. The high correlations of grouped measures of variability after the third day with mean variability for the whole period would be expected, and indicate that they are measuring approximately the same thing. For later evaluations the mean variability for Days 1-3 and for Days 9-13 will be used as representative of variability early and late in practice.

As a partial test of the null form of Hypothesis 4 concerning the relationship of variability to level of performance throughout training, the correlations between variability (σ_t) and performance ($\bar{X}_t$) for the same day are shown in Table XVI.

TABLE XVI

ROTARY PURSUIT TEST PRODUCT-MOMENT CORRELATIONS BETWEEN VARIABILITY (σ_t) AND PERFORMANCE ($\bar{X}_t$) ON THE SAME DAY. N = 30

Day	1	2	3	4	5	10	15
r	.59	.54	.18	-.41	-.40	-.58	-.79

The correlations show that variability has a significant positive relationship to performance early in practice, but the correlations drop to zero in the first four days and then become increasingly negative through the remainder of the practice period. It may be concluded that variability as measured by the standard deviation of the daily trial scores (σ_t) is related to performance, but the direction of the relationship depends on the level of learning. The high positive correlation the first two days is probably an artifact of the method of measurement of variability. The measure is based on the standard deviation of the trial scores within each day. Because a large amount of improvement takes place within the first few days the standard deviation will be determined to a large extent by the amount of improvement rather than the variability of the individual from trial to trial.

As a further test of Hypothesis 4, correlations between grouped measures of variability and initial and final performance were computed to determine the possible value of measures of variability as predictors of performance on the same task. The correlations are shown in Table XVII.

TABLE XVII

CORRELATION OF INTRA-DAY VARIABILITY WITH DAILY MEAN SCORE, ROTARY PURSUIT TEST. N = 30

Performance ($\bar{X}_t$)	Variability (σ_t) Days 1-3	Days 4-8	Days 9-13	Days 14-15
Day 1	.62	-.48	-.46	-.40
Day 2	.59	-.59	-.56	-.50
Day 15	.30	-.58	-.73	-.76
Gain	-.13	-.31	-.46	-.55

Using Guilford's table of the significant values of r (8, p.548), a correlation of .361 is significantly different from zero at the 5% level and a correlation of .463 is significant at the 1% level. It may be concluded then, that the mean variability of the first three practice days is not significantly related to final level of performance or to gain in performance from Day 1 to Day 15. Grouped measures of variability after Day 3 show significant negative relationships to final level of performance. In every case performance ($\bar{X}_t$) early in training shows a higher correlation with final performance than does variability at the same stage of learning (see Table VI).

Other methods of estimating intra-day, intra-individual variability were investigated. The variance of the trial scores for each individual for each day was used as a measure of variability, but the results obtained were essentially the same as those obtained using standard deviations. Either measure probably would be satisfactory, but the standard deviation has been used because it returns the values to their original power.

For purposes of comparison the correlation for consecutive days for both the variance and the standard deviation are shown in Table XVIII. It is apparent that the variances give neither more nor less a consistent measure of variability than the standard deviations of the scores.

As other measures of variability, the 10 – 90% range and the average deviations were computed for each day's trial scores for the first three subjects, but these measures were highly correlated with the variance and standard deviation. Because these measures are less convenient to handle mathematically and appeared to be measuring the same thing, they were not analysed further.

TABLE XVIII

INTER-DAY CORRELATIONS OF ROTARY PURSUIT TEST STANDARD DEVIATIONS AND VARIANCES OF DAILY TRIAL SCORES. N = 30

Day	vs. Day	$r_{\sigma\sigma}$	$r_{\sigma^2\sigma^2}$	Day	vs. Day	$r_{\sigma\sigma}$	$r_{\sigma^2\sigma^2}$
1	2	.33	.32	8	9	.60	.60
2	3	.24	.25	9	10	.43	.44
3	4	.04	.03	10	11	.27	.21
4	5	-.07	-.10	11	12	.23	.16
5	6	.35	.41	12	13	.38	.36
6	7	.29	.24	13	14	.23	.20
7	8	.36	.32	14	15	.54	.50

Intra-Individual Variability: Inter-Day

The analysis thus far described has been of variability within the individual within each day. It is possible to obtain an additional measure of variability within the individual between days. There are three ways to measure this inter-day variability. The first to be considered is the maximum likelihood estimate of the standard deviation of the daily mean trial scores ($\overline{X}_t$) for each individual about his own mean for the entire 15 days. These are the scores shown in Table I of Appendix D, and the measure is derived by computing the standard deviation of each row. The standard deviations for each individual are shown in Table XIX, indicated by the symbol $\sigma_{\overline{X}_t}$. Unfortunately this measure is not one of variability alone but is also a measure of the amount of learning. A large amount of improvement will tend to increase the sigma of the scores. The correlation of $\sigma_{\overline{X}_t}$ with gain in performance from Day 1 to Day 15 yields a coefficient of .90, indicating that the standard deviation of the daily mean trial scores is a measure, to a large extent, of improvement of performance rather than variability of performance.

To compensate for the effect of learning, a standard score was computed for each individual for each day. To obtain this score the deviation of the individual $\overline{X}_t$ scores from the daily group mean ($\frac{\sum_{i=1}^{30} \overline{X}_t}{30}$) were divided by the standard deviation of the between-individual scores for that day.

$$\text{Standard Score} = z_X = \frac{X - \overline{X}}{\sigma}$$

The measure of inter-day variability obtained from these scores is the standard deviation of each individual's standard scores over the 15 day practice period, and will be indicated by the symbol σ_{z_X}. These standard deviations are shown in Table XIX. This measure is affected by the amount

TABLE XIX

INTER-DAY MEASURES OF VARIABILITY, ROTARY PURSUIT TEST

Subject	$\sigma_{\bar{X}_t}$	σ_{z_x}	σ_{σ_t}	Subject	$\sigma_{\bar{X}_t}$	σ_{z_x}	σ_{σ_t}
1	62.41	.244	3.689	16	70.45	.372	4.910
2	63.42	.361	4.330	17	64.30	.436	6.241
3	67.15	.188	4.552	18	64.19	.306	4.271
4	54.89	.401	3.226	19	63.95	.443	2.877
5	63.53	.250	5.495	20	61.42	.423	5.220
6	58.02	.399	4.638	21	53.84	.259	4.480
7	55.33	.403	2.921	22	46.53	.593	4.393
8	66.57	.395	3.998	23	63.08	.345	6.374
9	66.32	.460	6.129	24	61.30	.346	3.937
10	48.22	.522	6.079	25	74.19	.590	5.380
11	65.58	.366	3.561	26	53.08	.480	4.830
12	47.57	.474	4.442	27	56.20	.390	4.675
13	66.43	.371	5.065	28	52.64	.394	4.435
14	54.20	.337	3.732	29	47.68	.657	3.407
15	58.12	.377	4.276	30	40.46	.624	3.415

of learning only to the extent that the rate of learning differs from the average for all subjects. The individual who learns more rapidly or less rapidly will appear more variable than the individual who learns at the same rate as the average for the group.

The third measure of intra-individual, inter-day variability is the maximum likelihood estimate of the standard deviation of each subject's daily variability scores σ_t, or the standard deviation of each row of Table II of Appendix D. This standard deviation of the standard deviations will be indicated by the symbol σ_{σ_t}. The product-moment correlations of the three measures of inter-day variability with each other are:

$$\sigma_{\bar{X}_t} \text{ vs. } \sigma_{z_X} : \quad r = -.47$$

$$\sigma_{\bar{X}_t} \text{ vs. } \sigma_{\sigma_t} : \quad r = .03$$

$$\sigma_{z_X} \text{ vs. } \sigma_{\sigma_t} : \quad r = .00$$

The three measures of variability are apparently different measures. The standard deviation of the mean scores ($\sigma_{\bar{X}_t}$) is not used further, for, as was shown above, it is principally a measure of improvement.

As a test of Hypothesis 5 regarding the relation of inter-day and intra-day measures of variability, the correlations of measures of inter-day variability with measures of intra-day variability were computed. These correlations, along with correlations with performance, are shown in Table XX.

TABLE XX

CORRELATIONS OF MEASURES OF INTER-DAY VARIABILITY WITH MEASURES OF INTRA-DAY VARIABILITY AND MEASURES OF PERFORMANCE ON THE ROTARY PURSUIT TEST. N = 30

	$\sigma_{t\ 1-3}$	$\sigma_{t\ 9-13}$	$\bar{X}_{t\ 1}$	$\bar{X}_{t\ 15}$	Gain $\bar{X}_t$
σ_{z_X}	.14	.56**	-.06	-.41*	-.44*
σ_{σ_t}	-.20	.04	-.26	-.03	.18

*Significant at the 5% level of confidence.
**Significant at the 1% level of confidence.

Using the values previously cited, a correlation of .361 is significant at the 5% level of confidence, and a correlation of .463 at the 1% level. The standard deviation of the standard scores is significantly correlated only with variability late in practice. The standard deviation of the standard deviations is not related to either of the measures of intra-day variability. Inter-day variability cannot be predicted from initial intra-day variability, but one of the measures is related to final performance. Hypothesis 5 is only partially supported. Measures of inter-day variability are not related to initial performance so cannot be predicted from initial performance. The correlations of the standard deviations of the standard scores with final performance and gain in performance are significant between the 5% and 1% level of confidence. It is doubtful if measures of inter-day variability are related to measures of performance.

Time of Training to Reach a Criterion

As an aid in evaluating measures of variability, the number of trials required for each individual to reach two performance criteria were tabulated. The criteria used are a single trial score of 200 ($X_t = 200$) and a trial series mean of 200 ($\bar{X}_s = 200$). The results are shown in Table XXI.

The correlation of the criteria with each other is .88, and correlations with Day 15 performance ($\bar{X}_t$) are:

$$\text{Criterion } X_t = 200: \quad r = -.78$$

$$\text{Criterion } \bar{X}_s = 200: \quad r = -.90.$$

Because the trial series criterion is highly related to final performance, only the criterion of $X_t = 200$ will be used. The product-moment correlations of this criterion with measures of variability and performance are shown in Table XXII. The correlations with variability were computed to test the null form of Hypothesis 6 concerning the relation of variability early in practice to time of training. With a correlation of .46 significant at the 1% level of confidence, all the above correlations are significant. Although the correlation is low, time of training may be predicted from variability early in training. The correlation of initial

TABLE XXI

NUMBER OF TRIALS TO REACH TWO CRITERIA OF PERFORMANCE ON THE ROTARY PURSUIT TEST

Subject	$X_t = 200$	$\bar{X}_s = 200$	Subject	$X_t = 200$	$\bar{X}_s = 200$
1	57	80	16	37	60
2	74	110	17	51	100
3	32	60	18	87	115
4	71	90	19	81	105
5	51	80	20	66	145
6	24	50	21	90	145
7	24	40	22	100	185
8	59	95	23	93	110
9	97	155	24	116	145
10	147	200	25	58	100
11	51	100	26	37	60
12	99	205	27	202	230
13	37	60	28	97	155
14	60	75	29	47	95
15	118	150	30	86	195

performance with the number of trials to reach the criterion is numerically higher than the correlation of initial variability with the number of trials. However, application of the Hotelling F test, as given in Johnson (17,p.54), shows that the coefficients do not differ significantly. Because a measure of performance must be obtained before the variability can be computed, a measure of variability is practicable only if it adds to the predictive efficiency of the measure of performance. The indication is that variability may be as good a predictor of

TABLE XXII

CORRELATIONS OF NUMBER OF TRIALS TO A CRITERION WITH MEASURES OF VARIABILITY AND PERFORMANCE ON THE ROTARY PURSUIT TEST. N = 30

	$\sigma_{t\ (1-3)}$	$\sigma_{t\ (9-13)}$	$\bar{X}_{t\ 1}$	$\bar{X}_{t\ 2}$
Criterion X_t = 200	-.49	.60	-.60	-.75

time of training as is initial performance, but further research is required to determine its usefulness as an additional measure.

Hypothesis 7 is concerned with the evaluation of a measure of initial variability in addition to a measure of initial performance as a predictor of final performance. To test the null form of the hypothesis, the multiple correlation of initial performance and initial variability with final performance was computed. The coefficient obtained was .50, a value of the same magnitude as the zero-order correlation of initial and final performance.[1] The same technique was applied to determine the contribution of initial variability in addition to initial performance in predicting the number of trials to reach a performance criterion. The multiple correlation coefficient obtained was .62. This is .02 higher than the zero-order correlation of initial performance and number of trials to a criterion, and does not represent a significant difference. There is no evidence from these analyses that initial variability adds to the efficiency of initial performance for predicting final performance.

Additional statistical analyses indicate that the zero-order correlation coefficients based on 30 cases are not sufficiently stable for multiple regression procedures. The interpretation of a multiple

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[1]This correlation was .50, the highest zero-order coefficient.

correlation from these data, then, is questionable, and no definite conclusion can be drawn with regard to the results stated above. However, there is no evidence in this study to support the hypothesis that the multiple correlation of a measure of initial performance and a measure of initial variability with the final level of performance on the same task is higher than the correlation of initial and final performance alone.

Summary of Conclusions for the Rotary Pursuit Test

The principle conclusions for the Rotary Pursuit Test, under the conditions of this investigation, may be stated as follows:

1. Initial and final performance are positively related. The hypothesis that they are related is supported.

2. There are individual differences in variability of trial scores on most of the days throughout the training period. The hypothesis that there are individual differences is supported.

3. Intra-individual variability late in practice cannot be predicted from intra-individual variability early in practice. The results do not support the hypothesis that intra-individual variability early in practice is related to intra-individual variability late in practice.

4. Intra-individual variability is positively related to performance early in practice but negatively related later in practice. This supports the hypothesis that intra-individual variability is related to level of performance on the same task.

5. Inter-day variability cannot be predicted from initial intra-day variability, although final intra-day variability is related to inter-day variability. The results partially support the hypothesis that inter-day and intra-day measures of intra-individual variability on the same task are related.

6. Time of training to a criterion may be predicted from initial variability. The hypothesis that measures of intra-individual variability early in practice are related to time of training to reach a performance criterion on the same task is supported.

7. No conclusion can be drawn with regard to the value of using a measure of initial variability in addition to a measure of initial performance in predicting final performance. However, there is no evidence to support the hypothesis that the multiple correlation of a measure of initial performance and a measure of initial variability with the final level of performance on the same task is higher than the correlation of initial and final performance alone.

CHAPTER IV

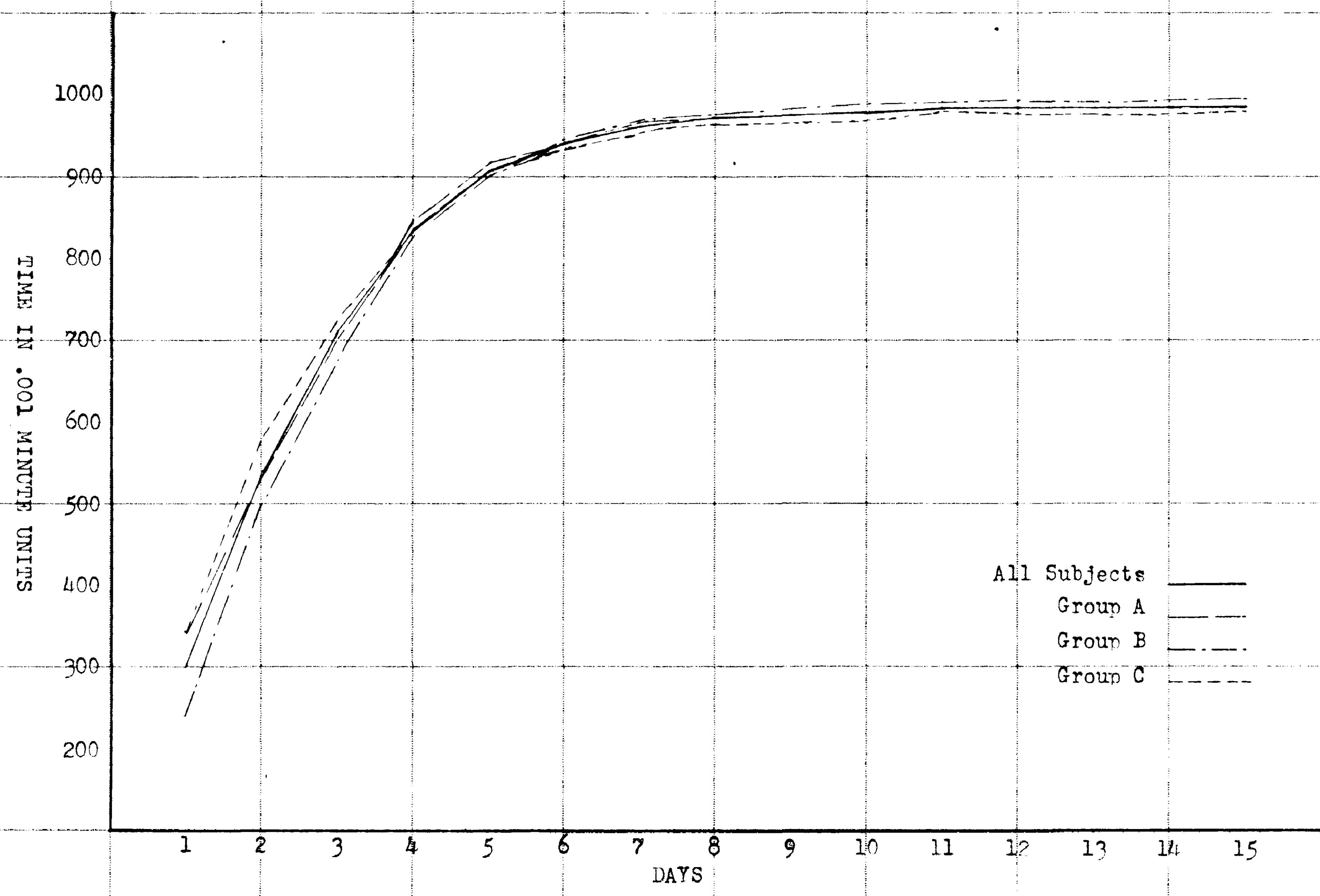
ANALYSIS OF RESULTS FOR THE S.A.M. TWO-HAND COORDINATION TEST

Level of Performance

The score obtained on the Two-Hand Coordination Test is the time in units of .001 minute, on the 1/2" diameter center area of the target. The scores for each individual are shown in Table III of Appendix D. They were derived by dividing the total score for each individual for each day by the number of trials for the day. This score will be represented by the symbol $\overline{Y}_t$. A graph of the mean $\overline{Y}_t$ for all subjects and for each group is shown in Figure 3. From the graph it may be seen that there are no consistent differences among groups and that almost all learning occurs in the first seven days. The mean for the group approaches the maximum possible score within that time.

To test the hypothesis that there are no significant differences in level of performance attributable to the order in which the tasks were practiced, the 15 day totals of the mean trial scores ($\sum_{J=1}^{15} \overline{Y}_t$) for each individual were analysed by means of the analysis of variance technique. The summary table for the analysis is shown in Table XXIII. The same randomly selected 24 subjects were used in this analysis as in the similar analyses for significance of order of practice on the Rotary Pursuit Test.

In order to test the null form of Hypothesis 1 concerning the relationship between initial and final performance and to determine the consistency with which the task measures performance from day to day, the appropriate inter-day correlations were computed and are shown in Table XXIV. Using .361 as the value of r significant at the 5% level of confidence,



TWO-HAND COORDINATION TEST: MEAN TRIAL SCORES

FIGURE 3

TABLE XXIII

ANALYSIS OF VARIANCE OF THE TWO-HAND COORDINATION TEST TOTAL MEAN DAILY TRIAL SCORES. N = 24

Source	Sum of Squares	df	Variance	F
Total	6067298	23		
Between Orders	390805	5	78161	-
Within Orders	5676493	18	315361	

performance on Day 1 is not significantly correlated with performance after Day 6. Performance on Day 2 is significantly correlated with performance through Day 9. It may be concluded then, that initial performance as measured on Day 1, is not significantly related to final performance as measured on Day 10. The relationship between performance on one day and performance later in practice decreases as the number of intervening days increases.

As shown by the correlations of consecutive days, the task measures performance with a high degree of consistency through Day 11. The drop in the correlations after Day 11 is attributable to the restriction in range, because most of the subjects were approaching the maximum possible score, and many did reach the maximum. The variability in the length of trial, although reaching only .007 minute as a maximum, would also contribute to a reduction in the inter-day correlations when scores reached the maximum. For the above reasons, analysis of scores on the Two-Hand Coordination Test will be made only through Day 10.

An estimate of the reliability of the daily mean trial scores ($\overline{Y}_t$) for the first ten days may be derived by the Hoyt analysis of variance technique (13). The summary of the analysis is shown in Table XXV. The

TABLE XXIV

INTER-DAY CORRELATIONS OF TWO-HAND COORDINATION TEST DAILY TRIAL SCORES ($\overline{Y}_t$). N = 30

	Day													
Day	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	.83	.66	.53	.40	.38	.27	.28	.16	.15	.22	.13	.21	.14	.07
2		.90	.78	.66	.61	.48	.51	.40	.35	.41	.32	.41	.24	.11
3			.94						.59					
4				.94					.69					
5					.95				.73					
6						.92			.83					
7							.93		.81					
8								.97	.93					
9									.93					
10										.97				
11											.85			
12												.88		
13													.77	
14														.97

analysis indicates that there are significant differences between individuals and, as would be expected in a learning situation, between days. The reliability coefficient of .918 indicates that the test is reliable.

TABLE XXV

ANALYSIS OF VARIANCE OF THE TWO-HAND COORDINATION TEST DAILY MEAN TRIAL SCORES ($\bar{Y}_t$), DAYS 1-10. N = 30

Source	Sum of Squares	df	Variance	F
Total	16416913	299		
Between Individuals	1199925	29	41376.73	12.16**
Between Days	14329027	9	1592114.06	467.97**
Residual	887962	261	3402.15	

$$r = \frac{41376.73 - 3402.15}{41376.73} = .918$$

Homogeneity of 30-Second Score Variability

The null form of Hypothesis 2, that there are significant individual differences in variability, may be tested by means of the L_1 criterion. The measures used as samples of behavior are the 30-second scores for each individual each day. Homogeneity, as shown by an L_1 ratio that may occur more than 5% of the time by chance, indicates that the samples are from a normal population and have the same standard deviation. Heterogeneity indicates that the samples may not be from normal populations and do not have the same standard deviations. The L_1 ratios obtained at different stages in training are shown in Table XXVI.

Variability of the 30-second scores is homogeneous for the first two days, so it may be stated that, on those days, there are no significant individual differences in variability. After Day 2 however, the variability of the scores is heterogeneous, indicating significant individual differences. The implication of this result is that variability, as measured by the 30-second scores, is of no value the first two days of

TABLE XXVI

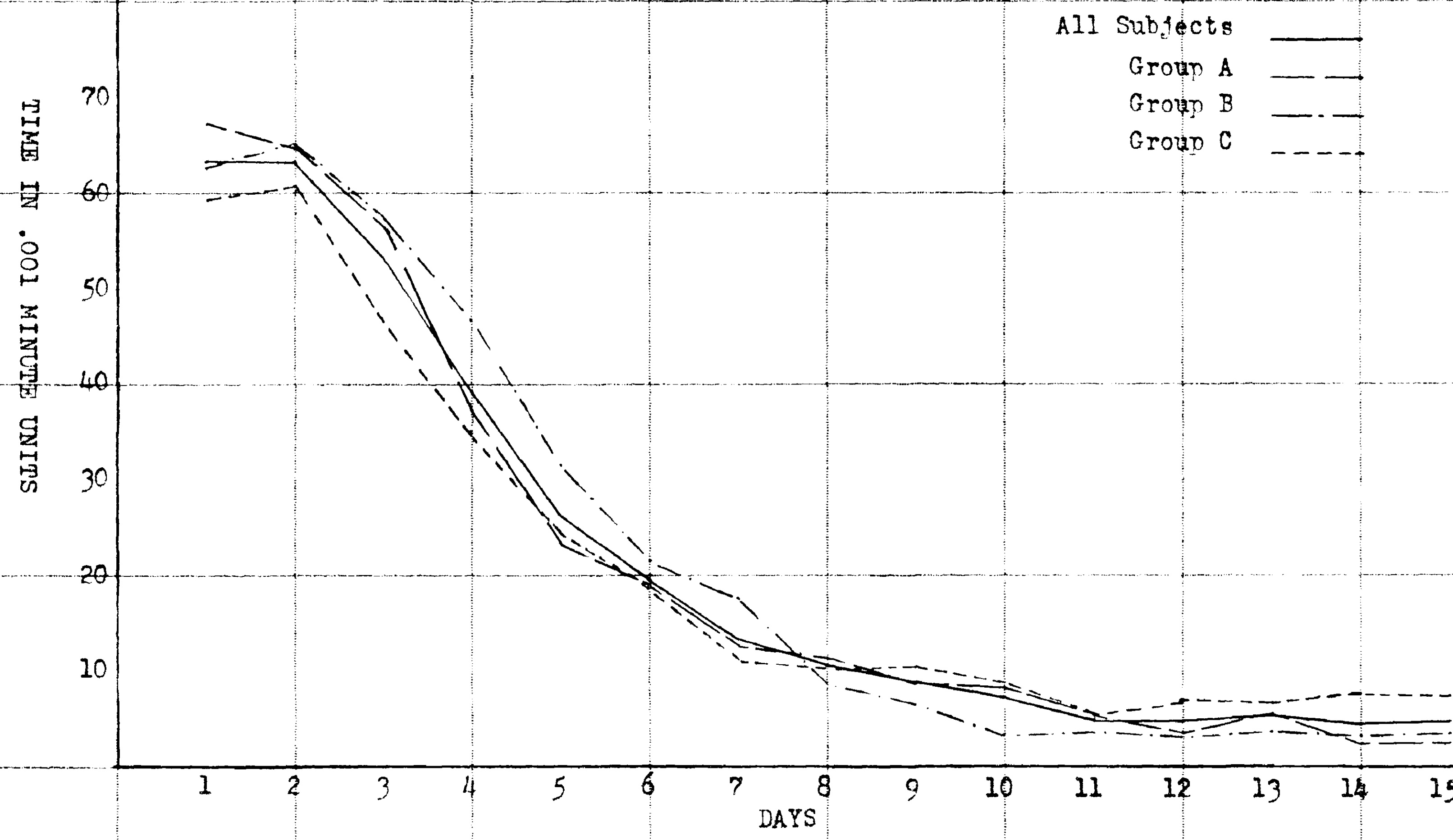
L_1 RATIOS, TEST FOR HOMOGENEITY OF VARIABILITY OF TWO-HAND COORDINATION TEST 30-SECOND SCORES (Y_h). N = 30

Day	1	2	3	5	10	15
L_1 Ratio	.926	.954	.838	.616	.259	.338
Probability Level	> 5%	> 5%	< 1%	< 1%	< 1%	< 1%

practice, because individual differences are not significant.

Intra-Individual Variability, Intra-Day. To arrive at a measure of the intra-day, intra-individual variability, the maximum likelihood estimate of the standard deviation of the 30-second scores was computed for each day for each individual. This measure will be indicated by the symbol σ_h, and the values are shown in Table IV in Appendix D. A graph of the mean σ_h for all subjects and by groups is shown in Figure 4. The mean variability curve for all subjects is a relatively smooth curve showing a marked drop after the second day. There appear to be no consistent differences between groups, and the weekends show no discernible effect on variability.

The mean variability curve is very similar in shape to that usually found in a situation where learning is measured by the reduction in errors. The curve obtained, then, would appear to support the common assumption that learning a motor skill consists essentially in the elimination of inadequate or useless movements. That the curve approaches zero as a limit is attributable to the fact that most of the subjects reached the maximum possible score before the end of the 15 day practice period. Variability was undoubtedly still present but could not be measured by the method used. The sharp reduction in variability after the second day cannot be explained by the limits of the task, for it took place during



TWO-HAND COORDINATION TEST: MEAN STANDARD DEVIATIONS OF 30 SECOND SCORES

FIGURE 4

the period of most rapid learning and before the subjects reached the maximum score.

To test an hypothesis that order of practice on the tasks had no effect on variability of performance, the 15 day sums of the daily standard deviations of the 30-second scores ($\sum_{J=1}^{15} \sigma_h$) were analysed. The summary of the analysis is shown in Table XXVII.

TABLE XXVII

ANALYSIS OF VARIANCE, TWO-HAND COORDINATION TEST TOTAL STANDARD DEVIATIONS OF DAILY 30-SECOND SCORES. N = 24

Source	Sum of Squares	df	Variance	F
Total	108673.94	23		
Between Orders	3351.63	5	670.33	-
Within Orders	105322.31	18	5851.24	

The analysis supports the null hypothesis that the order of practice does not significantly affect the variability of performance.

Inspection of the graph of the standard deviations of the 30-second scores (see Figure 4) indicates that there are small differences between the groups. To determine whether the differences are significant, the σ_h scores were analysed for all individuals as shown in Table XXVIII. The analysis shows that the differences between groups are not significant when evaluated against the residual variance alone (F_1), or when evaluated against both the residual variance and the interaction variance (F_2). The differences between days are highly significant as would be expected from inspection of the graph.

If variability is to be used to describe or predict behavior, it is important to know if the amount of variability shown by one individual

TABLE XXVIII

ANALYSIS OF VARIANCE FOR BETWEEN GROUP DIFFERENCES. TWO-HAND COORDINATION TEST STANDARD DEVIATIONS OF 30-SECOND SCORES DAYS 1-10. N = 30

Source	Sum of Squares	df	Variance	F_1	F_2
Total	179220.71	299			
Between Days	137298.18	9	15255.35	104.49**	106.29**
Between Groups	585.53	2	292.76	2.00	2.04
Interaction	1916.10	18	106.45	-	
Residual	39420.90	270	146.00		

remains relatively constant at the different stages of learning. In order to test the null form of Hypothesis 3 that intra-individual variability early in practice is significantly related to intra-individual variability later in practice, product-moment correlations were computed between variability (σ_h) for Days 1, 2, and 3 and all other days through Day 10. To determine the consistency of each individual's variability from day to day, the intercorrelations between consecutive days were also computed. The correlations obtained are shown in Table XXIX.

Because the analysis above showed that there were no significant individual differences in variability on Days 1 and 2, the correlations of these days with the other practice days would not be expected to be meaningful. The values shown in the table support this conclusion, for although some are significant, they do not fall into a meaningful pattern. Using the tabled values as given by Guilford (8, p.549), Day 3 is significantly correlated with Days 4, 5, and 6 at the 1% level, and with Day 8 at the 5% level. The correlations of variability on Day 3 with variability on Days 7, 9, and 10 do not differ significantly from zero. Initial

TABLE XXIX

INTER-DAY CORRELATIONS OF TWO-HAND COORDINATION TEST STANDARD DEVIATIONS OF 30-SECOND SCORES (σ_h). N = 30

Day	2	3	4	5	6	7	8	9	10
1	.01	-.27	-.48	-.37	-.37	-.42	-.30	-.31	-.24
2		.19	.26	.27	.22	.15	.11	.03	-.14
3			.69	.50	.58	.31	.38	.14	.16
4				.81					
5					.79				
6						.70			
7							.60		
8								.83	
9									.80

variability, as measured by Day 1 or Day 3, is not significantly related to final variability.

The intercorrelations between measures of variability on consecutive days indicate that they are significantly related from day to day, after Day 2, but the degree of the relationship is considerably less than that between performance scores on consecutive days (see Table XXIV).

For reasons stated above, only the measures of variability from Days 3 through 10 are used. Of these measures, Days 3, 5, and 10 will be used in later evaluations as representative measures throughout learning. Day 1 will be used only for purposes of comparison. Since the daily measures are limited in number and there is no logical way to group them, they will be used only as daily measures and will not be grouped.

An estimate of the reliability of intra-individual variability as measured by the standard deviations of the daily 30-second scores (σ_h) may be obtained by the Hoyt analysis of variance technique. The summary of the analysis is shown in Table XXX.

TABLE XXX

ANALYSIS OF VARIANCE FOR BETWEEN INDIVIDUAL DIFFERENCES, TWO-HAND COORDINATION TEST STANDARD DEVIATIONS OF 30-SECOND SCORES (σ_h), DAYS 1-10. N = 30

Source	Sum of Squares	df	Variance	F
Total	179220.71	299		
Between Individuals	15205.48	29	524.33	5.12**
Between Days	137298.18	9	15255.35	149.04**
Residual	26717.05	261	102.36	

$$r = \frac{524.33 - 102.36}{524.33} = .80$$

The obtained reliability coefficient of .80 indicates that measures of variability are less reliable than measures of performance. The reliability of the performance scores is .918 (see Table XXV). The analysis shows that there are significant differences in variability between individuals and, as shown previously, between days.

A measure of variability would be unnecessary if it measured the same aspect of behavior as does performance. Therefore, to test the null form of Hypothesis 4 concerning the relation of intra-individual variability to level of performance, product-moment correlations between measures of performance ($\overline{Y}_t$) and measures of variability (σ_h) were computed. The correlations are shown in Table XXXI.

Using .361 as the value of r significant at the 5% level of confidence and .463 as the value significant at the 1% level, it may be concluded that variability on days 3, 5, and 10 is significantly correlated

TABLE XXXI

CORRELATIONS OF MEASURES OF PERFORMANCE AND VARIABILITY, TWO-HAND COORDINATION TEST. N = 30

Performance ($\bar{Y}_t$) Days	Variability (σ_h) Days 1	3	5	10
1	.38	-.77	-.53	-.12
2	.47	-	-.63	-.35
3	-	-.72	-	-
5	-	-	-.80	-
10	.27	.14	-.40	-.95

with performance on the same day. The correlation of the measures on Day 10 is sufficiently high to conclude that both are measuring the same thing, and the use of a measure of final variability in addition to final performance is superfluous. Variability is related to performance at some stages of learning, therefore Hypothesis 4 is partially supported. All of the significant correlations of variability with performance are negative except correlations of Day 1 variability with performance. This may be explained by the fact that there was more learning on Day 1 than on the following days, and as a result the standard deviation of the 30-second scores for that day would be correspondingly increased. One would therefore expect it to be positively related to performance. From Table XXXI it may also be stated that final level of performance cannot be predicted from initial variability.

<u>Intra-Individual Variability, Inter-Day</u>. The above analysis has been of measures of intra-individual variability within days. The inter-day variability of each individual will also be computed and used as an additional measure. The measures used will be the maximum likelihood estimate

of the standard deviation of the standard scores, indicated by the symbol (σ_z), and the maximum likelihood estimate of the standard deviation of the daily standard deviations of 30-second scores, indicated by the symbol (σ_{σ_h}). The values for each measure are shown in Table XXXII.

TABLE XXXII

INTER-DAY MEASURES OF VARIABILITY,
TWO-HAND COORDINATION TEST. N = 30

Subject	σ_{z_y}	σ_{σ_h}	Subject	σ_{z_y}	σ_{σ_h}
1	.178	25.86	16	.446	26.16
2	.552	28.60	17	.917	29.40
3	.313	21.72	18	.521	27.76
4	.442	22.62	19	.786	25.80
5	.319	27.85	20	.494	24.14
6	.289	33.24	21	.122	21.34
7	.512	26.61	22	.192	18.57
8	.381	18.82	23	.326	21.27
9	.150	23.69	24	.220	21.78
10	.544	22.21	25	.390	26.66
11	.675	25.21	26	.418	27.76
12	.505	20.79	27	.388	21.54
13	.394	30.23	28	.206	22.48
14	.268	25.01	29	.466	26.44
15	.755	25.41	30	1.446	7.71

Their computation is the same as for the analysis of the Rotary Pursuit Test results. The correlation coefficient of -.30 between the two measures does not differ significantly from zero. To test the null form of

Hypothesis 5 regarding the relation of measures of inter-day and intra-day variability, product-moment correlations were computed. The correlations are shown in Table XXXIII.

TABLE XXXIII

CORRELATIONS OF INTRA-DAY AND INTER-DAY MEASURES OF INTRA-INDIVIDUAL VARIABILITY, TWO-HAND COORDINATION TEST. N = 30

	σ_{h1}	σ_{h3}	σ_{h5}	σ_{h10}
σ_z	-.42*	.37*	.35	.48**
σ_{σ_h}	.48**	.21	-.15	-.71**

From the correlations it may be stated that measures of inter-day variability are related to measures of intra-day variability at some stages of learning. The only high relationship is that of σ_{σ_h} with σ_h Day 10, a negative correlation.

To show the relationship of measures of inter-day variability to level of performance, Table XXXIV is given.

TABLE XXXIV

CORRELATIONS OF MEASURES OF INTER-DAY VARIABILITY WITH MEASURES OF PERFORMANCE, TWO-HAND COORDINATION TEST. N = 30

	Performance ($\bar{Y}_t$)		
	Day 1	Day 2	Day 10
σ_z	-.48**	-.54**	-.62**
σ_{σ_h}	-.14	.08	.72**

The standard deviation of the standard scores shows a significant negative correlation with initial and final performance. The standard deviation of the standard deviations is positively and significantly correlated with final performance, but not related to initial performance. Although they are related, inter-day measures of variability are not measuring entirely the same aspect of behavior as are performance scores.

Time of Training to Reach a Performance Criterion

Three levels of performance were chosen as criteria, and the number of trials required by each individual to reach each was tabulated. The criteria chosen are:

C_1 : Trial score of 960
C_2 : Trial series mean of 960
C_3 : One perfect trial.

The score of 960 was chosen because it was the highest trial series score that all subjects reached. A perfect trial was defined as a trial in which the contact was kept on the center 1/2" diameter target throughout the entire trial. The number of trials required to reach the criteria is shown in Table XXXV. The intercorrelations of the number of trials to attain each of the three criteria are shown in Table XXXVI. The correlations show that all three measures are highly related. Because the number of trials to reach one perfect trial is a less artifical criterion, it will be used in further evaluations.

To determine the relationship between level of performance and time of training, and to test the null form of Hypothesis 6 concerning the relationship of intra-individual variability early in practice to time of training to reach a performance criterion, the correlations shown in Table XXXVII were computed. From the correlations it may be stated that the criterion is significantly related to performance on Days 2 and 10. Day 1 variability shows a higher correlation with the criterion than does Day 1 performance, being significant at the 5% level; but the difference between the correlations is not significant. It is doubtful that initial intra-individual variability is related to time of training to reach a

TABLE XXXV

NUMBER OF TRIALS TO REACH THREE CRITERIA OF PERFORMANCE ON THE TWO-HAND COORDINATION TEST.

Subject	C_1	C_2	C_3	Subject	C_1	C_2	C_3
1	32	44	54	16	27	32	35
2	53	56	66	17	34	52	58
3	31	40	40	18	34	48	48
4	49	52	81	19	45	52	52
5	28	28	49	20	37	40	52
6	26	36	42	21	37	44	37
7	44	48	44	22	36	52	49
8	37	48	50	23	26	36	36
9	38	60	70	24	44	48	52
10	61	72	68	25	26	44	41
11	26	36	37	26	34	48	48
12	29	32	46	27	29	48	44
13	17	24	32	28	34	44	49
14	42	44	47	29	20	36	34
15	58	72	89	30	66	108	112

TABLE XXXVI

INTERCORRELATIONS OF NUMBER OF TRIALS TO REACH THREE PERFORMANCE CRITERIA. N = 30

	C_1	C_2
C_2	.86	-
C_3	.84	.89

TABLE XXXVII

CORRELATIONS OF MEASURES OF PERFORMANCE AND INTRA-DAY VARIABILITY WITH NUMBER OF TRIALS TO REACH ONE PERFECT TRIAL, TWO-HAND COORDINATION TEST. N = 30

	$\bar{Y}_1$	$\bar{Y}_2$	$\bar{Y}_{10}$	σ_{h1}	σ_{h3}	σ_{h5}
C_3	-.28	-.55**	-.76**	-.40*	.32	.65**

performance criterion.

A test of Hypothesis 7 involves a multiple correlation of initial variability and initial performance with final performance. Again, it is questionable if the zero-order correlation coefficients are sufficiently stable; but in the case of Day 1 performance and Day 1 variability, none of the correlations are significant at the 1% level of confidence. No purpose would be served, then, in computing a multiple correlation coefficient. It is not possible to test the hypothesis that the multiple correlation of measures of initial performance and measures of initial variability with final level of performance on the same task is higher than the correlation of initial and final performance alone. The same conclusion is applicable to the prediction of time of training from Day 1 performance and Day 1 variability.

Summary of Conclusions for the Two-Hand Coordination Test

Under the conditions of this investigation, the following conclusions may be drawn:

1. Final performance cannot be predicted from initial performance. The evidence does not support the hypothesis that initial performance is related to final performance.

2. There are individual differences in variability of performance after the second day of practice. This supports the hypothesis that there are individual differences in variability of performance.

3. Intra-individual variability late in practice cannot be predicted from intra-individual variability early in practice. There is no evidence to support the hypothesis that intra-individual variability early in practice is related to intra-individual variability late in practice.

4. Intra-individual variability is related to performance at some stages of learning, but final performance cannot be predicted from initial variability. The hypothesis that intra-individual variability is related to level of performance is partially supported.

5. Some inter-day and intra-day measures of intra-individual variability are related, but in general the relationships are low. The hypothesis that inter-day and intra-day measures of intra-individual variability are related is partially supported.

6. It is doubtful that initial variability is related to time of training to reach a performance criterion. No conclusion may be drawn with regard to the hypothesis that measures of intra-individual variability early in practice are related to time of training to reach a performance criterion on the same task.

7. It is not possible to test the hypothesis that the multiple correlation of measures of initial performance and measures of initial variability with the final level of performance on the same task is higher than the correlation of initial and final performance alone.

CHAPTER V

ANALYSIS OF RESULTS FOR THE S.A.M. COMPLEX COORDINATION TEST

Level of Performance

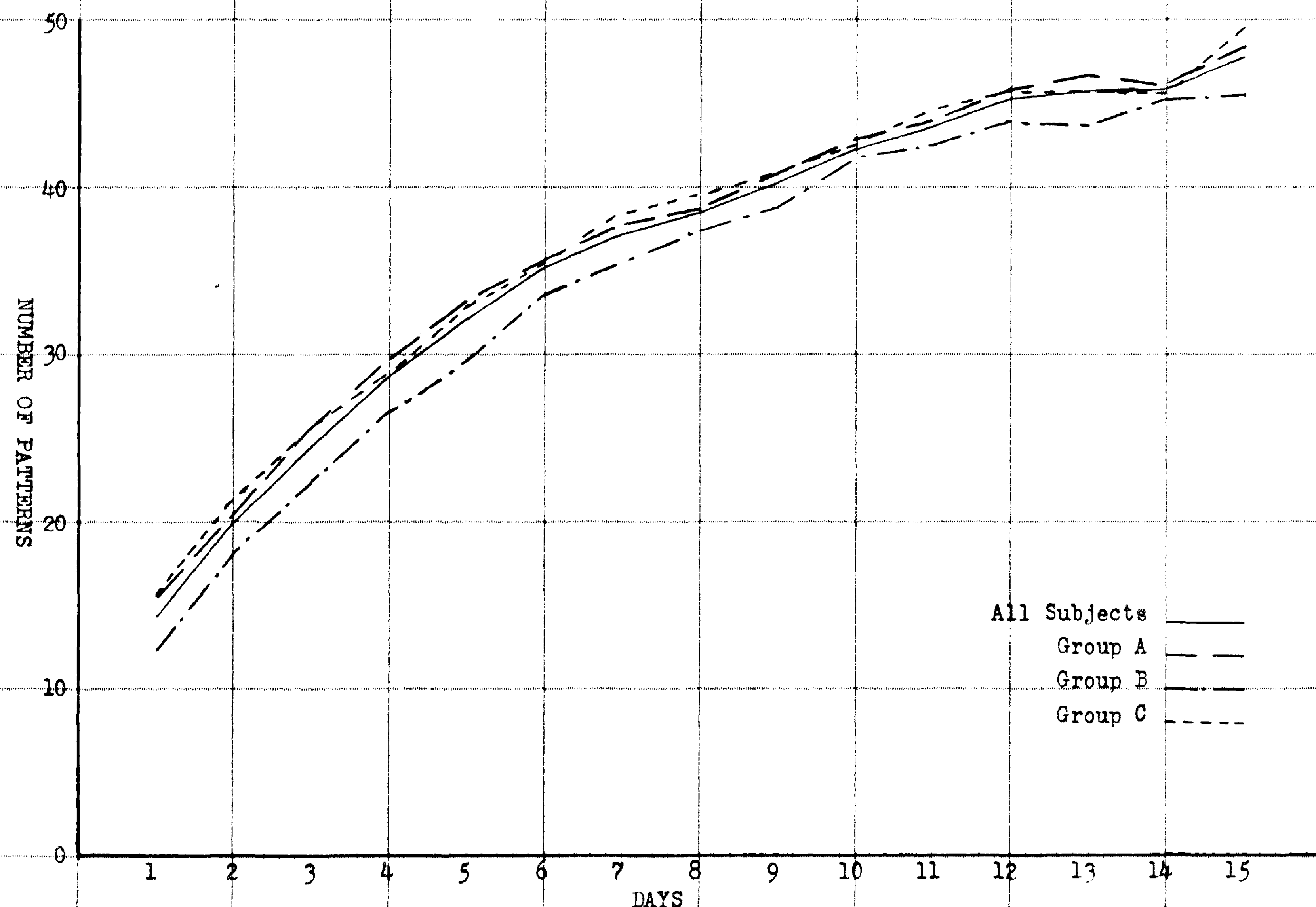
The Complex Coordination Test was scored on the basis of the number of patterns matched per unit of time. The mean number of patterns matched per four minute trial series each day is shown for each individual in Table V in Appendix D. This score will be referred to as the daily mean trial series score, and indicated by the symbol $\overline{Z}_s$. A graph of the mean $\overline{Z}_s$ for each group and for all subjects is shown in Figure 5. From the graph it may be seen that performance improved at a relatively steady rate throughout the training period, and was still improving after 232 minutes of practice during the period.

The performance of Group B appears to be at a lower level than for the other groups, so an analysis was made to determine if the differences among the groups are significant. The summary of the analysis is shown in Table XXXVIII.

TABLE XXXVIII

ANALYSIS OF VARIANCE FOR BETWEEN GROUP DIFFERENCES, COMPLEX COORDINATION TEST DAILY MEAN NUMBER OF PATTERNS MATCHED PER TRIAL SERIES ($\overline{Z}_s$).
N = 30

Source	Sum of Squares	df	Variance	F
Total	55723.73	449		
Between Days	42913.69	14	3065.26	102.18**
Between Groups	468.24	2	234.12	7.73**
Interaction	68.97	28	2.46	-
Residual	12272.83	405	30.30	



COMPLEX COORDINATION TEST: MEAN NUMBER OF PATTERNS MATCHED PER 4 MINUTE TRIAL SERIES

FIGURE 5

The analysis shows that there are significant differences between days, as would be expected, and that there are also significant differences between groups. To determine if Group B is the group producing the heterogeneity, a further analysis was made of Groups A and C only. The summary of the analysis is shown in Table XXXIX.

TABLE XXXIX

ANALYSIS OF VARIANCE, COMPLEX COORDINATION TEST DAILY MEAN NUMBER OF PATTERNS MATCHED PER TRIAL SERIES ($\overline{Z}_s$), GROUPS A AND C. N = 22

Source	Sum of Squares	df	Variance	F
Total	40461.65	329		
Between Days	30852.96	14	2203.78	68.98**
Between Groups	.03	1	.03	-
Interaction	22.48	14	1.60	-
Residual	9586.18	300	31.95	

Groups A and C do not differ significantly, so it may be concluded that Group B contributes the most to the variance among groups and is the group producing the heterogeneity. This is not the same group that was below the mean on the Rotary Pursuit Test. There are no known factors in the experiment that will account for the lower level of performance of Group B, so no conclusion is drawn with regard to the cause of the difference. Because there is no evidence to indicate that the group should not be included in the analysis with the other groups, no differentiation will be made between it and the other groups.

To determine whether the order in which the tasks were practiced had a significant influence on the level of performance on the Complex Coordination Test, an analysis was made of the total mean daily trial series scores ($\sum_{J=1}^{15} \bar{Z}_s$). The same 24 subjects were used as in the previous analyses for effect of order of practice. A summary of the analysis is shown in Table XL.

TABLE XL

ANALYSIS OF VARIANCE OF THE COMPLEX COORDINATION TEST TOTAL MEAN TRIAL SERIES SCORES. N = 24

Source	Sum of Squares	df	Variance	F
Total	141717	23		
Between Orders	35041	5	7008.2	1.18
Within Orders	106676	18	5926.4	

From the analysis it may be concluded that the order in which the tasks were practiced had no significant effect on the level of performance on the Complex Coordination Test.

In order to determine the consistency with which the Complex Coordination Test measures performance from day to day, and to test the null form of Hypothesis 1 concerning the relationship between initial and final performance, inter-day correlations were computed as shown in Table XLI. Only the correlations of value to the present analysis are shown. Using .463 as the value of r significantly different from zero at the 1% level of confidence, it may be concluded that initial performance is positively and significantly related to final performance. All of the consecutive days are highly related, indicating that the test is a consistent measure of performance.

The magnitude of the intercorrelations indicates that the test is a reliable measure; but, to derive a reliability coefficient for the entire training period, the Hoyt technique was used. A summary of the analysis

TABLE XLI

INTER-DAY CORRELATIONS OF COMPLEX COORDINATION TEST DAILY MEAN TRIAL SERIES SCORES ($\bar{Z}_s$). N = 30

	Day													
Day	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	.85	.73	.65	.65	.68	.64	.63	.71	.58	.62	.69	.65	.69	.68
2		.89	.82	.79	.79	.74	.73	.81	.70	.69	.70	.72	.72	.71
3			.89											.69
4				.95										.76
5					.93									.73
6						.90								.74
7							.95							.79
8								.93						.83
9									.93					.83
10										.92				.83
11											.92			.88
12												.94		.90
13													.95	.92
14														.93

is shown in Table XLII. The obtained reliability coefficient of .985 shows that the test is a highly reliable measure of performance. It may also be concluded that there are significant differences between individuals and, as would be expected, between days.

Homogeneity of Variability of Performance Scores

An estimate of an individual's variability of performance on the Complex Coordination Test within each day may be based on either the 30-second scores or the trial (one minute) scores. Using the 30-second scores

TABLE XLII

ANALYSIS OF VARIANCE FOR BETWEEN INDIVIDUAL DIFFERENCES, COMPLEX COORDINATION TEST DAILY MEAN NUMBER OF PATTERNS MATCHED PER TRIAL SERIES ($\bar{Z}_s$). N = 30

Source	Sum of Squares	df	Variance	F
Total	55723.73	449		
Between Individuals	10571.31	29	364.53	66.11**
Between Days	42913.69	14	3065.26	555.90**
Residual	2238.73	406	5.51	

$$r = \frac{364.53 - 5.51}{364.53} = .985$$

the estimate is based on a sample of 16 scores the first day and 32 scores on all subsequent days. Using the trial scores, the estimate is based on 8 scores the first day and 16 scores on all subsequent days. Deriving a measure of variability from the larger number of trials each day is desirable, but has the disadvantage of being based on scores of very small magnitude. Deriving a measure of variability from the trial scores means using a smaller sample, but the scores are twice as large. Even with the latter measure, however, the scores are not sufficiently large to allow any considerable variability, for the range is from zero at the beginning of practice to a maximum of 18 at the end of the 15 days of practice. A measure of variability based on these scores would not be expected to be very discriminating among individuals.

To test the null form of Hypothesis 2 concerning the existence of individual differences in variability of performance, the L_1 test was applied to both the 30-second scores (Z_h) and the trial scores (Z_t). The obtained ratios are shown in Table XLIII. The results of the L_1 tests show that the variability of the 30-second scores may be considered significantly

TABLE XLIII

L_1 RATIOS, TEST FOR HOMOGENEITY OF VARIABILITY, COMPLEX COORDINATION TEST. N = 30

Day	Z_h	Prob. Level	Z_t	Prob. Level	Day	Z_h	Prob. Level	Z_t	Prob. Level
1	.901	< 5%	.766	< 1%	8	.961	> 5%	.873	< 1%
2	.967	> 5%	.880	< 1%	10	.963	> 5%	.901	< 5%
3	.947	< 5%	.896	< 5%	12	.968	> 5%	.939	> 5%
4	.948	< 5%	.908	> 5%	14	.959	> 5%	.923	> 5%
5	.950	< 5%	.932	> 5%	15	.952	< 5%	.900	< 5%
6	.966	> 5%	.927	> 5%					

different among individuals at the 5% level of confidence on only five of the days shown. The variability of the trial scores is significantly different among individuals at the 1% level of confidence on three of the days shown, and at the 5% level on three other days. Because they do not differentiate among individuals every practice day, neither measure is completely satisfactory. The variability of the trial scores may possibly be a better measure because it shows differences at a more significant level. Both measures will be used in most of the later analyses. Hypothesis 2 cannot be refuted, for there are significant individual differences on at least some practice days.

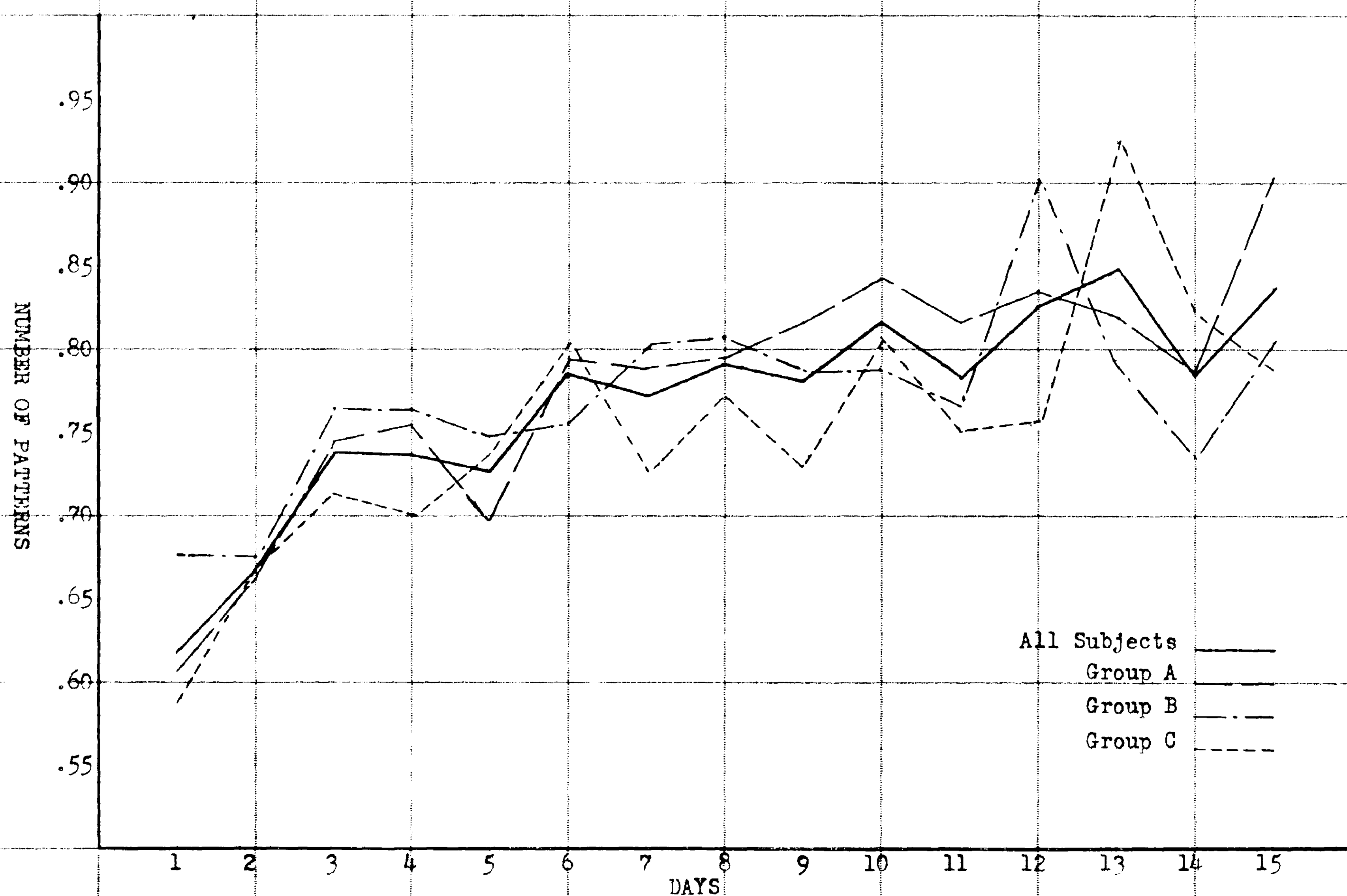
Intra-Individual Variability: Intra-Day

The L_1 test results indicate that measures of variability of performance on the Complex Coordination Test are of little value in describing or predicting behavior, but an analysis of the measures was made to check these results. The maximum likelihood estimates of the standard deviations of the 30-second scores, and of the trial scores, for each individual and for each day, are shown in Tables VI and VII in Appendix D.

The maximum likelihood estimates of the standard deviations of the 30 second scores are indicated by the symbol σ_h, and of the trial scores by the symbol σ_t. Graphs of the mean σ_h and σ_t, by groups and for all subjects, are shown in Figures 6 and 7 respectively. Inspection of the graphs shows, that by either measure, variability increases with practice. The day to day fluctuations of the curve of the mean σ_t are a little greater than the fluctuations of the curve of the mean σ_h, but the curves are essentially similar.

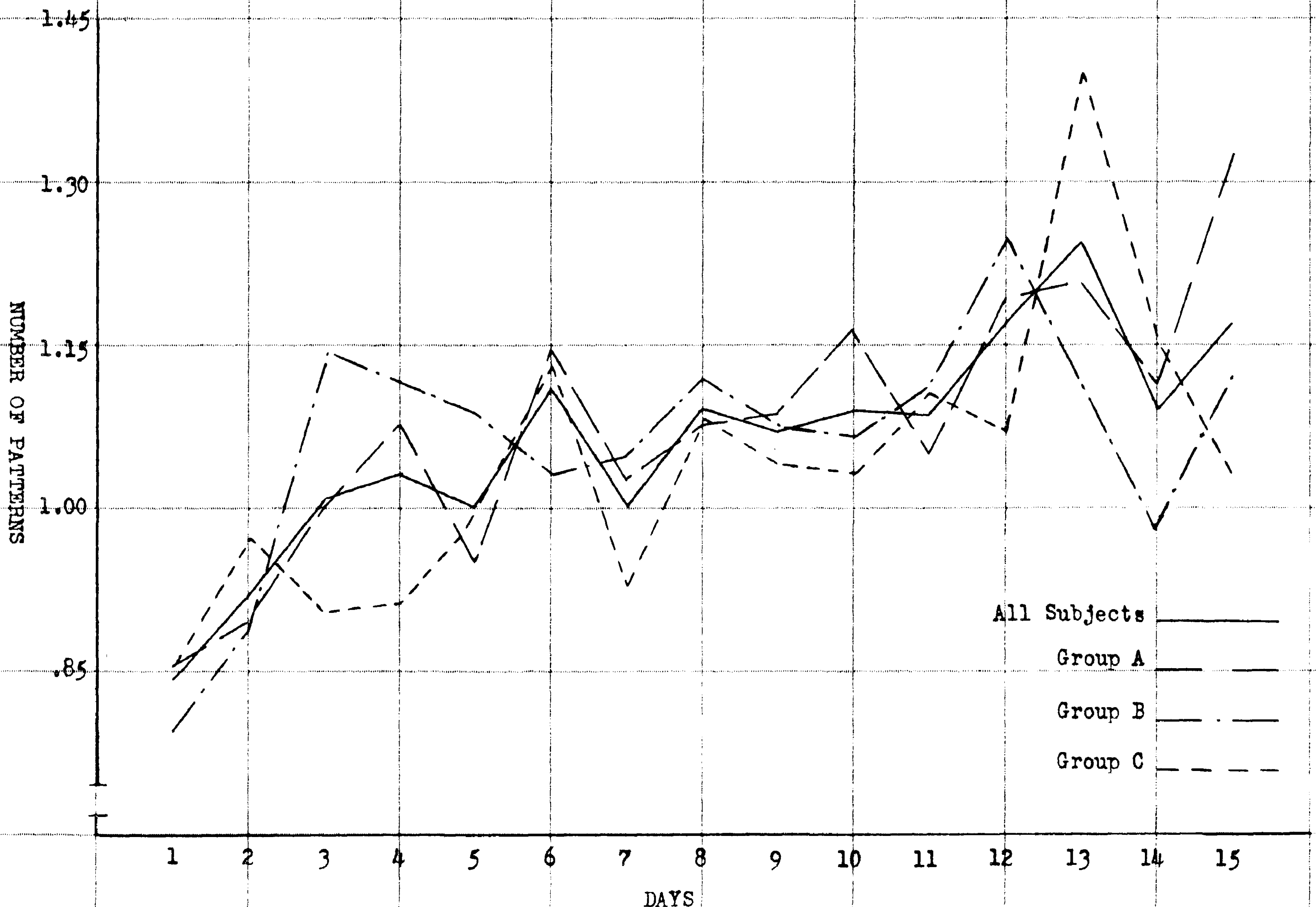
The Complex Coordination Test fits Woodworth's classification of tasks scored as output per unit of time. The results obtained agree with his statement that under this scoring condition, variability will increase with practice. Inspection of the graphs fails to indicate any consistent differences among the three groups, but because significant differences were found in the level of performance of the three groups, both the σ_h and the σ_t values were analysed for group differences. The analysis of the σ_t values throughout training is shown in Table XLIV. The analysis shows that differences among the groups are not significant when evaluated against the residual variance (F_1) or the residual and interaction variance (F_2). The analysis of the σ_h values resulted in the same finding. Table XLIV also shows that there are significant differences between days as would be expected.

Inspection of the graphs (Figures 6 and 7) shows that both measures of variability have approximately the same characteristics, and so would be expected to be highly correlated. The product-moment correlation between the two measures on Day 1 is .732 and on Day 15 is .846. The



COMPLEX COORDINATION TEST: MEAN STANDARD DEVIATIONS OF NO. OF PATTERNS MATCHED PER 30 SECONDS

FIGURE 6



COMPLEX COORDINATION TEST: MEAN STANDARD DEVIATIONS OF NO. OF PATTERNS MATCHED PER TRIAL

FIGURE 7

TABLE XLIV

ANALYSIS OF VARIANCE FOR BETWEEN GROUP DIFFERENCES, COMPLEX COORDINATION TEST STANDARD DEVIATIONS OF TRIAL SCORES (σ_t). N = 30

Source	Sum of Squares	df	Variance	F_1	F_2
Total	30.198	449			
Between Days	4.331	14	.309	5.237**	5.15**
Between Groups	.099	2	.050	-	-
Interaction	2.024	28	.072	1.220	
Residual	23.744	405	.059		

measures cannot be considered identical, although they are highly related; so as stated above, both were used in most of the analyses described below.

To determine whether the order in which the tasks were practiced had any effect on variability of performance, the total standard deviations of the 30-second scores ($\sum_{J=1}^{15} \sigma_h$) for each individual were analysed. The 24 subjects used in the previous analyses of order of practice were used in this analysis. The summary is shown in Table XLV.

TABLE XLV

ANALYSIS OF VARIANCE OF COMPLEX COORDINATION TEST TOTAL STANDARD DEVIATIONS OF DAILY 30-SECOND SCORES. N = 24

Source	Sum of Squares	df	Variance	F
Total	26.098	23		
Between Orders	3.882	5	.7764	-
Within Orders	22.216	18	1.2342	

The analysis shows that there are no significant differences in variability attributable to the order in which the tasks were practiced.

In order to test the null form of Hypothesis 3, that initial intra-individual variability is significantly related to final intra-individual variability, and to determine the consistency of each individual's variability from day to day, product-moment correlation coefficients of the σ_h values were computed between Day 1 and all other days, and between consecutive days. These correlations are shown in Table XLVI.

TABLE XLVI

INTER-DAY CORRELATIONS OF STANDARD DEVIATIONS OF 30-SECOND SCORES, COMPLEX COORDINATION TEST (σ_h). N = 30

							Day							
Day	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	.14	.08	.20	.27	.17	.16	.18	.30	.06	.18	.24	.02	.09	-.22
2		.07												
3			.29											
4				.28										
5					.22									
6						.27								
7							.28							
8								.33						
9									.27					
10										.51				
11											.46			
12												.07		
13													.52	
14														.27

The results of the L_1 test as presented in Table XLIII showed that the variability of the 30-second scores was significantly different among individuals only on some of the practice days. From this finding one would not expect the inter-day correlations to be high or even significant. The correlations confirm this expectation, for none of the correlations of Day 1 with other days differs significantly from zero. Of the consecutive day intercorrelations, only three are significantly different from zero. It may be concluded that there is no relationship between initial and final intra-individual variability as measured by the standard deviations of the 30-second scores, and in only three instances are consecutive day measures of variability related.

The L_1 ratios for the variability of the trial scores (see Table XLIII) indicate that the intercorrelations of the standard deviations of the trial scores would not be expected to be any higher than the intercorrelations of the standard deviations of the 30-second scores. For that reason, σ_t intercorrelations were computed only for trial days representing initial, middle, and final levels of training and for which the L_1 ratios were significant. The correlations with mean variability for the training period ($\bar{\sigma}_t$) are also shown. The intercorrelations are shown in Table XLVII.

TABLE XLVII

INTER-DAY CORRELATIONS OF STANDARD DEVIATIONS OF TRIAL SCORES (σ_t). COMPLEX COORDINATION TEST. N = 30

	Days				
Days	2	3	8	15	$\bar{\sigma}_t$
1	.01	-.14	-.09	.44*	.37*
2		-.18	.39*	.13	-
3			-.03	.10	-
8				.28	.48*
15					.72*

*Significant at the 5% level of confidence.

The table shows that initial variability is significantly correlated with final variability between the 5% and 1% level of confidence, and only one other inter-day correlation is significant at less than the 5% level. Because the relationship between initial and final variability is of doubtful significance, no definite conclusion can be drawn. It may be stated, however, that the standard deviations of the trial scores are not consistent measures of variability from day to day.

The mean standard deviation of the trial scores is derived from the daily standard deviations so would be expected to be correlated with each one of them. Only the correlation with Day 15 is high, but, because it is considerably less than 1, the mean variability was used as an additional measure. For later evaluations, σ_h Days 1 and 15 and σ_t Days 1, 8, 15 and $\bar{\sigma}_t$ were used as representative measures of variability throughout training.

The consecutive day correlations indicate that the measures of variability are not highly reliable. An estimate of the reliability of the σ_h scores, derived by means of the Hoyt technique, and a summary of the analysis is shown in Table XLVIII. The measure of variability is more reliable than would be anticipated from the inter-day correlations, but it is considerably lower than the reliability coefficient of the performance scores ($r = .985$). The analysis shows that there are significant differences between days and between individuals. Differences between days would be expected in a learning situation; but differences between individuals might not be expected from the results of the L_1 tests, for they showed that only on a few days were there significant differences between individuals. The significance found by the analysis of variance may be explained by the fact that the analysis was made over the entire

TABLE XLVIII

ANALYSIS OF VARIANCE FOR BETWEEN INDIVIDUAL DIFFERENCES, COMPLEX COORDINATION TEST STANDARD DEVIATIONS OF 30-SECOND SCORES (σ_h). N = 30

Source	Sum of Squares	df	Variance	F
Total	8.168	449		
Between Individuals	2.001	29	.0690	6.161**
Between Days	1.637	14	.1169	10.438**
Residual	4.530	406	.0112	

$$r = \frac{.0690 - .0112}{.0690} = .84$$

practice period of 15 days, whereas the L_1 test was made of single days throughout the period. The conclusion is that the standard deviations of the 30-second scores differentiate between individuals over the entire practice period, although they do not differentiate on each day.

To determine the reliability of the standard deviations of the trial scores, a similar analysis was made and is shown in Table XLIX.

TABLE XLIX

ANALYSIS OF VARIANCE FOR BETWEEN INDIVIDUAL DIFFERENCES, COMPLEX COORDINATION TEST STANDARD DEVIATIONS OF TRIAL SCORES (σ_t). N = 30

Source	Sum of Squares	df	Variance	F
Total	30.198	449		
Between Individuals	6.125	29	.211	4.306**
Between Days	4.331	14	.309	6.306**
Residual	19.742	406	.049	

$$r = \frac{.211 - .049}{.211} = .77$$

From the analysis it may be concluded that standard deviations of the trial scores are not as reliable as the performance scores. The σ_t values have a lower reliability coefficient than the σ_h values, but the difference between the reliability coefficients is quite small. There are significant differences between days and also between individuals. The standard deviations of the trial scores also show significant differences over the entire training period, although they do not discriminate each day.

The above conclusions are significant for the problem under investigation. Measures of variability based on the 30-second scores, or on the trial scores, differentiate between individuals over the entire practice period, but do not differentiate every day of that practice period. Therefore, using a measure of variability on any one day would probably be of little value to predict later variability or performance. The low inter-day correlations give further support to this conclusion, for they show that variability as measured in this situation is not a sufficiently stable characteristic to be useful in describing or predicting behavior. In view of the above conclusions a further analysis would not be expected to be profitable, but it was carried out in order to test specifically the hypotheses set up.

To test the null form of Hypothesis 4 that at any stage of learning intra-individual variability is related to level of performance, intercorrelations between performance and variability on the same day were computed. Correlations were computed for both measures of variability, but only on the days on which there were significant individual differences. The correlations are shown in Table L. Only two of the correlations differ significantly from zero between the 5% and 1% levels of confidence, while

TABLE L

CORRELATIONS OF MEASURES OF VARIABILITY WITH PERFORMANCE, COMPLEX COORDINATION TEST. N = 30

Variability	Performance ($\bar{Z}_s$) Day 1	Day 2	Day 3	Day 4	Day 5	Day 8	Day 10	Day 15
σ_h	-.01	-	.35	.41*	.42*	-	-	.23
σ_t	.02	.15	.20	-	-	.20	.29	.30

*Significant at the 5% level of confidence.

the others are not significant. It is doubtful that there is a relationship between variability and performance.

To determine the relationship of variability at one stage of practice to performance at another stage, the correlations shown in Table LI were computed. The standard deviations of the trial scores were used as the measures of variability.

TABLE LI

CORRELATIONS OF STANDARD DEVIATIONS OF TRIAL SCORES WITH MEAN TRIAL SERIES SCORES, COMPLEX COORDINATION TEST. N = 30

	σ_{t1}	σ_{t8}	σ_{t15}	$\bar{\sigma}_t$
$\bar{Z}_{s1}$	.02	.03	.01	.12
$\bar{Z}_{s2}$	.00	.07	.03	.23
$\bar{Z}_{s15}$	.17	.04	.30	.47**

From the correlations shown, it may be concluded that variability at one stage of learning is not related to performance at another stage. The only relationship is between the mean standard deviation of trial scores and performance on Day 15. This correlation is positive and significant at the 1% level of confidence, indicating that individuals who reach a higher level of performance tend to be more variable.

The test of Hypothesis 7 would involve the computation of the multiple correlation of a measure of initial performance and a measure of initial variability with final level of performance. As demonstrated by Guilford (9, p.437), no purpose would be served by computing this correlation, for the only significant correlation among the three variables is between initial and final performance. Although the obtained correlations cannot be considered stable, there is no evidence that the multiple correlation of a measure of initial performance and a measure of initial variability with final level of performance on the same task is higher than the correlation of initial and final performance alone.

Intra-Individual Variability: Inter-Day

Inter-day measures of intra-individual variability have been computed for the Complex Coordination Test in the same manner as for the other tasks. These measures are the maximum likelihood estimates of the standard deviations of the standard scores and the maximum likelihood estimates of the standard deviations of the 30-second scores and trial scores, for each individual. The standard scores are based on deviations of the individual daily mean trial series scores ($\overline{Z}_s$) from the group mean trial series score for each day. The standard deviation of the standard scores will be indicated by the symbol σ_z, the standard deviation of the standard deviations of the 30-second scores by the symbol σ_{σ_h}, and the standard deviation of the standard deviations of the trial scores by σ_{σ_t}. The values of the between-day measures of variability are shown in Table LII. The intercorrelations of the three measures are as follows:

$$\sigma_{\sigma_h} \text{ and } \sigma_{\sigma_t} : r = .57$$

$$\sigma_{\sigma_h} \text{ and } \sigma_z : r = .09$$

$$\sigma_{\sigma_t} \text{ and } \sigma_z : r = .18.$$

TABLE LII

INTER-DAY MEASURES OF VARIABILITY, COMPLEX COORDINATION TEST.

Subject	σ_z	σ_{σ_h}	σ_{σ_t}	Subject	σ_z	σ_{σ_h}	σ_{σ_t}
1	.197	.101	.222	16	.508	.136	.238
2	.398	.117	.200	17	.249	.106	.281
3	.313	.120	.252	18	.400	.104	.188
4	.529	.121	.142	19	.381	.095	.194
5	.524	.171	.311	20	.620	.114	.236
6	.348	.112	.323	21	.258	.159	.290
7	.378	.114	.152	22	.401	.116	.283
8	.268	.120	.289	23	.302	.174	.297
9	.438	.111	.236	24	.407	.152	.218
10	.188	.098	.167	25	.446	.117	.281
11	.540	.124	.253	26	.498	.101	.191
12	.452	.109	.178	27	.300	.080	.219
13	.379	.157	.317	28	.334	.099	.211
14	.364	.101	.160	29	.573	.127	.258
15	.304	.114	.271	30	.612	.094	.149

The σ_{σ_h} and the σ_{σ_t} values are significantly related as would be expected, because the σ_h and the σ_t values from which they are derived are highly correlated. The standard deviations of the standard scores are not related to the other two measures.

To test the null form of Hypothesis 5, that inter-day and intra-day measures of intra-individual variability on the same task are related, the product-moment correlations shown in Table LIII were computed. Correlations with performance are also shown. Of the two measures of variability of variability, only the σ_{σ_t} values are used in this analysis.

TABLE LIII

CORRELATIONS OF MEASURES OF INTER-DAY VARIABILITY WITH MEASURES OF INTRA-DAY VARIABILITY AND MEASURES OF PERFORMANCE, COMPLEX COORDINATION TEST. N = 30

	σ_{t1}	σ_{t8}	σ_{t15}	$\bar{\sigma}_t$	$\bar{z}_{s1}$	$\bar{z}_{s2}$	$\bar{z}_{s15}$
σ_{σ_t}	-.11	-.08	.37*	.37*	.30	.12	.47**
σ_z	.14	-.01	.17	.15	-.22	.09	-.02

*Significant at the 5% level of confidence.
**Significant at the 1% level of confidence.

With .36 as a coefficient significant at the 5% level of confidence, two of the correlations of σ_{σ_t} with intra-day measures of variability could be attributable to chance at a probability level of less than 5%. The σ_z is not related to intra-day variability. It is doubtful that there is a relationship between intra-day and inter-day measures of intra-individual variability. The σ_{σ_t} is significantly and positively related to final performance, but σ_z is not related to initial or final performance.

Time of Training to Reach a Criterion

The performance criteria established for the Complex Coordination Test are:

$$C_1 : \bar{Z}_t = 10$$
$$C_2 : \bar{Z}_s = 10.$$

These criteria were chosen because they represent the highest performance level that was reached by all subjects. The number of trials to reach

each criterion is shown in Table LIV.

TABLE LIV

NUMBER OF TRIALS TO REACH PERFORMANCE CRITERIA ON THE COMPLEX COORDINATION TEST.

Subject	C_1	C_2	Subject	C_1	C_2
1	62	84	16	56	64
2	46	76	17	132	176
3	54	72	18	95	116
4	124	152	19	80	144
5	50	84	20	52	76
6	44	64	21	68	88
7	47	72	22	63	72
8	36	44	23	47	52
9	96	132	24	55	92
10	131	176	25	82	128
11	163	184	26	48	88
12	71	100	27	152	180
13	55	92	28	68	136
14	60	84	29	34	88
15	110	116	30	60	80

The correlation between the criteria is .92, so only criterion 1 is used in further analyses. The correlations of measures of variability and measures of performance with number of trials to reach a trial score of 10 are shown in Table LV. These correlations were computed to test the null form of Hypothesis 6 concerning the relation of measures of variability and time of training to a criterion.

TABLE LV

CORRELATIONS OF NUMBER OF TRIALS TO REACH A TRIAL SCORE OF 10 WITH VARIABILITY AND PERFORMANCE, COMPLEX COORDINATION TEST. N = 30

Day	Variability σ_h	σ_t	Performance $\bar{Z}_s$
1	-.22	-.24	-.64**
8	-	-.19	-.90**
15	-.29	-.17	-.71**
Mean, Days 1-15	-	-.50**	-

From the above correlations it may be concluded that measures of intra-individual variability early in practice are not related to time of training to reach a performance criterion on the same task. There is no evidence, therefore, to support Hypothesis 6. Mean variability (σ_t) is related negatively to time of training, but this relationship is of no value for predictive purposes. It indicates, however, that an individual who is more variable reaches the criterion level of performance in fewer trials. This relationship would not ordinarily be expected but is in line with the positive relationship between mean variability and performance shown above. Number of trials to a criterion is negatively related to performance as would be expected. The relationship is highest on Day 8, which may be attributable to the fact that most subjects reached the criterion level at or shortly before the eighth day.

Initial variability does not correlate significantly with time of training or with initial performance, so no purpose would be served by attempting to determine the multiple correlation of measures of initial variability and initial performance with time of training to reach a criterion of performance.

Summary of Conclusions for the Complex Coordination Test

Under the conditions of this investigation, conclusions for the Complex Coordination Test may be stated as follows:

1. Final performance can be predicted from initial performance. The hypothesis that initial performance is related to final performance on the same task is supported.

2. There are individual differences in variability of performance on some practice days. The hypothesis that there are individual differences in variability of performance is partially supported.

3. It is doubtful whether final variability can be predicted from initial variability. No conclusion can be drawn with regard to the hypothesis that intra-individual variability early in practice is related to intra-individual variability later in practice on the same task.

4. Final level of performance cannot be predicted from initial variability. It is doubtful whether variability is related to performance at any stage of practice, but the indications are that individuals who reach a higher level of performance tend to be more variable. No definite conclusion may be drawn with regard to the hypothesis that intra-individual variability is related to level of performance on the same task.

5. It is doubtful that inter-day and intra-day measures of intra-individual variability are related. No conclusion may be reached with regard to the hypothesis that inter-day and intra-day measures of intra-individual variability on the same task are related.

6. Measures of intra-individual variability cannot be used to predict time of training to reach a criterion. The hypothesis that measures of intra-individual variability early in practice are related to time of training to reach a performance criterion on the same task is not supported.

7. There is no evidence to support the hypothesis that the multiple correlation of a measure of initial performance and a measure of initial variability with the final level of performance on the same task is higher than the correlation of initial and final performance alone.

CHAPTER VI

ANALYSIS OF THE INTERRELATIONS AMONG TASKS

In the previous three chapters we examined the relationships of measures of performance and variability within the Rotary Pursuit Test, the Two-Hand Coordination Test, and the Complex Coordination Test. The purpose of this chapter is to examine the correlations of the measures among these tasks, particularly with reference to the most complex task, the Complex Coordination Test. The relationships within each task are of importance in the preliminary evaluation of measures of variability, but for the purposes of this study, the relationships of variability on one task to performance and variability on another are of greater significance. The correlations within each task do not indicate that variability can be a very useful measure for prediction of performance or variability among tasks. Correlations among tasks have been computed in order to provide more evidence with regard to this possible conclusion.

Intercorrelations of Measures of Initial and Final Performance

In order to test the null form of Hypothesis 8 concerning the relation of measures of performance on one task to measures of performance on the other two tasks, intercorrelations were computed between measures of initial and final performance on the three tasks. The correlations are shown in Table LVI. An examination of Table LVI shows that there is a relationship between initial and final performance on the Rotary Pursuit and Complex Coordination Tests, but not on the Two-Hand Coordination Test. Initial performance on the Rotary Pursuit and Complex Coordination Tests is not correlated with final performance on the other tests. Initial performance

TABLE LVI[1]

INTERCORRELATIONS OF MEASURES OF PERFORMANCE AMONG TASKS.
N = 30

	2	3	4	5	6
1. Rotary Pursuit Day 1 ($\bar{X}_{t1}$)	.50**	.16	.04	.35	.35
2. Rotary Pursuit Day 15 ($\bar{X}_{t15}$)		.08	.58**	.23	.47**
3. Two-Hand Day 1 ($\bar{Y}_{t1}$)			.15	.61**	.45*
4. Two-Hand Day 10 ($\bar{Y}_{t10}$)				.24	.41*
5. Complex Coord. Day 1 ($\bar{Z}_{s1}$)					.68**
6. Complex Coord. Day 15 ($\bar{Z}_{s15}$)					-

on the Two-Hand Coordination Test is related to final performance on the Complex Coordination Test at the 5% level of confidence.

Tests of the significance of the differences among the correlations show that final performance on the Rotary Pursuit Test is as much related to final performance on the other tasks as it is related to Rotary Pursuit Test initial performance. Final performance on the Two-Hand Coordination Test is more nearly related to final performance on the other tasks than it is to Two-Hand Coordination Test initial performance.

It is important to know whether an individual who is highly variable on one task is also highly variable on another task. To determine this, the null form of Hypothesis 9, concerning the relation of measures of variability among tasks, was tested by computing product-moment correlations between measures of intra-day variability on the three tasks used. These correlations are shown in Table LVII.

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[1] In this chapter, all correlations significant at the 5% level of confidence are indicated by a single asterisk. A double asterisk indicates significance at the 1% level of confidence.

TABLE LVII

INTERCORRELATIONS OF MEASURES OF INTRA-DAY VARIABILITY AMONG TASKS. N = 30

	2	3	4	5	6	7
1. Mean σ of Rotary Pursuit Trial Scores, Days 1-3, ($\sigma_{X_{t\ 1-3}}$)	-.26	.28	-.35	-.05	-.11	.06
2. Mean σ of Rotary Pursuit Trial Scores, Days 9-13, ($\sigma_{X_{t\ 9-13}}$)		-.34	.00	-.19	-.17	-.22
3. σ of Two-Hand 30-Second Scores Day 1, ($\sigma_{Y_{h\ 1}}$)			-.27	.24	.51**	.30
4. σ of Two-Hand 30-Second Scores Day 3, ($\sigma_{Y_{h\ 3}}$)				-.02	-.19	-.42*
5. σ of Complex Coord. Trial Scores Day 1, ($\sigma_{Z_{t\ 1}}$)					.44*	.37*
6. σ of Complex Coord. Trial Scores Day 15, ($\sigma_{Z_{t\ 15}}$)						.72**
7. Mean σ of Complex Coord. Trial Scores, Days 1-15, ($\overline{\sigma}_{Z_t}$)						-

Examining the correlations we note that variability on the Rotary Pursuit Test is not related to variability on the other two tasks. Variability on Day 1 on the Two-Hand Coordination Test is correlated with final variability on the Complex Coordination Test at the 1% level of significance. This correlation is difficult to interpret and is possibly due to chance, for the L_1 test showed that the variability of the 30-second scores on the Two-Hand Coordination Test did not differ among individuals. Variability on Day 3 on the Two-Hand Coordination Test correlates with mean variability on the Complex Coordination Test at the 5% level of confidence. Because the significance of this correlation is doubtful, no conclusion is drawn as to whether the measures are related.

The only other significant correlations shown in the table are within one task, and in no case is a measure of variability on one task related to a measure of variability on both of the other tasks. It is doubtful that there is a relationship among measures of intra-day variability on the three tasks used.

As a further test of Hypothesis 9 the intercorrelations of measures of inter-day variability on the three tasks were computed. The coefficients obtained are shown in Table LVIII.

TABLE LVIII

INTERCORRELATIONS OF MEASURES OF INTER-DAY VARIABILITY AMONG TASKS. N = 30

	2	3	4	5	6
1. σ of Standard Scores, Rotary Pursuit (σ_{z_X})	.00	.39*	-.28	.38*	-.16
2. σ of σ of Trial Scores, Rotary Pursuit ($\sigma_{\sigma_{X_t}}$)		-.20	.18	-.22	.46*
3. σ of Standard Scores, Two-Hand (σ_{z_Y})			-.30	.30	-.31
4. σ of σ of 30-Second Scores, Two-Hand ($\sigma_{\sigma_{Y_h}}$)				-.12	.32
5. σ of Standard Scores, Complex Coord. (σ_{z_Z})					.18
6. σ of σ of Trial Scores, Complex Coord. ($\sigma_{\sigma_{Z_t}}$)					-

The standard deviations of the standard scores on the Rotary Pursuit Test are correlated with the corresponding measures on the other tasks between the 1% and 5% levels of confidence. The standard deviations of the standard deviations of the trial scores on the Rotary Pursuit Test are also related to the corresponding measures on the Complex Coordination Test between the 1% and 5% levels of confidence. Therefore it is doubtful that the measures are related. None of the other intercorrelations shown in Table LVIII differ significantly from zero. There is little evidence to support Hypothesis 9. The indications are that the measures of variability used in this study are of little value for purposes of description or prediction of the behavior observed. It is possible to measure variability of performance reliably and to discriminate between individuals in most instances, but individual variability is not consistent from day to day on the same task and appears to be specific to each task.

The appropriate test of Hypothesis 10 would require the computation of the multiple correlation of measures of variability and performance on the less complex tasks with final level of performance on the most complex task. Testing this hypothesis would determine whether or not measures of variability in addition to measures of performance predict a complex performance better than measures of performance alone. If the final level of performance on the most complex task of the three used may be better predicted from combinations of measures of variability and the conventional measures of performance on the less complex tasks, then one might infer that performance on a more complex task, such as piloting an airplane, could be better predicted by using measures of variability of performance in addition to measures of performance. Using initial performance on the Complex Coordination Test, initial and final performance on the other two tasks, and six of the measures of variability shown in Table LIX, a multiple correlation was computed with final performance on the Complex Coordination Test. As the analysis of this multiple regression progressed, it was found

TABLE LIX

CORRELATIONS OF MEASURES OF VARIABILITY AND PERFORMANCE AMONG TASKS.

Variability	Rotary Pursuit $\bar{X}_{t1}$	Rotary Pursuit $\bar{X}_{t15}$	Performance Two-Hand $\bar{Y}_{t1}$	Performance Two-Hand $\bar{Y}_{t10}$	Complex Coord. $\bar{Z}_{s1}$	Complex Coord. $\bar{Z}_{s15}$
Mean σ of Trial Scores, Days 1-3, Rotary Pursuit ($\sigma_{X_{t\ 1-3}}$)	-	-	.16	.14	.37*	.45*
Mean σ of Trial Scores, Days 9-13, Rotary Pursuit ($\sigma_{X_{t\ 9-13}}$)	-	-	-.03	-.40*	-.17	-.32
σ of Standard Scores, Rotary Pursuit (σ_{z_X})	-	-	-.17	-.47**	.01	-.18
σ of σ of Trial Scores, Rotary Pursuit ($\sigma_{\sigma_{X_t}}$)	-	-	-.05	.10	-.15	.24
σ of 30-Second Scores, Day 3, Two-Hand ($\sigma_{Y_{h\ 3}}$)	-.17	-.05	-	-	-.48**	-.46**
σ of Standard Scores, Two-Hand (σ_{z_Y})	-.01	-.29	-	-	-.26	-.45*
σ of σ of 30-Second Scores, Two-Hand ($\sigma_{\sigma_{Y_h}}$)	.19	.64**	-	-	.00	.26

that the results were not interpretable because of the original instability of the zero-order correlations and the number of decimal places necessary to carry in the calculations.[1] It was concluded, therefore, that a test of Hypothesis 10 was not practicable with the data available.

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[1] A discussion applicable to the limitation imposed by the instability of the zero-order correlations may be found in Peters and Van Voorhis (20, p.245). Evidence with regard to the number of decimal places required is given by Hotelling (12, p.7).

A partial substitute for Hypothesis 10 may be stated as: there are relationships between the final level of performance on the most complex task and measures of variability on the other tasks. To test the null form of this hypothesis, correlations were computed between measures of performance on the most complex task and measures of variability on the other tasks. These correlations are shown in Table LIX. Correlations with measures of performance on the two less complex tasks are also shown.

From this table of correlations it may be seen that one measure of variability, i.e.,,the standard deviation of the 30-second scores on the Two-Hand Coordination Test on Day 3, is correlated with initial and final performance on the Complex Coordination Test at the 1% level of confidence. There are two correlations with the criterion that are significant between the 5% and 1% levels. There are two significant correlations with performance on the other tasks, but they cannot be interpreted on the basis of the evidence available. Because the three highest correlations of variability with the criterion are at, or just below, the 1% level of significance it is difficult to draw definitive conclusions with regard to the relationship between final level of performance on the most complex task and measures of variability on the other two tasks. The correlations are as high as the highest correlation of measures of performance on the other tasks with the criterion (see Table LVI), so the indication is that some measures of variability may be as useful for predicting the criterion as are measures of performance.

To determine whether the relationships of variability with the criterion are independent of the relationships of measures of performance in predicting the criterion, one could compute correlations between the criterion and a measure of variability with measures of performance on the same task partialled out. Again, because of the relative instability of the correlations involved such a partial correlation analysis appeared to be unjustifiable. Therefore, with the data available, it is not possible to determine whether measures of variability are of value in addition to measures of performance in predicting final level of performance on the Complex Coordination Test.

Summary of Conclusions for the Analysis of Interrelations Among Tasks

1. Except for initial performance on the Rotary Pursuit Test, measures of performance on one task are related to some measures of performance on the other tasks. The hypothesis that measures of performance on one task are related to measures of performance on the other two tasks is partially supported.

2. It is doubtful that there are relationships among measures of variability on the three tasks. No conclusion may be reached with regard to the hypothesis that measures of variability on one task are related to measures of variability on the other two tasks.

3. There is no definitive evidence in this study to indicate that there is or is not a relationship between final level of performance on the most complex task and three of the measures of variability on the other two tasks. It is not practicable to test the hypothesis that using final level of performance on the most complex task as a criterion, the multiple correlation of measures of performance and measures of variability on the two less complex tasks is higher than the multiple correlation with measures of performance alone.

CHAPTER VII

DISCUSSION, SUMMARY, AND CONCLUSIONS

The purpose of this chapter is to discuss and compare the results obtained for each test used and to present conclusions arrived at on the basis of the results for the three tests. The results are taken up in the same order as they are presented in each chapter.

Discussion of Results

Level of Performance. The level of performance reached with respect to the maximum possible score differed for each task used, and this difference must be taken into account in interpreting and comparing the results. On the Rotary Pursuit Test, scores approached the maximum possible score but did not reach it. On the Two-Hand Coordination Test, many subjects did reach the maximum score. Scores obtained on the Complex Coordination Test, however, were not limited by the task itself. Level of performance on all three tasks was highly consistent from day to day and reliable throughout the training period. Initial and final performance were positively related on the Rotary Pursuit and Complex Coordination Tests, but were not related on the Two-Hand Coordination Test.

Initial performance on the Rotary Pursuit Test was not related to initial performance on the other tasks, but final performance was related to final performance on the other tasks. This trend is in agreement with a conclusion stated by Hollingworth (10), that the correlations between tasks become greater the longer the practice is continued. He suggested three possible reasons for this increase. His first suggestion was that variability decreased with practice, and there were therefore less chance factors operating when a degree of skill had been attained. This would not be applicable in this situation, for on the Complex Coordination Test variability increased with practice. The second possible explanation is that the tasks themselves changed as the individual became more skilled. It is quite probable that this occured with the three tasks used in this investigation, for the comments of the subjects indicated that it was often not until they had practiced for several days that they realized the true nature of the tasks and fully understood what was required for mastery of the tasks. For example, on the Two-Hand Coordination Test it was not readily apparent that the general movement of the target was circular; and, depending on the quadrant of the circle, the movement required for one hand was always in the same direction. This change in the nature of the task may account for the fact that initial performance on this task was not related to final performance.

Hollingworth's third suggestion to account for the increase of inter-task correlations with practice was that there is a general ability that becomes more apparent as a higher level of skill is reached and as more measures are taken. This possibility cannot be evaluated in this investigation.

Significance of Individual Differences of Variability. Variability of the trial scores, or of the 30-second scores, was highly discriminative among individuals on both the Rotary Pursuit and Two-Hand Coordination Tests. Variability of the Complex Coordination Test scores, however, differed among individuals on only a few days. It may be stated that there are individual differences in intra-individual variability, although the differences do not exist on every day on each task.

This result is of both theoretical and practical significance. Prior to this investigation it was known that there was variability in performance from one trial to another. The source of this variability was attributed both to factors within the individual and to factors associated within the environment and the test itself. There has been no evidence to indicate which is the more important source, or that the variability was attributable to any factors other than chance factors operating through the individual or the environment. The establishment of the existence of individual differences in variability shows that there are factors operating within the individual, and these factors differ from one individual to another. There are, then, more than just chance factors involved. As previously cited, Hull (14, p.315) made the statement that coordinated movement may have as many independent dimensions of variation as there are muscles involved in its production. If the dimensions of variation are independent, then individuals must differ throughout the range of possible dimensions. Hollingworth (11) concluded that there were individual differences in variability; but he used only six subjects and did not test for the significance of the differences. Woodrow (27) compared variability from one day to another and found that it differed within the individual, but he did not show that there were individual differences in that variability.

The results of this investigation show that a part of the variability observed is associated with the individual, but under the conditions imposed and with the methods used, its measurement gives little additional information. The results obtained from the measurement of variability within the individual are summarized below.

<u>Intra-Individual Variability: Intra-Day</u>. The trend of intra-individual variability with practice differed for each task. The mean variability on the Rotary Pursuit Test increased the first half of the

training period and then dropped to a level slightly below the initial level. On the Two-Hand Coordination Test, variability showed a sharp decrease and approached zero, while on the Complex Coordination Test, it increased with practice. Of the three tasks, variability of performance on the Two-Hand Coordination Test was the most consistent, although the correlations between consecutive days are lower than the consecutive day intercorrelations of the performance scores. Variability on the other tasks was not consistent, and on each task was less reliable than performance on the same task. On the Rotary Pursuit and Two-Hand Coordination Tests, the relationships between variability and performance on the same day are positive early in practice but become negative, and increasingly so, until the final day of practice. It is doubtful if variability on the Complex Coordination Test is related to level of performance on the same task.

A different trend of intra-individual variability with practice would be expected for tasks scored in different ways, but the Rotary Pursuit and Two-Hand Coordination Tests were scores in exactly the same manner. The objective of maintaining contact with a target was the same for both tasks but, of course, the methods of attaining the objective differed. The reduction of variability with practice on the Two-Hand Coordination Test, as differing from the Rotary Pursuit Test, may be partially, but not completely, explained. The most obvious factor is that the level of difficulty of the Two-Hand Coordination Test was lower, and subjects were able to reach the maximum score. Variability was therefore very much restricted by the scoring limits of the task. There undoubtedly was variability present, but it was not measured.

The lower level of difficulty of the Two-Hand Coordination Test accounts for the result of the mean variability approaching zero. However, it does not account for the difference in the shapes of the variability curves for the two tasks before performance begins to level off and before the task ceiling can limit the scores. On both the Rotary Pursuit Test and the Two-Hand Coordination Test the most rapid learning takes place in the first six days. Because the objective and scoring of each task is essentially the same, even though the methods are different, one would expect the trend of the variability to be the same during the periods when the most rapid learning was taking place and before the scoring limits were reached. The results, however, do not bear out this expectation. There is no apparent explanation of the different results on the tasks other than that the trend of the variability with practice is specific to the methods of attaining the objective of the task rather than to the objective itself. The increase of variability with practice on the Complex Coordination Test, as differing from the trend of the other tasks, may be explained on the basis of the difference in the scoring method used.

Intra-individual variability as measured was shown not to be consistent or highly reliable. This may be attributable to the inadequacy of the method of measurement, the nature of the conditions of this study, or both. In any event, the measure appears to be of little practical value in the description or prediction of an individual's performance.

From Hull's (14) analysis with regard to simple learning, one would not expect variability in one skill to be related to variability in another. Our results are not conclusive on this point, for it is doubtful whether there are relationships among measures of variability on the different tasks. The unreliability of variability on each task, however, would preclude the possibility of obtaining high correlations of measures of variability among tasks. The low intercorrelations obtained, therefore, are not an adequate test of the implications of Hull's analysis.

Measures of variability were not found to be useful for predicting performance or variability within the experimental situation; but this does not eliminate the possibility that they might be of value for predicting performance or variability on a more, or a less, complex task in another situation. The possibility is unlikely; for, again, variability was not found to be sufficiently consistent to be of value for prediction.

Intra-Individual Variability: Inter-Day. The results obtained from the computation of measures of inter-day variability do not fall into a pattern that can be easily interpreted. There are some relationships among the measures of inter-day and intra-day variability and performance, but there are no relationships that are of predictive value. It may be, however, that measures of inter-day variability could be useful for predicting performance or variability in some other situation, but under ordinary circumstances, they would not be practicable. Measures of inter-day variability require observations of behavior over a relatively long period rather than on only one or a few days and, in addition, require rather extensive computation. Therefore, the measures would be worthwhile only if their predictive value were high.

Time of Training to Reach a Criterion. Initial variability was found to be related to time of training on the Rotary Pursuit Test. On the Two-Hand Coordination Test a relationship was doubtful, and on the Complex Coordination Test there was no relationship. The relationship of intra-individual variability to time of training, then, varies with the task.

Suggestions for Further Investigation. The experimental conditions under which this investigation was conducted were established in order to approximate the conditions of the typical testing situation. The results, then, should be applicable to those situations. The indication is that the usual measures of intra-individual variability will not be useful in predicting performance, variability, or training time on the same task and probably not on tasks other than those used in the testing situation. This does not preclude the possibility of predicting performance from variability under totally different conditions.

In order to make a more complete evaluation under the conditions used in this study, a further investigation should be made with the same experimental design, but with a larger number of subjects. A larger number of subjects would stabilize the correlations obtained and make possible the use of multiple regression techniques to evaluate the usefulness of measures of variability in addition to measures of performance. If based on a larger sample, a factor analysis should be carried out to determine the factorial structure of performance and variability measures. This could be accomplished by an analysis of the matrix of inter-day correlations of measures of performance, of measures of variability, and of the matrix composed of the best correlations of performance with variability. From this analysis should come an indication of the underlying order and differential factorial composition of measures of performance and variability.

It may be possible to derive a better measure of intra-individual variability than the measures used in this study. Hollingworth's (11) technique of correlation of scores for the first and last half-hour of each experimental period could be adapted and used as a measure of variability. This could be done by computing correlations of the odd-even trial or trial series scores through a reasonable period of practice. An individual whose scores correlated highly could be considered consistent in his performance and less variable than an individual whose odd-even scores showed little correlation. Hollingworth found that the measure of variability based on correlations of the scores was highly related to the measure based on the mean deviations from the median score. With the experimental design used in this investigation, however, odd-even correlations would be less influenced by the amount of improvement than were measures based on deviations from mean performance.

To explore the possibility that the characteristics of measures of variability might differ under other experimental conditions, further research should be conducted in which the level of motivation is varied. Motivation, of course, is a difficult variable to control in psychological investigations, but in this study the intent was to maintain only a minimal level of motivation. It may be that the individual differences in variability that were found are attributable in large part to possible differences in level of motivation. If such were the case, then efforts to equalize the motivation of all individuals at any level would tend to reduce individual differences. On the other hand, individual differences within each day may be attributable to factors other than motivation, but the inconsistency of variability from day to day may be caused by variations of motivation from day to day within each individual. Stabilization of the level of motivation from day to day, then, would tend to stabilize the level of variability from day to day and yield more consistent results for purposes of prediction.

There has been no attempt in this study to determine the source of variability of performance. The individual differences found indicate that there is a factor, or factors, operating other than chance. Level of motivation may be the most important factor as pointed out above, but for consistent results it might be necessary to attempt to control an individual's physiological condition as affected by sleep, diet, previous activity, etc. A control of these factors might reduce individual differences, and also stabilize those remaining differences from day to day.

Summary and Conclusions

The purpose of this investigation was to make an evaluation of measures of intra-individual variability of performance as predictors of performance, variability, and training time on three psychomotor tasks. The tasks used were the S.A.M. Rotary Pursuit Test, the S.A.M. Two-Hand Coordination Test, and the S.A.M. Complex Coordination Test. Specific hypotheses were tested by the results obtained under controlled conditions in which 30 individuals practiced on all three tasks for a period of 15 days.

The results of this study indicate that, in general, a more extensive use of measures of variability is not warranted in the description and prediction of attainment of motor skills and proficiences. On the basis of analyses of the data for all the tasks and under the conditions of the experiment, the following specific conclusions with regard to the hypotheses tested appear justified:

1. The relationship between initial and final performance on the same task is specific to the task.

2. There are individual differences in variability of performance.

3. It is doubtful that intra-individual variability early in practice is related to intra-individual variability late in practice.

4. Initial variability is not related to final performance on the same task. The relationship between variability and performance on the same day varies from negative to positive with the amount of learning and with the task on which the measures are made.

5. The relationships between intra-day and inter-day measures of intra-individual variability do not fall into an interpretable pattern, for they vary with the measure, the amount of learning, and the task.

6. The relationship between initial variability and time of training to reach a criterion of performance varies with the task.

7. The relationship of measures of performance among tasks varies with the amount of learning from no relationship to a low positive relationship.

8. It is doubtful that measures of variability are related among tasks.

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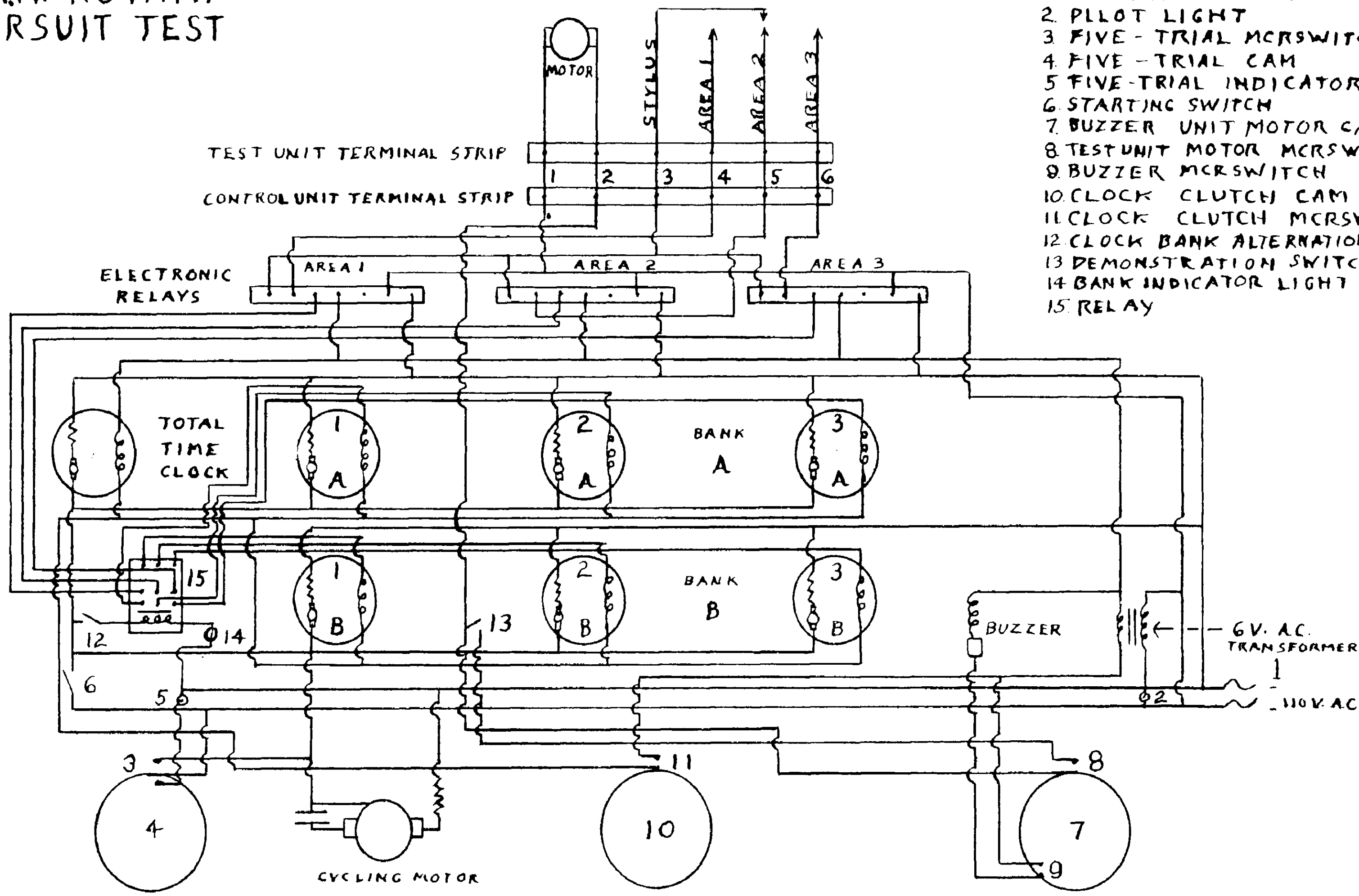
APPENDIX A

WIRING DIAGRAMS AND FUNCTIONAL DESCRIPTIONS OF APPARATUS

WIRING DIAGRAM
S.A.M. ROTARY
PURSUIT TEST



KEY

1. POWER SWITCH
2. PILOT LIGHT
3. FIVE-TRIAL MCRSWITCH
4. FIVE-TRIAL CAM
5. FIVE-TRIAL INDICATOR
6. STARTING SWITCH
7. BUZZER UNIT MOTOR CAM
8. TEST UNIT MOTOR MCRSWITCH
9. BUZZER MCRSWITCH
10. CLOCK CLUTCH CAM
11. CLOCK CLUTCH MCRSWITCH
12. CLOCK BANK ALTERNATION SWITCH
13. DEMONSTRATION SWITCH
14. BANK INDICATOR LIGHT
15. RELAY

FIGURE I

FUNCTIONAL DESCRIPTION OF S.A.M. ROTARY PURSUIT TEST AND CONTROL UNIT

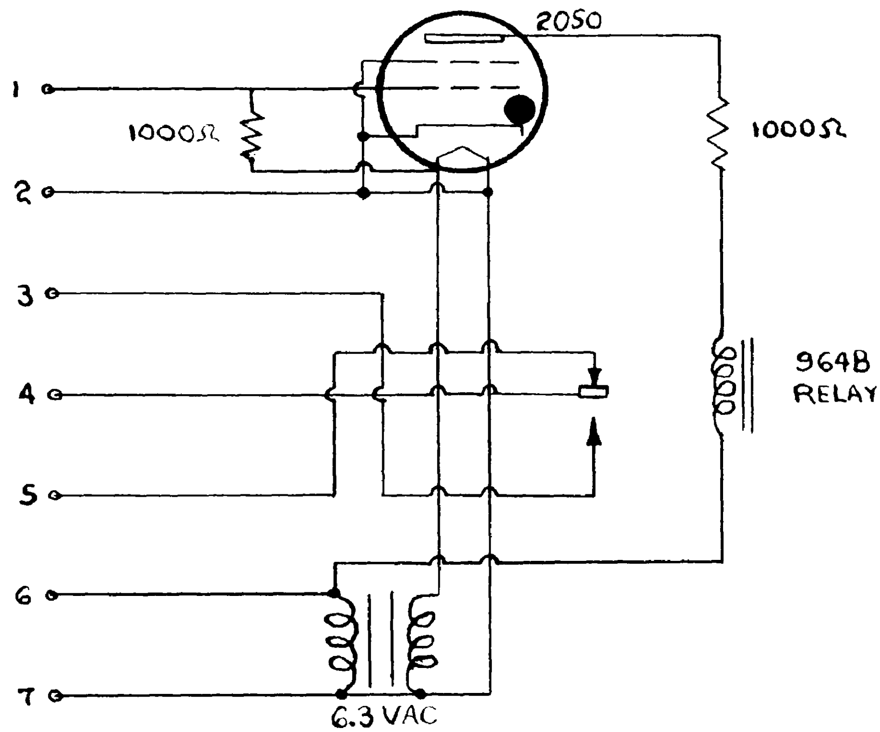
Sequence of Events. The sequence of events used in the experiment is as follows:

1. The starting switch is manually depressed and the cycling unit motor starts to rotate.
2. Three seconds later the turntable starts to rotate, and the warning buzzer sounds for 0.5 seconds.
3. One and a half seconds later the circuit to the timer clutches is completed, and scoring is possible if the stylus is in contact with the target. The scoring period continues for 20 seconds.
4. At the end of the scoring period the buzzer sounds for 0.5 seconds, and simultaneously the circuits to the test unit motor and the timer clutches are opened.
5. After 8.5 seconds rest the warning buzzer sounds for the next trial. This sequence continues automatically for five trials, after which the cycling mechanism stops.

Scoring. The scoring circuit is shown in Figure I in Appendix A. For each target area there is an electronic relay, the diagram of which is shown in Figure II of Appendix A. A common lead from each electronic relay is connected to the stylus. A separate lead is connected to one of the areas from each electronic relay. Contact of the stylus with any one of the three target areas will complete the circuit through the thyratron tube of the corresponding relay. This will in turn close the circuit to the corresponding electric timer, and the timer will continue to run as long as the stylus is held in contact with that target area and the scoring circuit is completed through the cycling mechanism. Scoring is in units of .001 min. on Type S 6 Standard Electric Timers. A manual switch operates a relay to score on the upper bank of timers on alternate trials. The single clock at the left of the control unit is used to indicate the total time of the trial, and a manual switch may be used to time the interval between trials or between series of trials.

Functional Description of Cycling Mechanism. (See Figure I, Appendix A). When the main power switch (1) is turned on, a red pilot lamp (2) lights and clock motors are energized. At the beginning of a series of trials the five trial microswitch (3) rests in one of the depressions of cam (4) and current flows thru the five trial indicator light (5). When the main starting switch (6) is closed microswitch (3) is by-passed, and the cycling unit motor is energized. As cam (4) turns, microswitch (3) closes, opening the circuit to the indicator lamp and closing the circuit to the cycling motor independent of the starting switch. Cam (7) activates the test unit motor microswitch (8) and also the buzzer microswitch (9), causing the test unit motor to rotate and the buzzer to sound for 0.5 seconds.

1.5 seconds after the unit motor begins to rotate, cam (10) activates the clock clutch microswitch (11), making scoring possible if the electronic relay for any scoring area is closed. At end of 20 second scoring period cam (7) completes its rotation and opens microswitch (8), stopping test unit rotation. Simultaneously cam (10) opens microswitch (11), stopping scoring. After 8.5 seconds rest cam (7) again activates test unit motor and buzzer microswitch (9), while cam (10) activates clock clutch microswitch (11) to begin a new trial period. At the end of five trials cam (4) opens microswitch (3) to end the first five trials. The total time clock runs during all test periods. A manual switch (12) selects the bank of clocks desired for scoring and must be switched at the end of each trial in order to alternate clocks. Switch (13) may be used to demonstrate the test unit.



Thyratron Type 2050

Terminals	
1 and 2	to grid bias control
3	bottom relay contact
4	moving relay contact
5	top relay contact
6 and 7	to 115 volts AC

USAF SAM Electronic Relay

FIGURE II

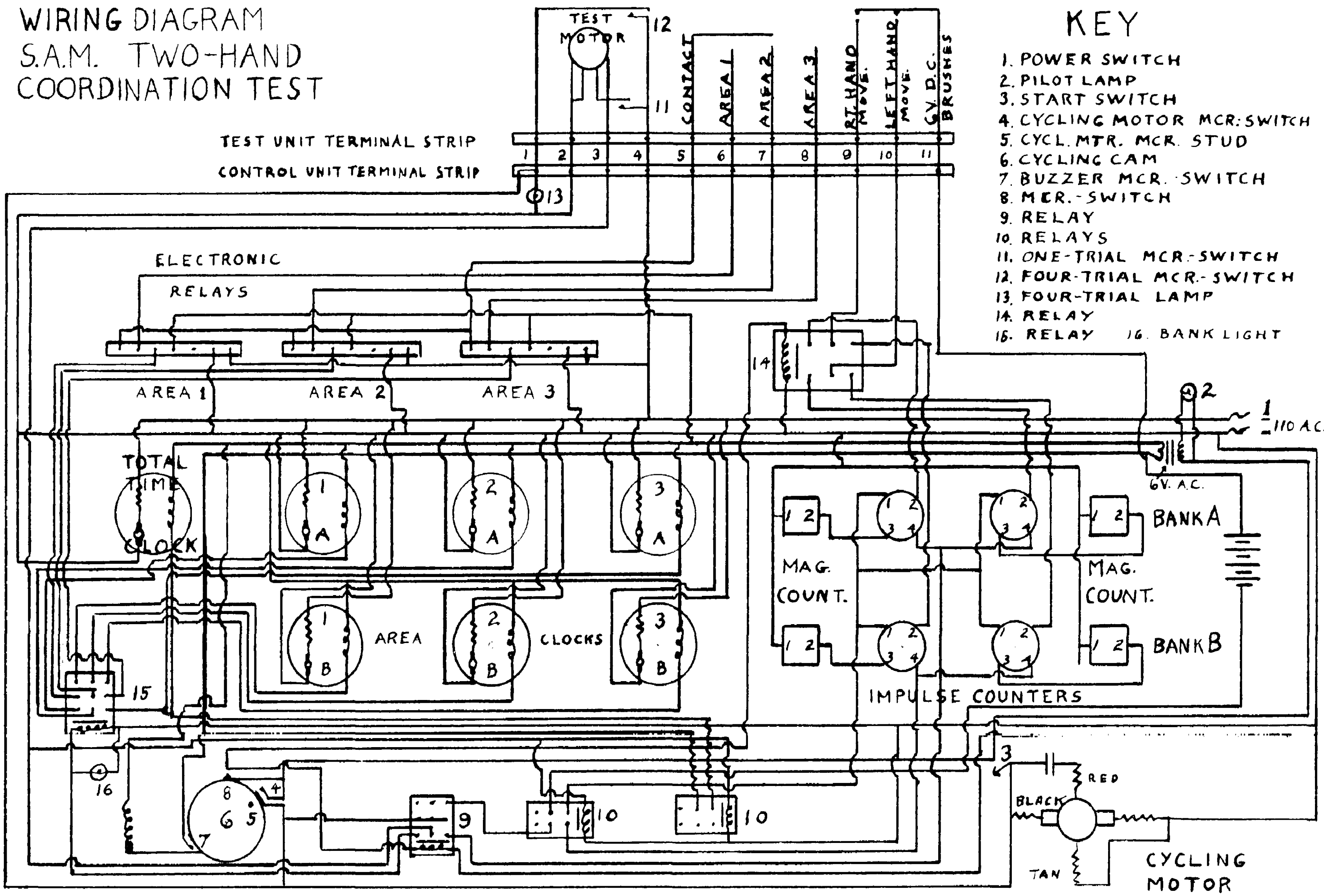

WIRING DIAGRAM
S.A.M. TWO-HAND
COORDINATION TEST
TEST MOTOR
12
11
CONTACT
AREA 1
AREA 2
AREA 3
RT. HAND MOVE.
LEFT HAND MOVE.
6V. D.C. BRUSHES
TEST UNIT TERMINAL STRIP
CONTROL UNIT TERMINAL STRIP
1 2 3 4 5 6 7 8 9 10 11
13
KEY
1. POWER SWITCH
2. PILOT LAMP
3. START SWITCH
4. CYCLING MOTOR MCR. SWITCH
5. CYCL. MTR. MCR. STUD
6. CYCLING CAM
7. BUZZER MCR. SWITCH
8. MCR.-SWITCH
9. RELAY
10. RELAYS
11. ONE-TRIAL MCR.-SWITCH
12. FOUR-TRIAL MCR.-SWITCH
13. FOUR-TRIAL LAMP
14. RELAY
15. RELAY
16. BANK LIGHT
ELECTRONIC
RELAYS
AREA 1
AREA 2
AREA 3
14
2
1
110 A.C.
6V. A.C.
TOTAL TIME CLOCK
1 A
2 A
3 A
1 B
AREA
2 B
CLOCKS
3 B
MAG. COUNT.
MAG. COUNT.
BANK A
BANK B
IMPULSE COUNTERS
15
16
8
6
5
7
4
9
10
10
3
RED
BLACK
TAN
CYCLING MOTOR

FIGURE III

FUNCTIONAL DESCRIPTION OF THE S.A.M. TWO-HAND COORDINATION TEST AND CONTROL UNIT

Sequence of Events. The sequence of events used in the experiment is as follows:

1. The starting switch is manually depressed and the cycling unit motor starts to rotate.

2. Three seconds after the cycling motor starts, the warning buzzer sounds for one second.

3. Two seconds after the buzzer begins to sound the test unit motor starts, the disc begins to rotate, and the circuit is completed to the timer clutches so that scoring is possible on Bank A.

4. 30 seconds after the disc begins to rotate, scoring is switched to Bank B timers and counters.

5. When the disc has completed one revolution (60 seconds) the circuits to the test unit motor, the timer clutches, and the counters are opened, and the buzzer sounds for 1 second. The disc stops and scoring can no longer be continued.

6. After 13 seconds rest the warning buzzer sounds for the beginning of the next trial and the above cycle is repeated for a total of four trials. At the end of the fourth trial the cycling motor stops and the circuit to the "Four Trial Lamp" is broken.

Scoring. The scoring circuit for the Two-Hand Coordination Test, as shown in Figure III, Appendix A, is the same as for the Rotary Pursuit Test scoring except that the timer banks are alternated automatically on the Two-Hand Coordination Test.

Functional Description of the Cycling Mechanism. (See Figure III, Appendix A). When power switch (1) is closed, red pilot lamp (2) lights. The cycling motor microswitch (4) is held open by a stud (5) on the cycling cam (6). When the spring loaded start switch (3) is closed microswitch (4) is shorted out, and the cycling unit motor begins to turn. As soon as the microswitch (4) moves off stud (5) the start switch may be released, and the cycling mechanism will continue to operate until both microswitch (4) and the four-trial microswitch (12) are closed at the same time. Three seconds after the cam has started turning microswitch (7) closes, and the warning buzzer sounds for one second. Two seconds after the buzzer begins to sound, microswitch (8) closes. Microswitch (8) completes the 110 volt circuit to the coil of a relay (9). When relay (9) closes, the center pole by-passes microswitch (11) starting the test unit motor, and the poles on each end complete the clock clutch and counter circuits for Bank A, thus making scoring possible. When relay (9) closes, the circuit to the coil of relay (10) is completed, thus closing the relay and starting the total time clock. Microswitch (11) opens when the turntable begins to move, thus completing the circuit. The coil of relay (10) will remain energized as long as microswitch (11) remains open. After the test unit has been operating 30 seconds microswitch (8) will open and in turn open relay (9). This will break the circuit to Bank A clocks and counters and close the circuit (thru relay 10) to Bank B clocks and counters.

At the end of 60 seconds microswitch (11) will open breaking the circuit to the test unit motor and the coil of relay (10). When relay (10) opens the circuits to Bank B clock clutches and counters and the total time clocks are broken. At the same time the "end" buzzer sounds for one second as microswitch (7) strikes the "end" buzzer stud. Thirteen seconds after microswitch (11) closes, microswitch (7) again closes and sounds the warning buzzer for one second. The above cycle is then repeated. At the end of four trials of sixty seconds each, microswitch (12) closes at the same time as does microswitch (11). As microswitch (12) closes, the circuit is broken that by-passes microswitch (4), i.e., the cycling motor microswitch, and when microswitch (4) is closed ten seconds after the end of the fourth trial, the cycling mechanism stops. Also as microswitch (4) closes the green four-trial light goes out. The cycle of four trials is now complete. The time consumed from the start of the first trial to the end of the last is four minutes and forty-five seconds. The total operating time of the cycling mechanism is five minutes.

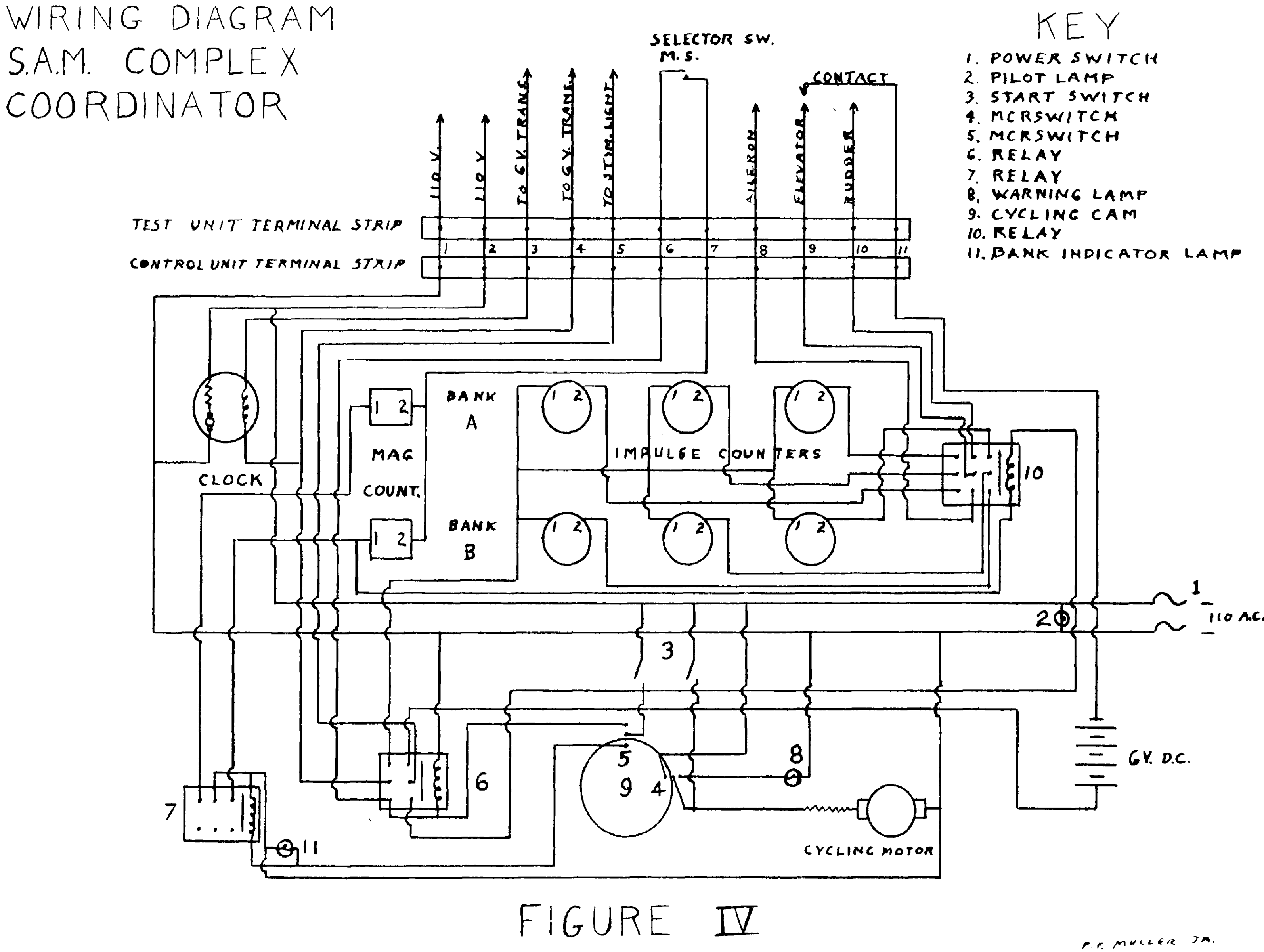

WIRING DIAGRAM
S.A.M. COMPLEX
COORDINATOR
KEY
1. POWER SWITCH
2. PILOT LAMP
3. START SWITCH
4. MCRSWITCH
5. MCRSWITCH
6. RELAY
7. RELAY
8. WARNING LAMP
9. CYCLING CAM
10. RELAY
11. BANK INDICATOR LAMP
SELECTOR SW. M.S.
CONTACT
110 V.
110 V.
TO 6V. TRANS.
TO 6 V. TRANS.
TO STIM. LIGHT
AILERON
ELEVATOR
RUDDER
TEST UNIT TERMINAL STRIP
CONTROL UNIT TERMINAL STRIP
BANK A
BANK B
MAG COUNT.
CLOCK
IMPULSE COUNTERS
110 A.C.
6V. D.C.
CYCLING MOTOR
P. F. MULLER JR.

FIGURE IV

FUNCTIONAL DESCRIPTION OF THE S.A.M. COMPLEX COORDINATION TEST CONTROL UNIT

Sequence of events. The sequence of events in the operation of the control unit for the Complex Coordination Test is as follows:

1. With the power on and the cycling unit stopped the "Ready" lamp is lighted. Pressing the start switch completes the circuit to the cycling unit motor.

2. After 3 seconds the "Ready" light is extinguished, the stimulus lights of the task unit appear, the electric timer begins to operate, and the circuit to the counters is completed so that scoring is possible on Bank A.

3. Thirty seconds later scoring is shifted to Bank B.

4. The operation of the cycling mechanism, the scoring mechanism, and the alternation of the counter banks will continue as long as the "start-stop" switch is in the "start" position. When the switch is placed in the "stop" position, the stimulus lights are extinguished and the circuit to the timer is opened, so that scoring is no longer possible. The cycling mechanism continues to rotate until the circuit to the "Ready" light is completed, 3 seconds prior to shifting to Bank A.

Scoring. The number of settings or patterns completed is counted by a magnetic counter operated by a microswitch attached to the switching mechanism of the task unit.

Functional description of the cycling mechanism. (See Figure IV, Appendix A). Power switch (1) lights pilot lamp (2). Pressing the start switch (3) to "on" causes current to flow to the cycling motor by-passing microswitch (4). Current also flows to microswitch (5). When microswitch (5) is closed relay (6) closes and locks and relay (7) opens. The closing of relay (6) completes the circuit to the stimulus lights, the clutch of the total time clock, and to one side of the counter circuit. The other side of the counter circuit is completed to bank A thru the open relay (7). The test will continue to operate until the switch (3) is moved to the off position, after which the cycling motor will run until microswitch (4) is closed by the stud on the cam.

After scoring has continued for 30 seconds, microswitch (5) will open and supply current to the coil of relay (7). When relay (7) closes, the circuit will be broken to counter bank A and closed to bank B. Relay (6) will remain closed as long as switch (3) is in the "on" position. At the end of 60 seconds relay (7) will open and scoring will again be possible on bank A. At the end of the trial period, switch (3) is turned to the "off" position, after which the cycling motor will run until microswitch (4) is closed by the stud on the cam.

APPENDIX B

SAMPLE SCORING SHEETS

Rotary Pursuit Test: Sample Scoring Form

NAME Barrett DATE 2/21/50 HOUR 1300 TASK ORDER 3-2-1

S.A.M. ROTARY PURSUIT - EXPERIMENTER Shevitz GROUP B TRIAL DAY # 5

TRIAL		AREA 1	AREA 2	AREA 3	TOTAL
1		109	118	62	289
2		113	146	37	296
3		111	137	38	286
4		90	132	60	282
5		112	133	46	291
	Total	535	666	243	1444
6		106	140	42	288
7		145	126	28	299
8		135	134	25	294
9		89	125	44	258
10		104	141	41	286
	Total	579	666	180	1425
11		135	106	45	286
12		136	139	31	306
13		137	140	28	305
14		158	118	23	299
15		147	117	25	289
	Total	713	620	152	1485
16		190	102	9	301
17		152	136	17	305
18		109	140	41	290
19		139	137	18	294
20		106	134	46	286
	Total	696	649	131	1476
20	TRIAL TOTAL	2523	2601	706	5830

Two Hand Coordination Test: Sample Scoring Form

NAME Barrett DATE 2/21/50 HOUR 1300 TASK ORDER 3-2-1

S.A.M. TWO HAND COORDINATOR - EXPERIMENTER Shevitz GROUP B TRIAL DAY #5

TRIAL	AREA 1	AREA 2	AREA 3	TOTAL	LEFT HAND*	RIGHT HAND*	TOTAL*
1a	327	89	54	470	369	483	852
b	333	110	34	477	388	433	821
	660	199	88	947			1673
2a	431	67	-	498	387	440	827
b	374	107	17	498	381	379	760
	805	174	17	996			1587
3a	347	75	27	449	405	478	883
b	253	182	25	460	347	495	842
	600	257	52	909			1725
4a	357	97	45	499	394	431	825
b	266	158	21	445	419	481	900
	623	255	66	944			1725
TOTAL	2688	885	223	3796			6710
5a	477	1	20	498	363	493	856
b	314	115	32	461	435	470	905
	791	116	52	959			1761
6a	372	74	49	495	342	479	821
b	425	67	8	500	380	403	783
	797	141	57	995			1604
7a	410	89	-	499	386	485	871
b	334	160	4	498	406	438	844
	744	249	4	997			1695
8a	408	33	42	483	414	418	832
b	279	157	61	497	478	353	831
	687	190	103	980			1663
TOTAL	3019	696	216	3931			6743
8 TRIAL TOTAL	5707	1581	439	7727			13453
MEAN	713.38	197.62	54.88	965.88			

*Amount of movement

Complex Coordination Test: Sample Scoring Form

NAME Barrett DATE 2/21/50 HOUR 1300 TASK ORDER 3-2-1

S.A.M. COMPLEX COORDINATOR - EXPERIMENTER Shevitz GROUP B TRIAL DAY #5

FIRST PATTERN: 5

TRIAL 1

	PATTERNS	AILERON*	ELEVATOR*	RUDDER*	TOTAL*
1a	2	19	15	13	47
b	3	9	15	14	38
	5	28	30	27	85
2a	3	13	18	16	47
b	3	18	20	18	56
	6	31	38	34	103
3a	3	22	13	13	48
b	3	12	15	15	42
	6	34	28	28	90
4a	2	13	25	15	53
b	4	14	22	30	66
	6	27	47	45	119
TOTAL	23	120	143	134	397

FIRST PATTERN: 28

TRIAL 2

	PATTERNS	AILERON*	ELEVATOR*	RUDDER*	TOTAL*
5a	3	16	19	15	50
b	3	14	17	14	45
	6	30	36	29	95
6a	3	16	21	16	53
b	4	8	25	30	63
	7	24	46	46	116
7a	3	21	18	14	53
b	4	18	15	17	50
	7	39	33	31	103
8a	3	17	25	26	68
b	4	17	15	21	53
	7	34	40	47	121
TOTAL	27	127	155	153	435

LAST PATTERN: 15

Complex Coordination Test: Sample Scoring Form
(Continued)

FIRST PATTERN: 15

TRIAL 3

	PATTERNS	AILERON*	ELEVATOR*	RUDDER*	TOTAL*
9a	3	18	22	12	52
b	3	19	20	13	52
	6	37	42	25	104
10a	4	12	22	25	59
b	4	16	19	25	60
	8	28	41	50	119
11a	3	27	19	15	61
b	3	16	20	12	48
	6	43	39	27	109
12a	3	13	27	27	67
b	4	15	20	22	57
	7	28	47	49	124
TOTAL	27	136	169	151	456

FIRST PATTERN: 2

TRIAL 4

	PATTERNS	AILERON*	ELEVATOR*	RUDDER*	TOTAL*
13a	3	18	25	15	58
b	3	23	15	18	56
	6	41	40	33	114
14a	4	15	22	20	57
b	3	19	17	18	54
	7	34	39	38	111
15a	3	19	23	20	62
b	4	24	18	12	54
	7	43	41	32	116
16a	3	12	21	27	60
b	3	20	15	15	50
	6	32	36	42	110
TOTAL	26	150	156	145	451
16 Min. TOTAL	103	533	623	583	1739

LAST PATTERN: 28

*Amount of Movement

APPENDIX C

INSTRUCTIONS TO EXPERIMENTERS AND SUBJECTS

APPENDIX C

INSTRUCTIONS TO EXPERIMENTERS AND SUBJECTS

Following are the instructions to experimenters and subjects. Instructions were read to the subjects in the experimental room just prior to administration of the tests and with the demonstrations indicated.

Introductory Instructions

Instructions to Experimenter. Confirm appointments for period of experiment. Check visual acuity and color vision. Make sure subjects have not had experience on tasks.

Instructions to Subject. The experiment we are conducting is a learning experiment sponsored by the U.S. Air Force through the Department of Psychology of the University. The general aim is to investigate performance on three tasks during a rather long period of regular practice. These tasks were part of the battery used by the Air Force in selecting pilots and other air crew members during the war. You will practice on these tasks every day for fifty minutes. When you complete the experiment you will be paid at the rate of fifty cents for each practice period.

You will have several rest periods between trials and tasks and these will be timed. I will give you enough warning so that you can be ready to start as soon as the rest period is over. Talking will be permitted only during the rest periods.

A continuous record of your performance will be kept, and during the rest periods I will tell you your best score for the preceding series of trials. You may see your own scores but we cannot give you any information about the scores of others or how you compare with others. PLEASE DO NOT DISCUSS YOUR SCORES ON THE EXPERIMENT WITH ANYONE ELSE PARTICIPATING IN IT UNTIL THE EXPERIMENT IS OVER. When it is completed we will discuss the experiment more fully and let you know how well you did in comparison with others.

Now there are two other things that are particularly important. First, for the purpose of the experiment it is absolutely necessary that you practice every day that you are scheduled and at the same hour every day, or your scores will be of no value. Second, since the results will depend on how well you cooperate and how hard you try, they will be of value only if you do your best at all times every day. We ask you then to do as well as you can on each task throughout the experiment.

I will explain each task to you before you try it. If you have any questions now or later feel free to ask them for we want you to understand what you are expected to do. Your first task will be: - -

Instructions for Rotary Pursuit Test: First Day

Instructions to Experimenter. 15 trials, 30 seconds rest at end of each five trials. Begin timing for rest as soon as five-trial light comes on. Have subject remove coat.

Instructions to Subject. (Turn on demonstration switch). This test is one of your ability to follow a moving target. Your task will be to keep the end of this rod on the metal target as it goes around. As you will notice, the target is composed of three separate areas, and the object is to keep the rod in the center of the target as much of the time as possible. (Demonstrate for 10 revolutions). You will do best if you relax and use a smooth, free swinging motion of the arm and shoulder. Your score will be the total amount of time, in thousandths of a minute, that you stay in actual contact with each area of the target. The maximum possible score for each trial is 333.

Stand directly in front of the apparatus with your toes approximately on the edge of the painted stripe. Hold the handle of the stylus lightly between your thumb and fingers with the back of your hand up. The stylus is made so that you cannot put any pressure on the rod so keep the handle level at all times or you will hit the edge of the disc. Also, keep the rod level and perpendicular to the surface of the disc. (Turn off demonstration switch).

Pick up the stylus and place it on the target in the correct manner, keeping your free hand at your side. Stand with your toes on the edge of the stripe. There will be a series of fifteen trials of 20 seconds each, with 10 seconds rest between each trial. There will be 30 seconds rest at the end of every five trials and during that time I will give you your scores for the preceding trials.

You will start with the rod about an inch above the target so when the buzzer sounds get on the target and try to stay on it. When the buzzer sounds the second time scoring will stop and the disc will stop so lift the rod and keep it off the target until the disc starts again. Do you have any questions.

Lift the rod off the target. Get on the target as soon as the buzzer sounds.

Instructions for Two-Hand Coordination Test: First Day

Instructions to Experimenter. Eight trials, 30 seconds rest after four trials. Begin timing for rest as soon as four-trial light goes off. Have subject remove coat. Begin instructions with contact button about an inch from the target. Illustrate movement of turntable and target by hand movements only.

Instructions to Subject. This is a two-hand coordination test. The black disc will rotate very slowly in a clockwise direction. This small brass target will move with the disc and will also move in an irregular manner within the curved slot. The target is composed of three separate areas and your task will be to keep the contact button as close as possible to the center. Your score will be the total amount of time, in thousandths of a minute, that you stay in contact with each area of the target and the amount of movement of each control. If you get off the target get back on as quickly as possible. The maximum possible score for each trial is approximately 1000.

You are to move the contact button by turning these two handles at the same time. The upper handle moves the button toward and away from you. (Demonstrate). The lower handle moves it from side to side.

Using your right hand on the upper handle only, move the button about an inch off the target and then back on again. Let go of the upper handle. Using your left hand on the lower handle only, move the button about an inch off the target and back on again. Now let go of the handle.

You will have eight one-minute trials with 15 seconds rest between each trial. At the end of four trials there will be an additional 30 seconds rest during which I will give you your scores for the preceding trials.

When the buzzer sounds, grasp the handles and when the target moves try to keep the button in the center. Don't release the handles during the trial. When the buzzer sounds again the disc will stop for 15 seconds. Make sure the contact button is on the center of the target and then release the handles until the next buzzer sounds. Any questions. Ready (press start button).

Instructions for Complex Coordination Test: First Day

<u>Instructions to Experimenter</u>. Reset for pattern #40. Demonstrate and read instructions. Two minute practice, 60 seconds rest, eight minute test period.

<u>Instructions to Subject</u>. This is a coordination test. Your task will be to line up a green light with each of the three red lights. Moving the stick from side to side moves the top green light from side to side. Moving the stick forward and backward moves the middle green light up and down, and moving the rudder bar moves the bottom green light from side to side. (Demonstrate full movement of all controls. Match pattern #40 while giving the following instructions.) I'll match a pattern for you to show how it is done.

Move the stick sideways to match the top green light with the top red light. Get it directly underneath. Then hold the stick in position to keep the top lights matched while you move it forward or backward to match the middle lights. Then hold the stick steady while you match the bottom lights with the rudder bar. When you have matched all three lights hold them. After a half a second, a new setting of red lights will appear. Immediately start matching the new setting of red lights without bothering to come back to neutral.

If a green light goes off altogether, move the control a little and the light will come on again. If you move anyone of the controls as far as it will go the green light will not appear. Ease back a bit to find the end green light. Do you have any questions. (Turn off lights, ask subject to sit in position.)

When the test starts you may use either your right or left hand on the stick, but use only one hand throughout the test. Keep your heels off the floor. You can move the seat forward or backward if you wish. The object is to match as many settings of the lights as you can in the time allowed. Your score will be the number of settings matched and the amount of movement of the controls. Remember to match the top row of lights first, then the middle row, and finally the bottom row.

You will have a two minute practice period, a one minute rest period, and then an eight minute test period. When I say ready, grasp the stick and put your feet on the rudder keeping your heels off the floor. Start matching the settings as soon as the lights come on. When the lights go off, take your feet and hand off the controls until I give you the next ready signal. Do you have any questions. Ready (press start switch). Start matching the settings as soon as the lights come on.

At the end of two minutes. Stop. Release the controls. Do you have any questions. We will begin the test in a few seconds and it will last eight minutes. Your score will be the number of matchings you can make in that time. Work as rapidly as you can. Begin when the lights come on. Ready. (Press start switch).

Instructions for Second Day

The procedure today will be the same as yesterday except for the fact that you will be given more trials on two of the tasks. We are interested in how rapidly you can improve so ask you to continue to do as well as possible.

Rotary Pursuit Test. You will have 20 trials on this task. After five trials you will have 30 seconds rest, after 10 trials 60 seconds, and after 15 trials a 30 second rest.

Remember to use a free easy motion of your arm and hand, keeping the stylus handle and rod level.

Two-Hand Coordination Test. On this task you will have two series of four trials with 30 seconds rest between each series.

Complex Coordination Test. You will have four four-minute trials on this task today, with one minute rest between trials. Match the settings as quickly as you can, beginning when the lights come on. Remember to keep your heels off the floor and use only one hand on the stick.

Instructions Read at the Beginning of the Second Week of Practice

We are going to continue this same procedure for the rest of the experiment but we want to remind you that our aim is to find out how high a level of skill you can reach and maintain on each task, in other words, "just how good you can get". We ask you to continue to do as well as you can every day and to try to improve your performance each time.

Instructions Read at the Beginning of the Third Week of Practice

Since your third week of practice begins today we would like to mention again that we want to see just how well you can do on each task. As long as there is room for improvement we would like you to continue to try to do better each day.

APPENDIX D

TABLES OF MEAN SCORES AND STANDARD DEVIATIONS

TABLE I

Rotary Pursuit Test; Area 1 Mean Trial Scores in .001 Minute

Sub-ject	Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	59.2	130.3	159.6	184.4	211.5	214.1	227.3	246.0	258.6	242.7	270.3	269.4	279.0	257.9	274.8
2	35.7	96.2	127.0	151.1	179.4	196.9	207.8	208.6	219.9	231.4	208.1	245.6	249.8	247.6	257.0
3	73.6	150.2	191.0	215.5	234.7	257.5	272.0	278.1	281.5	296.6	294.9	303.7	298.3	298.7	305.2
4	65.6	125.5	153.2	177.6	192.2	195.4	196.7	209.3	208.0	233.6	236.0	219.0	261.3	268.7	266.1
5	73.1	137.8	158.9	191.1	213.8	238.4	229.0	231.8	250.9	263.6	270.7	285.1	286.1	290.0	289.8
6	73.0	166.7	203.0	227.7	234.6	247.8	241.8	266.0	255.0	274.6	277.1	284.7	276.9	279.5	302.2
7	86.0	174.6	202.0	218.0	231.6	237.4	253.3	267.1	253.7	273.9	271.1	288.8	289.2	277.7	298.8
8	49.6	105.8	143.8	172.5	186.7	227.0	234.7	247.0	232.3	225.9	255.1	268.5	278.4	258.4	270.3
9	25.7	75.0	102.4	142.7	144.5	183.1	170.1	191.2	185.5	211.8	219.0	235.5	232.5	236.0	262.2
10	57.2	95.7	120.7	112.4	119.9	120.7	143.6	174.3	172.2	184.8	195.5	203.9	212.8	190.4	216.3
11	62.3	120.3	134.8	160.2	188.7	230.8	227.9	246.8	243.2	257.6	268.6	265.0	267.4	255.9	278.1
12	58.0	99.4	122.8	123.3	133.0	148.6	163.4	162.3	172.2	177.8	200.3	218.3	190.4	213.1	229.1
13	51.3	136.7	174.4	203.0	238.6	241.2	256.9	246.1	262.7	269.5	268.9	280.5	285.3	277.7	294.9
14	79.4	129.4	165.9	186.6	195.9	213.7	207.4	217.0	220.3	238.4	244.0	256.8	269.5	257.5	279.0
15	35.7	97.9	128.1	125.9	126.1	133.6	153.0	189.9	186.8	209.2	201.1	204.0	234.5	232.5	237.9
16	67.1	122.4	171.3	203.3	229.7	251.8	258.0	277.2	285.2	285.1	287.4	289.9	296.2	290.7	296.7
17	27.6	92.7	132.5	162.2	184.2	194.8	221.0	228.8	213.9	221.5	232.2	231.1	242.2	244.0	259.7
18	47.5	105.9	131.8	149.6	166.9	184.0	213.2	211.8	210.8	234.6	249.0	258.8	252.5	258.5	260.4
19	38.6	92.7	130.0	145.2	169.5	198.4	190.7	235.7	237.3	223.2	238.2	253.9	228.4	225.2	255.0
20	19.2	81.9	116.7	155.5	171.2	158.8	187.2	194.8	186.8	202.8	201.3	222.0	240.2	215.2	250.0
21	48.9	112.1	145.5	158.4	163.8	183.3	169.0	196.8	207.9	224.5	219.4	237.2	223.2	236.9	244.0
22	52.3	100.3	120.1	104.3	114.5	140.0	120.5	133.7	166.4	184.6	190.1	204.0	188.0	192.3	210.4
23	46.3	94.1	115.8	157.0	168.0	187.9	187.9	219.0	215.6	229.6	231.8	240.5	242.3	261.4	249.8
24	24.6	90.2	126.6	132.1	154.6	165.5	179.3	191.7	175.2	199.7	202.6	218.8	228.9	244.4	257.9
25	52.1	108.9	141.4	166.9	189.8	220.5	216.2	226.6	251.2	275.7	286.7	280.2	270.4	296.4	297.1
26	97.4	127.9	186.0	200.5	203.0	225.6	242.9	250.4	247.1	250.5	270.9	266.3	268.4	261.9	260.4
27	20.7	65.3	93.5	129.5	117.6	145.0	130.1	157.0	146.6	145.2	175.5	204.2	230.1	190.1	213.6
28	32.4	109.8	147.9	137.6	159.6	175.1	196.0	177.7	196.1	189.6	226.9	224.9	223.8	208.4	223.7
29	63.1	138.5	162.5	152.8	182.3	204.2	191.8	218.7	202.0	167.5	218.5	218.8	219.5	240.9	254.1
30	50.2	119.1	132.3	137.7	148.7	148.9	159.0	166.4	152.3	190.1	190.8	192.7	199.5	197.2	201.4

TABLE II

Rotary Pursuit Test: Area 1 Standard Deviations of Trial Scores

Sub-ject	Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	25.25	17.98	19.51	19.53	21.86	23.27	18.74	14.95	19.08	18.32	14.32	14.79	14.27	13.36	13.49
2	23.46	13.03	16.38	21.59	25.25	22.81	26.89	22.28	15.77	20.61	24.88	15.66	12.27	16.18	23.57
3	20.06	21.24	15.77	21.16	22.20	14.26	12.20	13.03	15.37	10.07	12.11	9.11	12.94	11.69	8.51
4	20.77	18.08	16.91	18.10	21.28	20.85	20.52	24.32	20.93	16.61	23.73	25.35	15.81	17.88	14.40
5	21.93	30.57	23.19	19.11	17.11	20.94	14.91	22.60	12.85	22.60	16.72	13.16	12.42	12.75	10.94
6	27.56	27.29	20.59	16.89	22.80	20.60	23.63	21.41	22.73	16.03	15.02	19.23	20.15	16.16	10.30
7	17.32	22.22	20.80	17.79	17.79	18.51	20.05	12.63	19.28	13.51	17.94	16.01	18.00	21.52	13.26
8	25.43	21.91	21.44	26.52	25.90	23.57	17.37	22.40	22.25	30.11	19.95	25.58	14.44	20.99	27.07
9	19.25	17.42	14.80	20.27	30.35	26.71	31.22	34.20	29.20	30.34	28.77	19.30	18.37	21.13	21.53
10	13.71	17.46	23.60	18.26	30.14	27.96	27.42	28.12	26.16	18.67	21.25	27.88	21.90	37.24	28.81
11	19.63	20.94	29.40	19.42	21.96	19.61	20.01	21.34	21.51	18.63	19.10	14.95	13.21	19.46	18.19
12	17.45	16.68	14.12	20.54	24.60	27.62	23.60	25.03	24.41	20.43	25.15	19.92	26.93	14.64	25.56
13	21.71	23.96	26.25	24.60	18.98	18.01	17.48	19.96	21.05	14.76	27.54	19.46	8.65	26.50	16.27
14	23.90	25.23	20.57	22.97	19.79	21.77	21.36	26.90	22.98	22.53	19.93	19.61	12.22	16.62	16.26
15	20.56	22.51	17.83	27.99	25.41	19.51	32.33	31.44	23.01	22.61	23.26	26.25	22.01	27.97	20.25
16	22.68	22.36	29.42	20.41	17.38	21.15	17.36	14.11	10.67	14.13	16.69	16.57	11.72	14.56	14.30
17	12.58	9.60	27.41	22.51	14.00	17.82	26.38	15.83	14.45	20.73	28.08	20.72	10.59	26.80	17.96
18	15.66	27.59	20.49	21.29	28.15	27.32	20.01	21.55	21.00	23.20	23.02	13.90	20.52	28.25	20.99
19	23.67	17.05	18.93	18.29	15.00	20.41	19.78	22.23	19.36	16.84	17.74	21.15	22.07	23.08	13.99
20	10.88	20.41	14.64	23.39	21.79	18.21	21.14	19.99	22.01	18.59	34.32	22.87	15.60	17.08	21.87
21	22.59	18.33	20.10	16.86	31.55	22.07	26.84	28.67	20.60	29.78	19.66	23.43	27.39	24.44	27.77
22	16.87	15.22	20.87	27.45	17.33	23.13	21.13	25.99	19.95	25.56	24.83	23.69	29.82	17.84	26.88
23	12.96	22.85	27.65	23.00	20.86	22.35	30.23	18.67	17.66	12.76	23.72	17.22	22.73	22.02	17.70
24	10.15	20.61	17.92	26.73	21.52	26.36	21.89	20.98	23.05	22.51	20.65	20.59	18.38	17.06	20.88
25	16.29	28.11	19.07	18.97	22.41	16.08	24.47	25.44	23.77	18.80	11.84	22.54	21.34	12.68	9.32
26	31.37	24.20	29.71	21.00	25.79	14.93	18.05	18.26	17.46	20.21	22.14	15.27	19.29	19.36	19.84
27	12.66	14.56	24.79	24.27	26.54	16.99	22.66	25.33	21.75	26.54	20.36	26.86	17.08	25.72	24.73
28	15.85	22.93	25.84	23.20	19.59	20.38	18.16	33.39	21.49	21.86	13.98	22.08	20.79	20.82	19.29
29	24.81	32.00	27.90	23.11	26.29	19.72	26.20	20.91	20.80	23.07	21.12	23.87	25.31	23.61	19.21
30	28.02	24.26	26.41	22.63	24.13	21.94	24.31	18.39	25.77	24.84	28.38	17.15	22.13	29.50	24.43

TABLE III

Two-Hand Coordination Test: Area 1 Mean Trial Scores in .001 Minute

Subject	Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	351.8	511.6	748.2	876.9	934.2	966.1	982.4	980.0	984.2	989.2	993.8	992.8	994.1	992.5	992.6
2	307.9	380.6	516.2	686.2	858.1	891.5	947.2	961.4	970.8	984.8	983.0	986.4	989.2	988.5	990.8
3	432.0	641.8	827.8	918.9	954.2	984.5	976.8	986.9	991.1	985.9	992.1	992.1	992.2	992.5	992.5
4	330.8	498.1	604.4	822.4	892.8	926.1	967.2	953.0	960.5	958.1	981.2	985.4	980.8	992.2	989.6
5	393.9	683.8	843.9	967.9	965.2	950.5	986.1	990.9	992.4	993.1	992.4	990.5	980.8	990.2	992.8
6	373.4	668.0	843.8	937.6	968.5	986.2	989.6	980.4	981.9	991.8	991.1	991.0	990.9	985.4	993.1
7	232.5	429.1	684.2	856.1	915.1	970.1	989.8	985.9	986.9	990.4	992.9	993.2	990.2	992.5	988.9
8	440.8	588.0	775.9	866.4	932.0	960.9	977.5	985.1	976.5	989.1	990.6	991.2	990.4	992.8	992.9
9	279.9	468.1	692.6	828.8	895.8	928.1	945.6	963.4	974.2	980.8	985.2	989.8	987.1	989.9	990.9
10	190.8	304.2	415.8	643.2	732.4	791.0	924.1	921.1	956.8	940.4	962.6	976.5	961.2	987.2	989.9
11	194.2	395.8	712.2	890.0	974.4	980.5	977.5	977.0	987.5	984.5	990.1	992.0	987.9	991.5	991.2
12	472.4	697.6	814.9	924.8	963.9	982.9	988.2	987.4	982.9	980.9	991.1	991.0	987.2	993.1	989.4
13	418.0	740.6	912.1	980.1	986.5	982.0	990.0	993.5	992.2	993.1	991.5	991.8	993.0	992.2	991.9
14	322.1	499.0	733.9	829.0	903.5	972.4	976.9	988.4	985.4	989.0	990.1	989.5	991.6	990.6	991.6
15	273.5	432.6	505.4	652.5	713.4	836.5	865.6	946.6	957.8	978.2	982.9	976.9	982.1	986.8	989.6
16	242.2	549.1	825.8	940.8	962.5	984.2	988.0	986.4	988.6	992.1	991.5	992.0	991.4	990.8	991.2
17	99.4	357.9	516.1	733.2	916.0	932.1	956.5	986.0	986.5	989.0	987.1	991.1	990.0	990.6	990.8
18	180.0	528.4	774.1	848.1	922.4	946.4	970.6	984.5	985.6	990.1	991.2	991.4	992.0	992.0	990.2
19	168.0	324.1	537.1	753.9	865.2	927.6	962.9	975.4	987.5	992.8	987.9	988.9	987.6	985.4	978.1
20	191.6	488.0	698.8	854.6	937.9	952.1	984.1	973.5	987.5	987.1	990.5	991.8	987.0	989.6	990.5
21	325.5	571.0	752.6	911.6	941.2	959.1	979.8	978.5	983.4	987.2	983.5	984.5	983.1	984.0	980.8
22	322.9	580.6	761.0	871.6	908.0	949.1	975.8	973.5	975.2	978.2	986.8	982.8	980.9	975.9	977.2
23	420.6	672.8	880.2	951.4	978.1	987.2	990.9	989.1	988.6	986.5	988.9	986.6	987.8	988.2	984.1
24	323.1	543.0	682.5	801.8	885.9	958.4	971.4	979.0	976.9	983.9	984.6	987.5	985.8	987.6	985.6
25	275.0	486.4	665.6	900.0	932.5	974.6	989.2	988.8	988.6	986.9	987.6	986.4	985.9	987.6	985.9
26	215.5	489.4	609.2	754.0	898.2	931.6	971.6	975.4	982.1	983.6	987.8	987.5	986.4	987.9	984.0
27	342.9	651.8	821.0	916.8	943.6	960.4	981.9	979.6	977.0	974.1	981.9	987.0	984.5	984.8	986.4
28	372.6	669.5	812.2	908.6	951.4	975.8	986.9	988.6	990.0	987.5	987.4	987.1	985.0	986.2	991.6
29	435.4	722.9	908.0	940.5	979.4	989.6	982.5	991.0	988.9	983.5	985.4	985.4	983.9	985.9	978.8
30	251.4	376.2	372.9	470.5	662.4	709.2	752.9	840.8	873.1	897.6	950.4	925.8	946.8	951.1	956.4

TABLE IV

Two Hand Coordination Test: Area 1 Standard Deviations of 30 Second Scores

Sub-ject	Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	68.09	64.23	65.02	38.89	22.89	16.46	10.49	10.04	8.94	4.63	1.26	1.54	1.34	1.80	2.15
2	78.73	62.84	77.69	67.06	30.92	29.84	24.46	11.54	13.80	4.42	7.54	7.95	3.34	2.70	2.33
3	69.96	47.55	43.74	29.68	19.85	10.70	18.22	5.52	2.92	10.62	1.48	.85	1.02	.44	.44
4	63.79	75.64	53.86	46.18	27.97	24.99	14.62	18.41	12.92	17.12	11.05	5.75	10.98	1.02	3.58
5	80.17	63.55	36.69	9.58	14.85	10.31	6.05	3.22	1.83	.73	.40	2.05	2.78	3.50	.50
6	89.33	85.81	38.06	25.43	13.02	6.36	3.51	9.19	8.54	1.41	4.08	3.39	3.60	9.15	.81
7	57.21	63.36	69.25	41.63	22.28	12.78	3.91	7.85	5.68	2.76	.81	.72	4.09	.57	8.13
8	49.15	59.77	35.24	29.00	20.84	17.15	10.85	5.90	10.83	4.16	3.59	4.21	3.27	.50	.63
9	65.74	64.94	66.54	39.57	35.94	29.21	16.54	12.65	10.65	8.09	13.33	3.44	7.46	2.82	3.69
10	63.01	61.18	84.88	64.20	50.83	40.50	23.55	32.62	15.43	25.87	16.04	13.50	19.16	4.44	3.15
11	58.96	67.66	64.05	37.48	9.80	12.49	19.83	12.99	4.34	8.01	2.69	.89	5.18	1.39	1.89
12	61.69	54.05	38.77	23.66	16.26	13.31	4.40	6.42	8.45	8.48	2.71	2.48	4.92	.63	2.70
13	90.92	57.68	39.94	12.02	5.03	12.79	8.25	1.44	2.13	1.63	2.49	2.42	1.71	2.13	2.29
14	74.37	53.24	45.04	47.50	34.44	11.58	12.52	3.04	6.86	4.15	2.64	2.91	2.23	2.55	2.17
15	42.69	70.15	54.25	82.56	63.01	35.92	60.80	17.48	14.93	8.16	4.26	9.80	7.13	3.30	2.86
16	74.02	64.86	32.99	29.76	16.18	7.56	4.68	6.07	4.14	2.74	2.38	2.31	2.47	2.78	2.47
17	36.18	70.19	85.12	62.14	26.05	24.50	16.65	4.60	6.87	2.22	4.70	2.76	3.24	2.82	2.31
18	65.63	77.31	64.16	40.27	47.28	27.00	13.24	5.51	8.70	2.11	2.42	2.75	2.03	2.16	2.44
19	53.52	65.73	77.15	52.15	35.34	29.87	18.89	15.03	4.67	2.92	6.77	3.76	5.92	7.67	10.74
20	66.39	57.50	62.91	42.88	25.75	25.96	6.43	16.69	5.99	5.56	4.36	2.25	6.93	3.12	3.28
21	55.30	64.62	43.82	23.78	17.12	21.52	9.89	12.13	6.78	3.52	4.60	4.92	6.63	9.76	6.50
22	60.74	45.99	39.41	38.70	30.51	16.88	10.94	9.58	10.29	8.11	4.67	5.56	4.37	10.59	11.41
23	50.95	57.63	35.01	23.98	10.19	3.65	2.61	3.20	3.93	4.06	3.72	4.69	4.44	4.29	5.01
24	52.73	67.34	38.70	46.70	26.67	13.38	12.10	7.62	10.13	6.94	6.61	4.60	4.18	4.50	5.28
25	65.21	48.97	71.76	40.12	23.58	17.40	3.18	3.81	3.63	3.83	4.38	3.92	4.15	4.00	4.93
26	60.49	87.32	62.99	57.17	49.54	36.84	17.02	13.58	8.29	5.53	3.96	4.04	4.43	4.20	4.95
27	70.09	58.40	45.91	24.28	23.70	16.02	9.48	11.45	13.38	15.35	6.71	4.08	5.30	4.84	5.27
28	58.60	54.72	44.60	27.60	12.54	8.85	4.43	3.22	3.08	4.25	3.81	4.27	5.94	4.10	6.04
29	74.27	62.82	31.17	21.36	11.11	2.20	6.40	2.53	3.18	4.07	3.72	3.47	4.31	4.71	10.10
30	47.44	56.79	52.26	46.97	40.52	52.42	37.93	41.35	42.75	31.20	12.22	27.32	18.75	21.09	13.45

TABLE V

Complex Coordination Test: Mean Number of Patterns Matched Per 4 Min. Trial Series

Subject	Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	16.25	22.00	24.50	29.75	32.50	35.75	37.75	40.25	43.50	43.00	44.75	46.50	46.00	46.50	47.50
2	17.00	23.75	29.00	32.00	34.50	40.50	38.50	40.00	45.75	49.50	49.75	53.00	54.75	52.75	54.50
3	18.00	22.50	26.50	33.25	38.50	43.25	41.00	42.25	45.50	43.75	50.00	50.25	53.00	50.75	51.75
4	8.00	18.50	25.50	27.00	28.50	30.00	30.50	31.50	34.00	38.50	38.50	35.25	39.50	37.50	39.00
5	11.50	18.50	26.50	32.50	35.75	32.50	41.75	43.25	43.50	45.50	45.00	48.25	49.50	47.50	51.75
6	20.00	23.75	28.00	34.25	39.50	41.50	43.75	43.00	42.00	45.75	48.75	51.50	53.00	53.25	59.00
7	18.00	23.25	28.50	34.25	37.00	39.75	44.75	43.75	46.00	48.25	46.25	50.75	50.25	48.75	45.75
8	20.50	24.75	32.50	40.00	42.00	45.25	46.75	51.00	49.50	52.25	51.75	54.25	54.25	55.25	56.50
9	12.00	15.75	21.75	26.25	28.50	31.25	36.25	35.75	37.00	41.00	44.00	44.75	47.50	45.25	49.75
10	11.00	14.25	19.50	20.25	23.50	27.75	29.00	31.00	32.50	33.25	34.50	37.00	36.25	37.00	40.25
11	13.50	18.00	21.00	22.00	26.50	25.25	27.00	27.75	29.25	31.25	31.25	36.50	37.75	37.50	40.75
12	16.50	21.75	24.75	28.50	31.00	35.00	37.75	38.00	40.75	39.00	42.50	40.25	39.50	40.50	44.75
13	15.00	17.75	24.00	29.00	31.50	34.50	41.50	39.50	40.00	44.00	48.00	45.75	48.50	49.00	48.00
14	17.00	22.00	27.25	28.50	34.25	36.25	36.25	37.50	42.50	42.25	40.25	46.00	44.25	47.25	46.50
15	13.00	19.00	22.00	24.25	25.75	29.25	29.50	35.50	33.25	37.75	37.50	37.00	39.25	41.25	42.50
16	14.50	22.75	28.75	33.00	39.50	42.75	43.75	46.00	48.50	53.25	52.75	55.00	56.00	53.25	58.50
17	11.50	16.00	19.25	22.00	22.50	26.00	27.75	30.25	33.50	35.25	36.75	39.25	39.00	40.25	40.25
18	10.00	13.75	17.75	22.00	25.00	29.25	31.25	35.25	33.75	38.25	39.50	40.50	41.00	42.50	43.50
19	11.50	15.50	17.25	24.25	27.00	31.25	33.25	34.25	37.25	40.50	40.00	42.25	40.50	42.75	40.75
20	8.50	18.00	23.75	32.00	33.25	38.00	40.00	40.75	40.25	41.00	44.50	44.75	41.75	44.25	43.00
21	15.50	20.25	28.50	30.00	32.25	37.25	37.50	40.75	43.25	45.25	47.25	48.25	46.50	48.25	52.00
22	16.00	19.50	25.75	29.75	36.75	40.00	39.50	41.50	40.00	42.25	46.50	46.50	44.50	43.00	45.25
23	20.50	26.50	30.00	36.75	38.75	39.50	43.50	44.50	46.75	49.50	51.25	52.75	53.50	55.00	60.00
24	15.00	21.50	27.00	33.00	37.50	37.00	41.50	40.50	40.25	45.00	41.00	47.00	45.75	43.00	48.50
25	14.50	19.75	19.75	23.25	24.50	31.00	34.25	37.50	39.00	40.25	41.75	42.25	43.50	45.00	49.25
26	14.50	22.50	25.75	33.25	38.00	39.50	44.25	47.25	45.75	46.50	52.75	49.75	54.50	55.75	57.25
27	10.50	15.00	18.00	18.75	19.25	25.25	25.75	27.75	28.25	33.50	35.25	37.25	36.50	35.25	39.00
28	16.00	20.50	25.75	27.25	32.75	34.50	36.50	37.00	38.25	41.75	41.00	42.00	41.50	41.00	45.00
29	21.00	25.25	31.00	30.75	31.50	36.00	40.50	42.25	47.50	41.75	49.25	49.75	50.00	52.50	53.75
30	14.00	22.50	27.00	29.25	34.25	36.50	37.00	36.25	36.75	38.50	39.25	37.75	42.25	39.75	40.50

TABLE VI

Complex Coordination Test: Standard Deviations of Number of Patterns Matched Per 30 Seconds

Subject	Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	.680	.718	.948	.772	.669	.842	.729	.822	.878	.907	.797	.738	.950	.931	.948
2	.619	.647	.871	.718	.738	.716	.931	.916	.772	.965	.751	.907	.846	.712	.975
3	.775	.693	.693	1.019	.738	.911	.793	.888	.896	1.015	.842	.683	.793	.827	1.047
4	.342	.535	.738	.833	.669	.718	.644	.669	.622	.644	.644	.798	.669	.821	.707
5	.512	.821	.780	.982	.718	.982	.870	.979	.948	1.030	1.184	1.032	1.119	.982	1.077
6	.730	.474	.672	.729	.619	.780	.879	.609	.762	.772	.777	.840	.751	.653	.907
7	.683	.564	.716	.581	.833	.861	.837	.842	.672	.861	.975	.787	.851	.689	.772
8	.512	.689	.801	.718	.762	.971	.847	.907	.780	.915	.718	.792	.906	.640	.840
9	.894	.740	.729	.683	.669	.689	.718	.761	1.040	.751	.842	.911	.716	.865	.941
10	.619	.608	.693	.761	.669	.671	.660	.707	.877	.808	.693	.907	.803	.871	.647
11	.479	.718	.660	.622	.644	.723	.833	.718	.745	.689	.856	.840	.772	.738	1.027
12	.442	.729	.640	.619	.660	.660	.729	.718	.817	.751	.738	.782	.669	.716	.946
13	.500	.553	1.073	.793	.669	.693	.859	.801	.879	.718	.568	.812	.914	.660	.916
14	.619	.762	.798	.759	.581	.803	.718	.821	.859	.813	.861	1.016	.761	.734	.780
15	.619	.751	.672	.595	.553	.745	.693	.914	.884	.683	.592	.907	.689	.767	.644
16	.981	.808	.837	.907	1.105	.787	1.047	.762	.669	.653	1.012	.976	.880	.865	.738
17	.512	.508	.615	.568	.821	.672	.842	.553	.780	.756	.665	.689	.751	.647	.695
18	.775	.634	.659	.718	.707	.865	.817	.911	.706	.906	.878	.878	.833	.592	.840
19	.629	.669	.723	.861	.833	.640	.767	.813	.602	.840	.718	.888	.619	.787	.777
20	.772	.718	.740	.916	.723	.842	.672	.893	.933	.942	.840	1.043	.906	.842	1.040
21	.574	.761	.504	.672	.695	.865	.896	1.027	.837	.827	.856	.967	.998	.967	.984
22	.817	.619	.792	.634	.756	.950	.564	.821	.880	.772	.644	.780	.914	.871	.865
23	.512	.859	.672	.911	.884	.716	.716	.669	.723	.965	.979	.797	1.203	1.040	.803
24	.500	.738	.907	.660	1.030	.871	.821	.878	.740	1.040	.871	.793	1.084	.833	.948
25	.750	.567	.621	.641	.669	.609	.684	.693	.793	.861	.608	.683	1.014	.751	.808
26	.544	.644	.792	.767	.718	.914	.915	.777	.772	.693	.797	.706	.693	.647	.628
27	.479	.554	.508	.545	.615	.677	.553	.621	.671	.693	.560	.745	.716	.665	.660
28	.516	.669	.608	.756	.641	.780	.716	.707	.659	.870	.871	.718	.859	.751	.707
29	.500	.574	.833	.628	.564	.718	.619	.772	.564	.706	.723	.706	.916	.914	.772
30	.683	.693	.888	.787	.813	.914	.793	.761	.665	.644	.588	.683	.851	.782	.716

TABLE VII

Complex Coordination Test: Standard Deviations of Number of Patterns Matched Per Trial

Sub-ject	Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	.641	.966	1.408	1.094	.957	1.123	1.094	1.436	.885	1.126	.834	.885	.966	1.148	1.360
2	.886	.772	1.183	1.033	1.025	.957	1.310	1.414	1.209	1.360	.964	1.238	1.250	1.167	1.438
3	1.414	.812	.719	1.448	.957	1.424	1.064	1.263	1.258	1.482	.894	1.094	1.238	.946	1.389
4	.707	.812	.957	1.000	.719	.894	.957	.885	.816	.957	.806	1.167	.957	1.204	1.000
5	.834	1.258	.885	1.360	1.062	1.628	1.153	1.515	1.544	1.784	1.770	1.389	1.628	1.500	1.769
6	.926	.574	1.033	1.263	.885	1.360	1.236	.577	1.095	1.209	.981	1.310	1.673	.793	1.571
7	1.069	.812	.957	.814	1.064	1.289	1.109	.854	.816	.854	.964	1.195	1.094	1.109	.892
8	.354	.911	1.204	1.033	1.033	1.448	1.078	1.238	.957	1.482	1.182	.964	1.548	.981	1.204
9	1.414	.929	1.031	1.031	.806	.981	.772	1.062	1.291	1.000	1.095	1.470	1.204	1.195	1.590
10	.886	1.031	.885	.854	.885	.929	.774	.774	1.088	.946	.806	1.183	1.062	1.390	.929
11	.517	1.154	1.000	1.033	.957	.834	.931	.929	.873	.750	1.424	1.258	1.094	.957	1.515
12	.641	.814	.834	1.025	1.064	.931	.892	1.095	1.276	1.000	.957	1.182	.806	1.025	1.276
13	.707	.814	1.852	1.438	1.088	.957	1.025	.719	1.154	.966	.816	1.413	1.360	.856	1.095
14	.886	.966	1.223	.957	.964	1.236	.998	1.360	1.148	1.031	1.340	1.265	.998	1.047	1.310
15	.463	1.342	.816	.854	.727	1.014	.957	1.544	1.250	.892	.806	1.238	1.047	1.138	.957
16	1.408	1.138	1.109	1.238	1.455	.946	1.123	.966	.957	.793	1.558	1.612	1.316	1.302	1.204
17	.354	.730	.911	.816	1.455	.632	1.340	.814	.885	1.167	1.047	.750	1.000	.680	.772
18	.926	.727	.964	.966	1.000	1.250	1.167	1.424	1.153	1.094	1.148	1.148	1.183	.719	1.148
19	.834	.500	1.078	1.123	.931	.981	.946	.964	.793	1.310	.966	1.153	.806	1.138	.834
20	.834	.894	1.236	1.549	1.078	1.265	.894	1.167	1.289	1.291	1.258	1.424	1.209	.998	1.653
21	.991	1.289	.619	.894	.929	1.302	1.204	1.558	1.167	1.195	1.327	1.436	1.746	1.526	1.366
22	1.069	.719	1.153	.814	1.327	1.460	.806	1.310	1.366	.727	.885	1.025	1.500	1.483	1.250
23	.834	1.310	.894	1.424	1.195	.885	.806	.885	.946	1.204	1.327	1.276	1.928	1.126	1.033
24	.707	1.360	1.000	.856	1.258	1.183	1.204	1.148	1.123	1.527	1.483	1.238	1.364	1.291	1.148
25	1.188	.680	.772	.834	.885	1.000	.727	.500	1.183	1.182	.814	.814	1.628	.774	1.138
26	.517	.957	.964	.793	.894	1.025	.998	1.223	1.153	.719	1.276	.964	.885	.998	.873
27	.517	.774	.632	.602	.750	1.078	.727	1.062	1.236	.957	.911	1.195	1.025	.981	1.000
28	1.069	.885	.727	1.047	.750	1.204	.957	.856	.629	.814	1.126	.894	1.455	1.064	.856
29	.463	.602	1.238	.793	.806	1.154	.719	1.094	.885	.964	1.078	.892	1.316	1.360	.892
30	1.195	1.204	1.094	1.078	1.153	1.148	1.183	1.236	.750	1.088	.911	1.031	1.209	.998	.806