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39

Learning Parameters and Human Abilities

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LEARNING PARAMETERS AND HUMAN ABILITIES

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Abstract

The purpose of this study was to explore the interrelationships among learning parameters and also the interrelationships between learning parameters and measures of human abilities. Thirteen learning situations were devised to evaluate possible psychological organizations within a domain of human learning. The subject's performance on each learning task was expressed by a rate parameter which described the average rate of learning, a curvature parameter which indicated whether the learning was faster during the first or second half of the situation, and an initial ability parameter. Thirty-nine reference measures of aptitude and achievement were used to assess potential relationships between human abilities and learning. The study was conducted at a U. S. Naval Training Center and included 315 enlisted men.

Two factor analytic techniques were employed to organize the interrelationships of the variables into more meaningful dimensions based upon common factor variances. The first technique was a conventional multiple-factor analysis of the intercorrelation matrix for the 28 learning parameters. The final rotated factor matrix of learning parameters produced seven learning parameter factors which were interpreted, and five factors which were discarded because of specificity or idiosyncratic factor loadings. Three rote learning factors were found. Two of the rote learning factors were defined in terms of the rate parameters and the curvature parameters and were independent

of the content or sensory modality involved. The third rote learning factor was obtained from the rate parameters for situations involving the learning of simple spatial material. The remaining four factors included Verbal Conceptual Learning, Spatial Conceptual Learning, Mechanical-Motor Learning, and "Early versus Late" Learning.

The second factor analytic technique was Tucker's inter-battery method which determined the number of factors in common between the learning parameters and the reference measures. This method yielded seven factors by which inter-battery learning parameter factors could be expressed as functions of the inter-battery reference factors, or vice versa. Four of the seven inter-battery factors were relatively clearly defined and were as follows:

1. Conceptual Process Factor. An inter-battery factor in which the process of thinking or conceptualization was dominant.

2. Rote Process Factor. An inter-battery factor in which a rote memory process was required.

3. Mechanical Factor. An inter-battery factor primarily found in activities which utilized mechanical principles. This factor also had a subtle dependency upon conceptual processes.

4. Psychomotor Coordination Factor. An inter-battery factor for tasks which involved precision and speed of arm, wrist, and finger movements.

From the specific findings, two general conclusions were drawn from the project. First, the factorial organization of the learning parameters was multidimensional. Therefore learning, within the limits of this investigation, was not a unitary trait or ability but contained

several factors which were dependent upon the psychological process involved in the learning task and the content of the material to be learned. And second, measures of learning and measures of aptitude and achievement, which have generally been treated experimentally as separate entities, have factors in common with each other. These factors were dependent upon the similarity of the psychological processes and the contents of the materials involved in the various learning tasks or reference variables. Thus, the ability to apply knowledge and the acquisition of knowledge have highly similar or identical properties.

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It is not possible to convey completely the contribution Dr. Ledyard R Tucker has made to this project. It should be apparent to the reader that the major value of this study resulted from techniques which he has developed. What will not be readily apparent are the subtle influences his teaching has had upon the writer. Only another student of his would be able to sense his influence on each page of this report.

Table of Contents

List of Tables

CHAPTER I

LEARNING AND HUMAN ABILITY

A. Introduction

Learning and human ability are common topics in psychology. Traditionally, however, they have seldom been conceptualized or investigated within the same theoretical system. Studies of learning have tended to be associated with the experimental psychologist who works with group data within an analysis of variance design. By comparison, studies of human ability have generally been based upon correlational and factor analytic approaches to individual differences and conducted by the differential psychologist. Ironically these two important concepts in psychology have lost their similarity and have been investigated separately. For example, with the finding that intelligence consists of a number of human abilities has also come the disappearance of the once-popular definition of intelligence as the ability to learn. However, measures of human abilities are employed to predict future behaviors, such as scholastic performance. On the other hand, students of learning have frequently experimented with conditions and variations which influence learning but have not been concerned with the possibility that a subject may or may not be equally good in learning something different. Certainly, experience in education has led to a conclusion that students learn different subjects at different rates. Although important advances have been made in both learning and human ability, the major aim of this project will be to investigate the interrelationships between learning and human ability when they are conceptualized within the same framework.

Historically, the present study of learning and human ability began with a suggestion made by Frederiksen, Carstater, and Stuit (1947, p. 437) that scores derived from miniature learning situations might be used to estimate performances in future learning situations. The use of miniature learning situations is analogous to the use of work sample tests for selecting personnel in industry in which, for example, an applicant lathe operator is given a brief performance test requiring the proper operation of a lathe and his performance is then used to estimate his proficiency on the job. An example which is more germane to learning is the U. S. Navy Radio Code Aptitute Test in which candidates learned several characters during a training period and were tested on their proficiency with them. Basically, Frederiksen, Carstater, and Stuit thought that a student's final grade in a course might be predictable from how well the student learned similar concepts and principles which might be taught in an hour's period of time before the course. In fact, many of the measures currently employed to predict accomplishments could be considered as learning measures (i.e., high school grade-point average to predict college grade-point average, premedical school grade-point average to predict medical school grade-point average, technical course grades to predict more advanced course grades, etc.). Although such examples are not miniature learning situations, they can serve as prototypes for new areas in which the prerequisite learning skills are not known.

The Breech Block Performance Test was developed to evaluate the proposal of Frederiksen, Carstater, and Stuit. This test is part of a controlled learning situation in which subjects are taught how to assemble the breech block of a 40 mm. antiaircraft gun. The subjects view a two-minute

sound film which describes the step-by-step assembly of the breech block, and are then given a three-minute trial on the assembly task. The training film-assembly task sequence is repeated several times which thus permits various types of learning scores to be analyzed. In studies at U. S. Naval Training Schools in which mechanical-motor skills were taught, Allison (1954, 1956a) demonstrated that measures of learning were related to measures of success in the respective schools. Furthermore, when such measures were combined with scores from the Navy Basic Test Battery better predictions of success resulted than were obtained from the Navy Basic Test Battery alone. Since these studies were conducted with subjects who had already been selected for training, the correlations between the learning scores and scores from the Navy Basic Test Battery, especially tests used for selection, were reduced.. Data obtained in another study (Allison, 1956b) with an unselected group of enlisted personnel indicated that the learning scores from the Breech Block Performance Test correlate with scores from the General Classification Test, the Arithmetic Test, and the Mechanical Test, all from the Navy Basic Test Battery. The highest correlation was between the learning scores and scores on the Mechanical Test. The implications of these studies were (1) learning measures derived from miniature learning situations can predict achievement in subsequent learning situations, and (2) learning measures are also related to measures of other human abilities.

The above studies imply questions which have been asked by previous investigators and underlie the present investigation: What is the nature of human learning? Is learning a general ability transcending tasks or a specific ability related to each task? Are there a number of learning

abilities and, if so, what are their determining characteristics? What is the relationship between learning and human ability?

B. Learning and Psychology

As one discusses learning with all its ramifications, learning shades into what someone else would characterize as thinking, and others as perceiving. Actually the three terms are members of a triad of delicately interlaced mental functions which have been identified as the cognitive processes. The experimental study of the cognitive processes is, however, indirect and inferential. Some experimental control is possible at the input phase of human behavior and certain consequences of mental activities may be observed at the output phase. But the operations and mechanisms of transmission which exist between the two stages remain essentially unknown. The problem is analogous to Poincare's wheel example (Ahmavaara, 1957; Cohen & Nagel, 1934, 1951) where one has a gear box which has the initial and final gears visible but the inner parts are hidden. The investigator may either speculate what the nature of the inner mechanisms is and then deduce behavior which would follow under those circumstances, or ignore the inner mechanisms and seek laws which allow the output to be expressed as a function of the input. Psychologists have often sought to discover subsets of stimuli which lead to similar consequences and, when present, have inferred that the intervening operations and mechanisms have functional congruency--that is, the mental activity is either the same or comparable. The experimental economy of such a finding or inference is that any member of the class of stimuli evoking similar behavior

may be substituted for the entire class. This statement is consistent, albeit metaphorical, with an underlying purpose and use of factor analysis. For example, those tests which have been found to be relatively pure measures of some ability may be used interchangeably if they contain the same amount of the given ability. Ahmavaara (1957, p. 17) refers to factor theory as "the only unified attempt at an abstractive theory of mind"; however, let us say that it does appear that psychology and one of its major tools are becoming increasingly preoccupied with the mediating stage of behavior, or, at least, that the clear-cut distinction between stimulus and response is losing its clarity.

The definition of learning to be adopted in this study is a general one patterned after many authors. According to Newman (1951, p. 392), "learning has to do with changes in our experience and in our behavior as a result of an earlier response in a similar situation." Gulliksen (1951) stated: "Broadly speaking, learning is present whenever there is any relatively permanent change in an organism's behaviour which is the result of its reaction to environmental influences." He further specified that the change should be sufficiently permanent to distinguish it from temporary changes such as sensory adaptation or fatigue and "warm up" phenomena, and also that the change should be a result of the organism's reaction to environmental influences such that learning can be distinguished from maturation or growth. For Ferguson (1954), learning refers to "changes" in "ability" to perform a specified task as a result of practice, with qualifications similar to Gulliksen.

For our purposes, learning is defined as a process inferred from behavior which is influenced by previous behavior and is distinguishable

from those behavioral changes attributable to fatigue, accommodation, maturation, and the like. As operationally used, when an individual's performance on a task changes with practice and with knowledge of his results, learning is presumed to have taken place and to have constituted the basis for the modification. By inference, characteristics or parameters which describe his performance are associated with and descriptive of the learning process. Three parameters (See Chapter III) are considered in this study to summarize an individual's performance on a learning task. The parameters consist of c_0, which represents the initial level of achievement prior to learning; c_1, which represents the average rate of learning; and c_2, which indicates whether the subject was learning faster during the first half or second half of the learning task.

C. Purpose and Rationale

The purpose of this research is to explore the interrelationships among learning parameters derived from several different learning tasks. It will be proposed that a number of learning abilities exist and can be obtained by factor analytic techniques. Questions will be raised to determine whether these abilities, or factors, are defined on the basis of the psychological processes involved, the content of the material to be learned, or by some other principle. Also, if learning factors are found, the relationships between learning abilities and existing measures of human abilities will be investigated.

The rationale for the study stemmed more from the field of human abilities than from existing learning theories. A brief historical

review may be helpful to clarify the writer's perspective. Ebbinghaus (1885) provided not only the impetus for studies of learning, memory, retention, and forgetting but also the method of plotting performance across time to assess learning. Thorndike (1898) by his Law of Effect emphasized the importance that knowledge of results has upon an individual's learning. Galton (1889) pioneered the statistical study of individual differences and developed the concept of correlation as a measure of the relationship between two variables. Binet (1903; Varon, 1936) elevated intelligence and specifically the measurement of intelligence to the cardinal issue in psychology. His concept of intelligence was a global one by today's standard and represented the combined effects of attention, reasoning, imagination, and judgment.. Spearman (1923, 1929), by his findings that mental activities tended to be correlated positively with each other, concluded that the correlations originated from a common source: intelligence. Thurstone (1932) introduced the technique of multiple factor analysis which extended and fractionated Spearman's concept into a number of human abilities or traits. The concept of intelligence has consequently undergone changes and is currently thought to be a composite of many identifiable human abilities. The problem of extracting and describing the operation of a general factor in factor analytic studies has been presented by Tucker (1940). He pointed out that a factor analysis of an intercorrelation matrix may result in a general factor and independent group factors but that the general factor may not be obtained when the criterion of simple structure is applied to the rotational phase. He also described a second possibility for obtaining a general factor in which the general factor may appear when matrices of higher order are factor analyzed (i.e., a matrix of correlated factors).

It seems that a general trend in psychometrics has been to postulate or uncover a global concept and to decompose the global concept later into more molecular components. The later investigations have in no way refuted the observations made earlier; in Spearman's case, it is still true that an individual who earns a high score on one intellectual task tends to earn a high score on a second intellectual task. What subsequent investigators have shown is simply that similar intellectual tasks tend to form clusters which are recognizably distinct from other clusters. Today, within the domain of intelligence, may be found such clusters as verbal ability, number ability, perceptual speed of closure, memory, and many others (see French, 1951). If the implication is accepted that intelligence is the ability to learn (McGeoch, 1942; Piaget, 1947), then it is plausible to ask if learning is likewise multidimensional and not a unitary trait.

The following thesis is advanced as a hypothetical structure which encompasses both learning and human ability. Human abilities in adults usually represent those descriptive characteristics of an individual which do not change with the passage of time. For example, the intellectual-type abilities summarized by French (1951) are relatively stable. However, developmental studies of abilities (Garrett, 1946; and implicit in Piaget's writings (1947)) would suggest that intellectual traits are far less stable and sometimes nonexistent at the pre-adult levels (i.e., traits of the five-year-old versus the ten-year-old, the fifteen-year-old, etc.) Many investigators suspect that personality traits, both at the pre-adult and adult levels,

may vary from time to time depending, of course, upon what happens to the people during the interim. Consider for a moment one of the better known and stable abilities--verbal ability--which is defined generally in terms of the level of one's vocabulary. From our own experiences, vocabulary level seems to increase as one grows up, to stabilize at some level for many years, and perhaps to decline slightly with advancing years. As such, the developmental course of verbal ability may be conceptualized as a learning curve in essentially the same way Ebbinghaus (1885) plotted performance against time. If human abilities are related to learning curves and are to have the property of being relatively stable, then they could be conveniently expressed as the asymptotes of learning curves. Human abilities are thus postulated as descriptive parameters of learning processes. The relationship between learning and human ability has also been discussed by Ferguson (1954). He proposed a theory which essentially treats human learning as one of man's abilities, which is obviously both similar and different to the unifying principle advocated here.

If human abilities are considered to be descriptive parameters of learning processes, one may be tempted to conclude that individual differences in abilities arise solely because individuals have reached different stages in learning. There are additional factors, however, that contribute to individual differences in human abilities, as well as learning. Some factors--for want of a better generic term--might be labelled physiological factors. For example, physical characteristics of the body would place limiting values upon various psychomotor abilities; differences in brain structure and metabolism may also account in part for

individual differences in learning. Still other factors, such as motivation and opportunity, undoubtedly contribute to individual differences in human abilities and learning.

D. Functional Organization of Learning and Human Ability

The results of factor analytic studies are often described in terms of characteristics of the tests used to investigate behavior, with no particular emphasis placed upon cortical or sub-cortical functions. Ferguson (1954, p. 95) apparently criticized this position when he pointed out that early factor analysts, namely, Spearman and Thomson, were concerned with brain functioning but that factor analysts are not currently seeking "to correlate the descriptive parameters of behavior... with any structural or dynamic properties of a brain model." That factor analysts are heading in this direction seems apparent. Guilford (1956, p. 287), after extensive factor analytic investigations, states "...although psychological factors are variables among individual differences they also indicate psychological functions within individuals." And French (1951, p. 1) refers to "the effectiveness of the method of factor analysis for studying the mind" and that "each factor analysis can explore only a relatively small aspect of the mind." The definitions of factors collected by French (1951) are not only made on the basis of test characteristics but also contain higher order inferences regarding mental functions.

The day may not be far away when the functional organization of learning and human ability may lend itself to correlates of brain functioning. Consider two disparate investigations which provide an obvious but speculative similarity. Fleishman and Hempel (1954b)

studied the factorial structure of a psychomotor task, the Complex Coordination Test, in which a subject learns to manipulate an airplane type stick and rudder in response to visual patterns. They concluded that "non-motor" factors (i.e., Spatial Relations, Visualization, and Mechanical Experience) play an important role during the earlier stages of practice but become increasingly less important during the later stages. On the other hand, they found that certain "motor" factors (i.e., Psychomotor Coordination and Rate of Movement) increase in importance with practice. Beck, Doty, and Kooi (1958) studied the electro-cortical reactions of cats associated with a conditioned flexion reflex and reported that the relative frequency of electroencephalographic responses were greater during the earlier training sessions than conditioned flexion responses but reversed during the latter sessions. The similarity between these studies--one a factorial study involving humans, the other a neurophysiological study with animals--supports the belief that factor analytic findings may relate to brain functioning. Confirmation studies that psychological factors relate to brain activity however still reside in the future. For example, Tikofsky (1957) in a recent factor study of the intercorrelations among psychological test scores and electroencephalogram variables found 14 factors which accounted for his correlation matrix of order 49 x 49. Nine of the 14 factors were either specific or doublet factors and interpretation was therefore not attempted. The five interpreted factors were defined either by psychological tests or by EEG variables but not by both domains. His study suffered by virtue of the experimental dependency which existed among psychological

and EEG variables which, incidentally, could have been overcome by applying Tucker's method of factor analysis (1958b).

Although studies similar to Tikofsky may be methodologically and theoretically premature, it is the writer's belief that psychology should attempt to organize human abilities in such a way that they may be related later to brain functioning (i.e., rates of learning to be correlated with frequencies of EEG responses). If this is done, it is further believed that the psychological functions involved in a task should be more important than the specific characteristics of the task and would have a greater likelihood for neurophysiological correlates.

This study therefore seeks to provide experimental support that human learning is organized in terms of the psychological processes which are involved. It is postulated that the following three major learning processes exist and are recognizably distinct by factor analytic techniques.

Rote Learning. The rote learning process is represented by the classic associational process which is concerned with the forming and strengthening of connections between a stimulus situation and a behavioral response (Katona, 1940). In this process each stimulus is to be associated with a specific response; both the stimulus situation and the behavioral response exist in the experience repertoire of the individual but the particular stimulus-response bond is unique. It is conceptualized that the number of bonds form a one-to-one correspondence with the number of stimulus-response associations. Thus, if n paired-associates are to be learned there are, in a sense, n rules to learn. Traditional paired-associates tasks are excellent examples of the rote learning process.

Conceptual Learning. The conceptual learning process involves the determination of the common or similar elements of complex stimulus situations before a connection can be made between the common elements and the behavioral response. It could be thought of as an iterative process which requires the formation of a hypothesis regarding the common elements and then verification of the hypothesis by determining whether the response is appropriate. If not, a modified hypothesis is developed and tested, ans so on, until the desired response is given. Experimentally, one way of investigating conceptual learning is through concept formation tasks in which a subject has to discover rules by which various things are assigned to several categories. In its most general form the conceptual learning process probably links together common elements of a stimulus-complex and response-complex. For example, when placed in a complex social situation with freedom to behave in many different ways, one learns that if his behavior is to be acceptable then it needs to contain a common element which has connections with the homogeneous characteristics of the social situation. The more subtle the common elements are, the more difficult the learning.

Conceptual learning appears to be the same type of learning summarized by Harlow (1936, p. 484) as conceptual learning, symbolic formulation, or inventive learning.

Motor Learning. The motor learning process is concerned with the associations between the stimulus conditions and overt motor responses which are not primarily verbal responses. McGeoch and Irion (1952) defined this process as perceptual-motor learning. Tracking operations

involved in the Rotary Pursuit Task are illustrative of motor learning. Assembly tasks require motor learning to some extent but undoubtedly contain rote learning and conceptual learning aspects, especially in the earlier stages. In its relatively pure form, motor learning appears to be primarily the acquisition of manipulative proficiency.

The above conceptualizations may imply preference to association theories of learning. This is not necessary and with appropriate changes in wording they could be presented in terms of cognitive reorganization. Neither were the descriptions intended to imply a neurophysiological basis for learning.

The above postulated organization is only one of several ways in which learning may be organized. An alternative organization is that the factorial structure of learning will be defined in terms of the 40 or more traits outlined by French (1951). More specifically, the following three factors are expected to account for most of the interrelationships among learning measures if this alternative is to be accepted.

Factor V: Verbal Knowledge. This is one of the best identified factors involved in human ability. It has also been labeled Verbal Comprehension and Verbal Ability. It is defined as an ability embodying the knowledge and understanding of the English language. Since similar factors have been found in studies with native speakers of other languages, the Verbal Comprehension factor might be generalized in definition to be a factor of general language knowledge and comprehension. Tests such as vocabulary, verbal analogies, and sentence completion correlate highly with this factor.

Factors S and V: Spatial Visualization. Spatial Visualization is actually a composite factor but will be treated here as one factor due to the overlapping nature of Factors S and V. Factor S, which has been identified as Spatial Relations and Orientation, is defined as the ability to comprehend the nature of the arrangement of elements within a visual stimulus pattern primarily with reference to the location of the subject. Factor Vz, identified as Visualization, is defined as the ability to perform mental manipulations of visual images. This ability is required in the solution of problems which involve a specified sequence of mental movements of objects appearing within a more or less complex stimulus pattern. Tests representing Factors S and Vs are described in Chapter II.

Factor Mk: Mechanical Knowledge. This ability is defined as knowledge of mechanical principles, devices, and tools which is acquired through training and experience. Tests which correlate highly with this factor require the subject to select the proper tool for a given use or to perceive visually the mechanical details of a problem situation and to apply various physical principles to arrive at a solution.

Although the nature of human learning may also be structured by the sensory modalities which are involved, this study is limited to the above alternative formulations. The general procedure of factor analytic investigations will be adopted. A series of learning tasks will be constructed which represent both the postulated psychological processes and known factors which have been described. The learning tasks as well as reference tests are described in Chapter II. The basic question being

raised by this study is whether the postulated factors will appear factorially as distinct traits or whether the learning parameters will be absorbed by existing human abilities. It is also possible that factors will be found which combine the learning processes with known factors (e.g., a verbal conceptual learning factor).

E. Review of Some Pertinent Experiments

Typical of correlational studies which have been conducted with learning measures are Pyle (1919), Peterson (1920), Garrison (1928), Dickenson (1941), and Allison (1954, 1956a). These studies have shown that learning measures, which vary in degree of crudeness, were related to intelligence scores, other test scores, or scholastic performance. Such studies offered little clarification of the dimensionality of learning or the relationships with aptitude and achievement measures. Until recently factor analytic studies of learning have in general suggested that learning is not a general trait but have not clarified the issue further. Illustrative of such studies are Perl (1934), Edgerton and Valentine (1935), Woodrow (1938, 1946), and Roff, Payne, and Moore (1954). Some reasons for the lack of studies which bring learning and human abilities together are offered by Ferguson (1954, p. 95) who states: "Those concerned with the description and classification of man's abilities have usually adopted an individual difference approach. They have paid scant attention to problems of learning. The experimentalists, engrossed in the study of learning, have for various theoretical and practical reasons shown little interest in individual

differences. They seem unaware that they too are students of man's abilities." Cronbach (1957) gave a similar analysis.

One of the pioneers in the joint effort of synthesizing learning and human abilities was Woodrow. After many investigations, Woodrow (1946) concluded that learning ability, defined as the amount of gain between initial measures and final measures, was not related to intelligence measures although initial and final measures may themselves be so related. He further doubts the existence of a unitary ability to learn. His statement that achievement manifested on a test performance was due in part to heredity as well as learning is compatible with Burt's recent attempt (1958) to provide a factor analytic explanation for the inheritance of mental abilities.

The work of Fleishman and Hempel (1954a, 1954b), Hempel and Fleishman (1954) and Fleishman (1953, 1954) is basic to the field of psychomotor performance for two reasons. First, they have shown how these performances are organized factorially, and second they have shown that different abilities are utilized at different stages of practice on specific psychomotor tasks.

Because of the probable relationship between memory and learning, Kelley's study (1954) of memory bears summarizing. He found that memory, which he defined in terms of immediate intentional retention, was not a unitary trait but contained at least three factors: (1) Rote Memory, which is the ability to recall learned, meaningless material; (2) Meaningful Memory, which is the ability to recall learned, meaningful material; and (3) Span Memory, which is the ability to recall perfectly a series

of unrelated items after only one presentation of the series. His findings would suggest that the rote learning process postulated in the present study may split factorially into more than one dimension. Kelley also found that the memory factors were observed in tasks presented by visual and auditory means and tended to transcend the content of the material. These interpretations would support the hypothesis of the present study that some learning abilities will be defined in terms of their psychological functions (i.e., rote learning, conceptual learning, and motor learning).

Further support that learning is multidimensional was found by Stake (1958) when he factor analyzed an intercorrelation matrix generated from learning parameters for 12 learning tasks, and various aptitude and achievement measures. His study, incidentally, was probably the first detailed inquiry based upon the rational learning function suggested by Gulliksen (1934). From his analysis Stake defined four learning factors. Two factors were interpreted as rote learning factors which, oddly enough, were independent of the rote memory factor identified by the reference tests. Another factor was found for learning tasks which require the use of numbers. A fourth factor, which involved a goodness of fit parameter, was interpreted as a concentration factor. His rote learning factor was not "fundamentally different" from a postulated relational learning dimension. Inasmuch as his relational learning concept would involve psychological processes which the present study considers to be conceptual learning, his analysis would suggest that conceptual learning would not emerge as a separate factor. Stake also found that when the incentive to learn was varied the relative positions of the subjects' performances remained essentially invariant.

Guilford (1956, 1958) recently formulated "the structure of the intellect" in a fashion which directly supports the psychological processes postulated herein. He presented several schemata for organizing the 40 or more abilities which have been noted earlier. In general, he reduced the identified factors into three groups: those factors which involved rote memory, those factors in which thinking (discovery) is required, and those factors which contain psychomotor elements. Guilford also credited Burt (1949) with an independent but similar organization of the memory and thinking factors.

F. Summary

This chapter has described the history and thinking behind the project. Human abilities in adults were considered to be parameters of learning abilities. One method by which human learning may be organized was presented in which three psychological processes would account for different types of learning. A more conventional organization in terms of existing factors was offered as an alternative. Ferguson provided theoretical support for the conceptualization of learning and human ability. Guilford organized human abilities into a schema similar to the postulated dimensions of learning. Experimental studies were cited which support the view that learning is not a unitary trait and, to a lesser extent, that learning may be organized by process, by known factors, or a combination of these two possibilities.

The basic problems which will be explored by factor analytic techniques are:

1. What are the principles by which learning parameters are organized?
2. What relationship exists between the learning domain and the human ability domain?

CHAPTER II

DESCRIPTION OF THE VARIABLES

A. Descriptions of the Learning Tasks

The selection or development of learning tasks to investigate the interrelationships among the learning parameters occupied a paramount position in this project. The basic problem was to find learning tasks which on an a priori basis could help to clarify whether human learning was organized in terms of the postulated psychological processes or existing human abilities.

Eleven of the 13 learning tasks were constructed specifically for the study and were pretested on high school subjects and Naval recruits to establish adequate levels of difficulty. The remaining two learning tasks were the Breech Block Performance Test which was developed previously for use in a series of research studies (Allison, 1954; Allison, 1956a; Allison,1956b) and the Rotary Pursuit Test which was used by permission of the U. S. Air Force.

The learning tasks utilized immediate knowledge of results as the major motivational force and reward. The standard procedure for administering six of the learning tasks, which were presented by 35 mm. black-and-white slides, was to project a stimulus slide using a Revere 888 automatic projector set for seven-second exposure during which time the subject committed himself to a response; and, following a three-second period to change slides, a slide containing both the stimulus and the correct response was projected for seven seconds during which time the subject marked his response right or wrong. After another three-second

change-over period, the next stimulus slide appeared and the procedure continued until a trial was finished. The subject recorded the number of rights and wrongs for the trial and the next trial began. A similar procedure was used for the Knob Code which was presented tactilely and the Sonar Test which was presented auditorily--namely, a stimulus was presented and subject committed himself to a response and was then informed as to the correct response. In the case of the CIC Plotting Test and the Sidewalk Maze, knowledge of results was made available after each trial. The nature of the Rotary Pursuit Test and the two assembly tests enabled a subject at all times to know how well he was performing. Since the learning tasks were administered on a group basis, the subjects tended to compete with each other even though no attempt was made to indicate how well other members of any group were performing.

The descriptions of the learning tasks follow. Samples of those tasks which lend themselves to printed means appear in Appendix A, which also contains the directions for the learning tasks. The numbers preceding each task are the code numbers of the learning parameters associated with each task. As mentioned in Chapter I, the learning parameters are c_1 (average rate of learning), c_2 (early versus late learning), and where appropriate c_0 (initial ability). The learning parameters and method for computing them are presented in Chapter III.

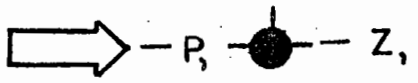
01 (c_1) and 14 (c_2). Word Code.

Description: Sixteen word-letter pairs, such as DESTROYER - K, ACTION - I, STATIONS - E. The words were selected on the basis of familiarity to a recruit; the letters were selected in order to

minimize misrecognition. Presented by 35 mm. slides as follows: A slide with a stimulus word (DESTROYER) is projected on a screen for seven seconds during which time the subject indicates which response letter he thinks belongs to the stimulus. Following a three-second period to change slides the stimulus word and correct response (DESTROYER - K) are projected for seven seconds which allows ample time for the subject to indicate whether his response is right or wrong. After a three-second delay the second stimulus slide is projected, followed by the appropriate stimulus-response slide. And so on through 16 sets of word-letter pairs per trial. The same word-letter pairs are presented for Trial 2 and succeeding trials with the order of presentation being randomized for each trial.

Number of trials: 9

02 (c_1) and 15 (c_2). Spatial Code.

Description: Sixteen symbol-letter pairs, such as 

C — I. The symbols are standard symbols used by the U. S. Army for reading maps. Presented by 35 mm. black-and-white slides as described above.

Number of trials: 10

03 (c_1) and 16 (c_2). Knob Code.

Description: Eight knob-word pairs, such as polygonal-shaped glass knob--AIR, round wooden knob--HEAT, elliptical-shaped, grooved metal knob--WATER. The knobs were the standard household types used on drawers and cabinets. The subject feels a knob located inside a box so constructed as to prevent visual recognition and then indicates on an answer sheet which name he believes to be correct. He next uncovers

the correct answer located on top of the box and marks his answer right or wrong. He then moves to the next station and repeats the procedure for eight knob-word pairs. The order of presentation is randomized for each trial.

Number of trials: 8

04 (c_1) and 17 (c_2). Sonar.

Description: Twelve sound-word pairs, such as associated with underwater sounds made by drumfish, iceberg, submarine, torpedo, etc. The sounds were obtained from recordings made by the U. S. Navy and used by permission. Presented by tape recording with a 10-second delay between each 10-second sound and identification which allowed the subject time to make a response. Order of presentation is randomized for each trial.

Number of trials: 10

05 (c_1) and 18 (c_2). Verbal Concept Formation I.

Description: Consists of 16 sets of four words with each set being assigned to one of the code letters A, B, C, or D. Four sets of words belong to each letter; the code letter represents an underlying concept. Concept A is that one of the four words is a number; concept B is that one of the four words is a sport; concept C is that two of the four words are homonyms; concept D is that all four words are units of measurement. The subjects are not required to identify the concepts except by the code letter. Inasmuch as the same 16 sets of words are presented each trial, although randomized in order of presentation, the subject may learn the correct code letters by either

conceptual learning or rote learning. (Informal inquiry later suggested that most subjects found it easier to discover the underlying concept than to apply a rote learning approach.) Presented by 35 mm. black-and-white slides as described above.

Number of trials: 8

06 (c_1) and 19 (c_2). Spatial Concept Formation I.

Description: Consists of 16 sets of four, two- and three-dimensional figures with each set being assigned to one of the code letters A, B, C, or D. Four sets of figures belong to each letter; the code letter represents an underlying concept. Concept A is that two of the figures are solids and the other two figures are the vertical two-dimensional projections of them; concept B is that one of the four figures is a circle; concept C is that all four figures could represent three-dimensional objects; concept D is that one of the four figures has a three-pronged, saw-like edge. The same but randomized series of slides is presented each trial and consequently the subject may learn either by a rote learning or a conceptual learning approach. This task parallels closely Verbal Concept Formation I except for stimulus content. Presented by 35 mm. black-and-white slides as described above.

Number of trials: 8

07 (c_1) and 20 (c_2). Breech Block Performance Test.

Description: This test is part of a controlled learning situation in which the subject is taught how to assemble the breech block of a 40 mm. antiaircraft gun. The subject views a two-minute sound film describing the step-by-step assembly of the breech block, and is then

given a three-minute trial on the assembly task. The training film-assembly task sequence is repeated six times. The assembly operations consist of a total of nine steps. The number of steps completed constitutes the score for a given trial.

Number of trials: 6

08 (c_1) and 21 (c_2). CIC Plotting Test.

Description: A highly simplified version of the plotting activities carried out by a Combat Information Center aboard a ship. For each trial the subject indicates on a modified polar-coordinate-paper grid the positions of 20 objects whose bearings and ranges are presented by a tape recording. The bearings and ranges of the objects vary for each trial. Essentially, the task is one of learning how to plot on polar-coordinate grids. By using carbon paper and a second grid with circles for the correct locations underneath the original the subject can count the number of correct marks after each trial.

Number of trials: 10

09 (c_1) and 22 (c_2). Verbal Concept Formation II.

Description: Consists of 16 sets of four words with each set assigned to one of the code letters A, B, C, or D. Four sets of words belong to each letter; the code letter represents an underlying concept. Concept A is that the four words constitute a message; concept B is that two words are synonyms and the other two words are antonyms; concept C is that all four words are objects; concept D is that one of the four words is a weapon. The four concepts are invariant across trials but the word sets are replaced in each trial with alternate sets. This task

therefore closely parallels Verbal Concept Formation I except that the subject has to discover underlying rules for assigning each group of stimulus words to a code letter. Presented by 35 mm. slides as described above.

Number of trials: 9

10 (c_1) and 23 (c_2). Spatial Concept Formation II.

Description: Consists of 16 sets of four, two-dimensional figures with each set assigned to one of the code letters A, B, C, or D. Four sets of figures belong to each letter; the code letter represents an underlying concept. Concept A is that two of the figures are the same as the other two figures but rotated 90° clockwise; concept B is that three of the figures when properly placed together constitute the fourth figure; concept C is that the four figures represent a design which is bilaterally symmetrical; concept D is that progressive increments to each preceding figure lead to the last figure. The four concepts are invariant across trials but the figure sets are replaced each trial with alternate sets. The task therefore closely parallels Spatial Concept Formation I except that the subject has to discover the underlying rules for assigning each group of stimulus figures to a code letter. Presented by 35 mm. black-and-white slides as described above.

Number of trials: 9

11 (c_1) and 25 (c_2). Mecanno Assembly Test.

Description: This learning task was developed by Dr. William G. Mollenkopf to assess the conceptual learning process in a mechanical-motor task. The subject is given instructions by means of 35 mm. slides

and an accompanying sound track as to the basic principles of gear rotation and step-down features. He is then given a five-minute trial to put together various gears, axles, and collars from a Mecanno Set (similar to the American Erector Set) in such a way that for each six turns of a crank a rubber-covered wheel will make one complete turn in the same direction. The subject earns one score point for each of the 12 operations required to complete the assembly task. The instruction-assembly task sequence is repeated five times.

Number of trials: 5

12 (c_1), 25 (c_2), and 27 (c_0). Sidewalk Maze.

Description: This is a simple paper maze on which the subject traces his way along a 1/4 inch path which winds hither and yon on an 8 1/2 x 11 inch sheet of paper. The back side of the maze sheet is printed with carbon material in such a way as to correspond to the path the subject attempts to follow. The carbon underlay comes into contact with a second sheet of paper which contains a distance scale roughly determined in terms of difficulty (i.e., it was considered more difficult to remain within the 1/4 inch boundaries of curved sections than straight sections; hence an inch path recorded on a curve section was considered to be equivalent to a longer path on a straight section). For each trial the subject is given 30 seconds to trace through the maze as rapidly as he can. The score, obtained from the carbon tracing on the second sheet, is the distance travelled before a discontinuity or overlap appears on the tracing.

Number of trials: 7

13 (c_1), 26 (c_2), and 28 (c_0). Rotary Pursuit Test.

Description: This is the standard U. S. Air Force Rotary Pursuit Test, Form B (CM803B), for which the subject is required to manipulate a stylus in such a way as to maintain contact with a small silver target set flush with the surface of a disc revolving at 60 rpm. The subject is given 15, 20-second trials separated by 10-second rest periods. The score per trial is the amount of time he maintains contact with the target.

Number of trials: 15

The way in which the learning parameters for the above tasks cluster should aid in the identification of some of the dimensions of human learning. A conventional factor analysis will be applied to the matrix of intercorrelation coefficients for the 28 learning parameters. The resulting factor structure will be rotated to simple structure. After rotation to this criterion, the major factor loadings for the learning tasks are expected to be distributed by one of the two possibilities indicated in Table II-1. The nature of factor analysis is such that other dimensions, perhaps combining these two organizations, may emerge.

B. Reference Variables

The second problem considered by this project is concerned with the interrelationship between the learning domain and the human ability domain. Are there factors common to the two domains? If so, what are the relationships between the factors common to each domain? Tucker's

Table II-1. Postulated Dimensions of Human Learning

	If organized by psychological processes:			If organized by human abilities:			
Learning Task	Rote Learning	Conceptual Learning	Motor Learning	Verbal Knowledge	Spatial Visualization	Mechanical Knowledge	Other
Word Code	XX			XX			
Spatial Code	XX				XX		
Knob Code	XX						Ma
Sonar	XX						Ma
Verbal Concept Formation I	X	X		XX			
Spatial Concept Formation I	X	X			XX		
Breech Block Performance Test	X		X			XX	
CIC Plotting Test		X	X		XX		
Meccano Assembly Test		X	X			XX	
Verbal Concept Formation II		XX		XX			
Spatial Concept Formation II		XX			XX		
Sidewalk Maze			XX				PC
Rotary Pursuit			XX				PC

Note: XX = This task is a relatively pure measure of the factor.
X = This task involves two factors
Ma = Associative Memory.
PC = Psychomotor Coordination.

inter-battery method of factor analysis (1958b) will be used to study these questions. This method will create two rotational problems if there are common factors: one to define the inter-battery factors in terms of the learning parameters, and a second to define the inter-battery factors in terms of the reference variables. The inter-battery method will permit the resulting two structures to be studied for similarity by computing the inter-battery factor correlations.

In order to apply the inter-battery method of factor analysis within the conceptual framework discussed in Chapter I, the contents of the learning tests were carefully studied in terms of the amounts of variance of these tests which might be accounted for by previously identified factors. Within reasonable limits, two or more tests of each overlapping factor were included as reference variables. These tests, for the most part, were selected either from the manual edited by French (1954), which is the result of a committee on multiple factor analysis and contains selected tests of well-defined factors; or from French (1951), which is a prior summary of factors contained in achievement and aptitude tests. All of the reference factors have been identified from studies where rotations have been made to the type of simple structure advocated by Thurstone (1947).

The tests or variables which constitute the standard reference variables for this study are listed below and grouped by factors with which they correlate highly. The number preceding each test is the referrant code number used throughout this study. The definitions of the factors and the descriptions of the tests have in most cases been taken from French (1951).

Factor Ma: Associative Memory. Defined as the ability to commit pairs of items to memory for short periods of time so that given one member of the pair the other can be recalled or recognized. This is apparently the same factor Kelley (1954) has more recently identified as Rote Memory and defined as the ability to remember bits of unrelated factual materials. Tests containing Factor Ma are listed below.

29. Recognition II

Description: The examinee is read a list of 25 words and indicates in a test list of 50 words, also read, whether or not each word was present in the first list.

Time-limit: Words read at 2-second intervals.

Score: Number right.

30. First Names

Description: The subject examines 20 first and last names and later reproduces the first names associated with the last names.

Time-limit: 90-second practice test; 5 minutes for memory and 3 minutes for test.

Score: Number of first names written correctly.

31. Word-Number

Description: The subject examines 20 word-number pairs and later reproduces the number associated with each word.

Time-limit: 90-second practice test; 5 minutes for memory and 3 minutes for test.

Score: Number of words correctly numbered.

32. Picture-Number

Description: The subject examines 20 pictures of common objects, each paired with a two-digit number and later reproduces the number associated with the picture.

Time-limit: 3 minutes for memory and 3 minutes for test.

Score: Number of pictures correctly numbered.

Factor I: Induction. Defined as the associated abilities involved in finding general concepts that will fit sets of data, the forming and testing of hypotheses. Tests containing Factor I are listed below.

33. Number Series

Description: Each item consists of a series of numbers which follow some rule. The examinee's task is to select the next number which is consistent with the series.

Time-limit: 8 minutes

Score: Number right minus 1/4 number wrong.

34. Letter Sets

Description: Each item consists of five groups of letters with four letters per group. Four of the letter groups have some common characteristic which the fifth group does not possess. The examinee selects the one group which does not follow the rule.

Time-limit: 8 minutes

Score: Number right minus 1/4 number wrong.

Factor R: General Reasoning. Defined as the ability to carry out the kind of reasoning required in the solution of mathematical problems. The reasoning process appears to be separate from mathematics achievement and tends to be found in a variety of reasoning tests, including non-mathematical o

The following tests have been found to contain this factor.

35. Arithmetic

Description: Part of the Navy Basic Test Battery items in this test consist of (a) problems involving routine computation, and (b) verbally stated problems measuring the ability to think in quantitative terms. The Navy Basic Test Battery had been administered prior to this experiment and the test scores were made available by the Navy.

36. Ship Destination

Description: Constructed by Christensen and Guilford, the subject uses knowledge of the position of a ship with respect to a port, wind direction, ocean current, and direction of travel to compute effective distance to port following given rules.

Time-limit: 15 minutes

Score: Number right.

37. Mathematics Aptitude

Description: Classic story problems in mathematics.

Time-limit: 10 minutes

Score: Number right minus 1/4 number wrong.

Factor D: Deduction. Defined as the ability to reason from given premises to their necessary conclusions, as perhaps best illustrated in syllogistic tests. The following tests contain this factor.

38. False Premises

Description: Constructed by Thurstone, the subjects are presented with formal syllogisms having certain nonsense words so that they cannot be solved

by reference to past learning. Some conclusions follow correctly from the premises while others do not. The subject indicates which conclusions are logically correct.

Time-limit: 8 minutes

Score: Number right.

39. Reasoning

Description: Constructed by Thurstone, the subjects are presented with formal, meaningful syllogisms, but some of the stated conclusions do not follow correctly from the premises. The subject indicates which inferences follow correctly from the premises.

Time-limit: 6 minutes

Score: Number right.

Factor V: Verbal Knowledge. This is one of the best identified factors involved in human ability. It has also been labeled Verbal Comprehension and Verbal Ability. It is defined as an ability embodying the knowledge and understanding of the English language. Since similar factors have been found in studies with native speakers of other languages, the Verbal Comprehension factor might be generalized in definition to be a factor of general language knowledge and comprehension. The following tests have been shown to have major loadings on this factor.

40. General Classification Test

Description: Part of the Navy Basic Test Battery, items in this test are of two types: (a) analogies, and (b) sentence completion. The Navy Basic Test Battery had been administered prior to this experiment and the test scores were made available by the Navy.

41. 36-Item Vocabulary

Description: Adapted from Carroll, this is a standard vocabulary test consisting of four-choice synonym items.

Time-limit: 10 minutes

Score: Number right.

42. Sentence Completion

Description: Constructed by Educational Testing Service, the subject selects the missing word of a sentence by deciding which word of five choices best fits the meaning of the sentence.

Time-limit: 7 minutes

Score: Number right.

Factor S: Spatial Relations and Orientation. Defined as the ability to comprehend the nature of the arrangement of elements within a visual stimulus pattern primarily with reference to the location of the subject. The following tests have been shown to have major loadings on this factor.

43. Cards

Description: Constructed by Thurstone, the subjects indicate which of six other cards in various rotational positions is "like" the stimulus card.

Time-limit: 6 minutes/20 items

Score: Number right.

44. Cubes

Description: Developed by Thurstone, the subjects indicate whether or not two drawings can be of the same cube, assuming no single cube can have two sides alike.

Time-limit: 5 minutes/44 items

Score: Number right.

Factor Vz: Visualization. Defined as the ability to perform mental manipulations of visual images. This ability is required in the solution of problems which involve a specified sequence of mental movements of objects appearing within a more or less complex stimulus pattern. The tests representing this factor are as follows:

45. Paper Folding

Description: Developed by Educational Testing Service, the subjects select from five choices the drawing which represents the unfolded version of the stimulus drawings. The stimulus drawings consist of two or three figures of a square piece of paper being folded and having a hole(s) punched in the last figure.

Time-limit: 10 minutes/20 items

Score: Number right.

46. Paper Form Board

Description: Developed by Thurstone, each item presents a drawing of black pieces which can be put together to form a figure presented in outline form. The subjects draw lines on the outline showing how the black pieces will fit together.

Time-limit: 7 minutes/42 items

Score: Number right.

Factor Mk: Mechanical Knowledge. Defined as knowledge of mechanical principles, devices, and tools, acquired through training and experience. The

following tests have been shown to have major loadings on this factor.

47. Mechanical Test

Description: Part of the Navy Basic Test Battery, items in this test consist of two types: (a) mechanical and electrical knowledge and (b) mechanical comprehension. Items of the latter type involve the ability to perceive visually the mechanical details of a problem situation and to apply various physical principles to arrive at a solution. The Navy Basic Test Battery had been administered prior to this experiment and the test scores were made available by the Navy.

48. Guilford-Zimmerman Mechanical Knowledge

Description: Part VII of the Guilford-Zimmerman Aptitude Survey, the subjects select one of five uses for a pictured tool or select one of five pictured tools for a given use.

Time-limit: 10 minutes/20 items

Score: Number right.

Factor N: Number Facility. This is also one of the better identified factors and is defined as facility in handling numbers in arithmetical operations. Tests of the four arithmetical operations are outstanding with respect to purity and loading on this factor. The following tests have been shown to have major loadings on this factor.

49. Addition

Description: This is a speeded test of the addition of sets of three, one-digit and two-digit numbers.

Time-limit: 3 minutes/90 items

Score: Number right.

50. Division

Description: This is a speeded test of the division of two-digit or three-digit numbers by single-digit numbers.

Time-limit: 3 minutes/90 items

Score: Number right.

Factor Ai: Aiming. Defined as the ability to carry out quickly and precisely a series of movements requiring eye-hand coordination. It is distinguished from Motor Speed (Factor Ms) by its association with tests that require the exact placement of pencil marks rather than mere rapid markmaking. The following tests have been shown to have major loadings on this factor.

51. Tracing

Description: Adapted from MacQuarrie, the subjects draw a line through a pattern requiring many turns.

Time-limit: 30 seconds for practice; 90 seconds for test

Score: Number of barriers passed.

52. Dotting

Description: Adapted from MacQuarrie, the subjects put a dot entirely inside circles of 1/16 inch diameters which are connected by lines.

Time-limit: 30 seconds for practice; 90 seconds for test

Score: The number of circles with a dot within the circle.

Factor Ms: Motor Speed. Defined as the speed by which coordinated finger movements are carried out. Eye-hand coordination is minimal. Tests representing this factor are:

53. Writing X's

Description: The subject writes X's as fast as he can on or near dots.

Time-limit: 30 seconds for practice; 90 seconds for test

Score: Number of X's written.

54. Writing Digits

Description: The subject writes the digits 1 through 9 as fast as he can on or near blank lines.

Time-limit: 30 seconds for practice; 90 seconds for test

Score: Number of digits written.

55. Tapping

Description: U. S. Air Force Two-Plate Tapping Test in which the subject taps two plates alternately as rapidly as he can with a stylus held in the preferred hand.

Time-limit: Three 1-minute trials with 30-second rest periods between trials

Score: Cumulative number of recorded taps.

Factor MD: Manual Dexterity. Defined as the ability to conduct simple but speeded tasks requiring eye-arm-hand coordination. Factor PC: Psychomotor Coordination, as represented in the Aiming Steadiness Test below, is subsumed here under Factor MD because it is a related factor and the test

representation of this factor is inadequate to define Factor PC distinctly. Tests containing this factor include:

56. Turning

Description: From the Minnesota Rate of Manipulation Tests, this test utilizes a long narrow board which contains 60 holes in four rows of 15 each. The subject uses two hands in turning over each of the 60 cylinders and replacing them in the same hole.

Time-limit: Two 30-second test periods

Score: Total number of cylinders turned over.

57. Placing

Description: From the Minnesota Rate of Manipulation Tests, this test utilizes the apparatus of variable 56 (Turning Test). The subject puts the blocks in the holes as fast as he can using one hand only.

Time-limit: Two 30-second periods

Score: Total number of blocks placed in holes.

58. Steadiness

Description: U. S. Air Force Steadiness Aiming Test in which the subject attempts to hold a rod balanced on a fulcrum such that the end does not come into contact with the sides of a hole through which it is inserted.

Time-limit: Three 30-second trials; 30-second rest periods between trials

Score: Total amount of time rod is in contact with sides of hole.

Factor P: Perceptual Speed. Defined as the ability to compare pairs of items or to locate a unique item in a group of identical items. Tests of

this ability are always speeded. Tests containing this factor are:

59. Clerical Aptitude

Description: From the Navy Basic Test Battery, the subject indicates whether pairs of names or numbers are similar or different; the names or numbers in each pair differ only in some small detail. The Basic Battery was administered prior to this experiment and the test scores were made available by the Navy.

60. Picture Discrimination

Description: Items in this test consist of a set of three faces. The subject indicates which face is unlike the other two.

Time-limit: 3 minutes

Score: Number right.

Factor SA: Speed of Association. Defined as the ability to make rapid associations between objects and the words which symbolize them. Tests of this factor are:

61. Words Associated with an Unfurnished House

Description: The subject selects from a list of 497 words those which were associated with an unfurnished house.

Time-limit: 2 1/2 minutes

Score: Number right.

62. Word Checking

Description: The subject selects from a list of 250 words those which do not grow and which are smaller than a football.

Time-limit: 2 minutes

Score: Number right.

Intelligence. The popular lay definition that "intelligence is the ability to learn" led us to include three standard tests which yield a measure of intelligence. These tests are:

63. Armed Forces Qualification Test

64. Otis Self-Administering Achievement Test

65. Oral Directions Test

Two additional variables are included in the study. These are:

66. Education. Number of years of education completed beyond elementary level.

67. Age

CHAPTER III

THE LEARNING PARAMETERS

The history of science suggests quite clearly that the age or developmental level of a particular science can be assessed by the usage made of mathematics and mathematical models. Precision is gained whenever knowledge has reached a stage where some variables can be expressed as explicit functions of other variables. Although mathematics and mathematical models underlie much of modern psychology, the study of learning is especially susceptible to mathematical rationalizations. These range from convenient descriptions of the shapes of learning or performance curves to extensive analytic work.

In a typical learning experiment the investigator is concerned with multiple data which usually consist of some type of scores obtained for many practice periods. There are alternative ways of treating such data (see Fleishman and Hempel (1954b) and Tucker (1958a)) but one common procedure is to summarize the data by applying curve fitting techniques to obtain a few parameters which can be used mathematically to reproduce closely the original observations. Such parameters may be determined for empirical curves in which an emphasis is placed upon letting the experimental data determine not only the parameters but also the particular function (i.e., Fisher's orthogonal polynomials (1946)), and for rational curves in which the function stems from theory and the parameters are determined by fitting the observations into the function (e.g., Thurstone (1930), Gulliksen (1953), Stake (1958)).

The learning model and particular parameters to be used in this study fall somewhere between empirical and rational functions. The model was

chosen because it could be applied to each of the learning situations and because the parameters could also have the same interpretations across learning situations. The purpose of the study is to determine whether like parameters will group factorially as hypothesized, that is, how learning processes are organized across situations, and not how learning takes place within a situation.

As stated earlier, learning was a process which could be inferred from performance measures obtained at several equally spaced time intervals or trials. A mathematical model was adopted in which the performance of an individual on a specified trial t could be expressed as a function of the trial number t and of certain parameters unique to that individual. Since any function can also be expressed as a sum of functions, the basic equation of this model may be written as follows:

$$\hat{p}_{it} = p_{i0} + p_{i1} + p_{i2} \quad , \tag{III.1}$$

and define as an error term

$$e_{it} = p_{it} - \hat{p}_{it} = p_{it} - p_{i0} - p_{i1} - p_{i2} \quad , \tag{III.2}$$

where

p_{it} = observed score of individual i on trial t ,

$\hat{p}_{it}$ = theoretical score of individual i on trial t ,

$p_{i0} = c_{i0}$ = initial ability for individual i ,

$p_{i1} = c_{i1} t \qquad (t = 1, 2, 3, \ldots, K)$,

$p_{i2} = c_{i2} \left[\left(t - \frac{1}{2} K \right)^2 - \frac{1}{4} K^2 \right] \qquad (t = 1, 2, 3, \ldots, K).$

If the basic equation is rewritten as

$$\hat{p}_{it} = c_{i0} + c_{i1}t + c_{i2}\left[(t - \tfrac{1}{2}K)^2 - \tfrac{1}{4}K^2\right] \quad , \qquad \text{(III.3)}$$

then c_{i1} and c_{i2} may be defined analogously to speed and acceleration in terms of the first two derivatives of equation (III.3) with respect to t as follows:

$$\frac{dp_{it}}{dt} = c_{i1} + 2c_{i2}\,(t - \tfrac{1}{2}K) \quad , \qquad \text{(III.4)}$$

and

$$\frac{d^2p_{it}}{dt^2} = 2c_{i2} \quad . \qquad \text{(III.5)}$$

The values of $\frac{dp_{it}}{dt}$ at mid-trial (where $t = \frac{1}{2}K$) is simply c_{i1} and thus represents the rate of performance (hence, learning) at mid-trial. It can also be shown that c_{i1} is the average rate of learning over the K trials.

The parameter c_{i2} is proportional to the second derivative of equation (III.3) and in terms of the analogous relation to acceleration this parameter indicates whether individual i was performing relatively better (hence, learning faster) during the first half of the learning task than in the second half. From equation (III.3) it can be deduced that if c_{i2} is negative the subject was learning more quickly during the first half of the learning task and is positive if the subject was learning more quickly during the latter half.

The method of least squares was employed to calculate the learning parameters (c_0 , c_1 , c_2) such that the sum of the squares of the

error term represented by equation (III.2) would be set at a minimum. This method may be expressed in matrix notation as follows:

$$\text{Let } C \equiv \| c_0 \vdots c_1 \vdots c_2 \| \tag{III.6}$$

$$X \equiv \left\| \begin{array}{ccccccc} 1 & \vdots & 1 & \vdots \cdots \vdots & 1 & \vdots \cdots \vdots & 1 \\ 1 & \vdots & 2 & \vdots \cdots \vdots & t & \vdots \cdots \vdots & K \\ 1 - K & \vdots & 4 - 2K & \vdots \cdots \vdots & t^2 - tK & \vdots \cdots \vdots & 0 \end{array} \right\| \tag{III.7}$$

$$(t = 1, 2, 3, \ldots, K)$$

$$\hat{p} \equiv \| \hat{p}_1 \vdots \hat{p}_2 \vdots \cdots \vdots \hat{p}_t \vdots \cdots \vdots \hat{p}_K \| \ . \tag{III.8}$$

Then

$$\hat{P} = CX \tag{III.9}$$

which is the matrix equivalent of equation (III.3).

If $\hat{P}$ is replaced by P, which is a row vector of observed performance scores, then the inverse of X will have the desired property of minimizing $P - \hat{P}$. Because X is not a square matrix it has no inverse; however, the quasi-inverse matrix $X'(XX')^{-1}$ does exist and has least squares properties. Thus,

$$C = PX\,(XX')^{-1} \ . \tag{III.10}$$

Let $W = X\,(XX')^{-1}$, then

$$C = PW \ . \tag{III.11}$$

The learning parameters were obtained from equation (III.11) by performing the appropriate matrix multiplication between the row vector

of performance scores and the weight vectors associated with a given parameter. Inasmuch as most of the learning tasks reported in this study were novel to the subjects, their c_0-parameters were set at zero or at a chance level. The weight vectors used to compute the learning parameters appear in Appendix B.

To summarize briefly, this chapter described the parameters by which the functional organization of human learning was investigated. The parameters consisted of c_0, which represents the initial level of achievement prior to learning; c_1, which represents the average rate of learning; and c_2, which indicates whether the subject was learning faster during the first half or second half of the learning task. The c_2-parameter will be identified in this report as a curvature parameter or as "early versus late" learning. Although it was recognized that the parameters represent characteristics of performance, it was inferred that performance was a consequence and expression of learning. It was assumed accordingly that any functional organization found among the parameters reflected a functional organization basic to human learning; therefore, it seemed defensible to define them as learning parameters.

CHAPTER IV

DATA COLLECTION AND ANALYSES

A. The Subjects

The experimental sample consisted initially of 483 enlisted men from eight recently formed companies. All subjects were undergoing recruit training at the U. S. Naval Training Center, Bainbridge, Maryland. The first tests of this project were administered during the first week of the regular nine-week training program; the last test was administered three weeks later. The total testing time per subject over the three-week period was 20 hours. When the data obtained from recalcitrant subjects and from subjects who were not present for one or more tests were excluded, complete and acceptable data were available for 315 subjects. The conclusions drawn in this report are therefore based upon 315 Naval recruits.

The subjects were 17 to 22 years of age with more than half of them falling in the 17-year-old group. In terms of education, they ranged from zero years of high school to two years of college; two-thirds of them had attended high school for three years or less. Intellectually, as reflected by scores on the Navy Basic Test Battery, the Armed Forces Qualification Test, and the Otis Mental Ability Test, the subjects were slightly below average and functioned at a level which would correspond to an average "I.Q." in the low 90's. A more complete description of the subjects may be obtained from the tables appearing in Appendix C.

B. The Testing Schedule

The subjects had been in the Navy only a few days during which time they had completed their basic processing and were assigned to one of

the eight companies. On June 1, 1955, the subjects attended en masse the "Welcome Aboard" ceremony conducted by Captain William J. Catlett, Commanding Officer of the Recruit Training Command at Bainbridge. At this time Captain Catlett described the learning project, asked for the subjects' cooperation, and introduced the writer. On June 2, 1955, five booklets of reference tests were administered to the men in four of the eight companies. The testing was conducted in an extremely large mess hall by Dr. John W. French and the writer. On June 3, 1955, subjects from the remaining four companies were given the reference tests. The order of presentation for these tests was constant for all subjects.

From June 7 to June 16 several additional reference tests and five of the 13 learning tasks were administered at the rate of one company per day. In order to test groups of subjects as small as four men and as large as 64 men, practical considerations required that the tests be administered in a "round-robin" manner to the subjects and, consequently, the order of presentation of these tests was not constant. These tests and those described in the next paragraph were administered by staff members of Educational Testing Service. The writer was solely responsible for administrative decisions and testing protocol.

The remainder of the learning tasks were administered to the subjects between June 17 and June 23. On each of these days, one or two tasks were given to all subjects. Some variation in the order of presentation existed when two tasks were administered--for example, in order to conserve on time two companies would participate in one learning task while two other companies participated in a second task and then the companies would exchange learning tasks.

The complete testing schedule showing the details briefly described above appears in Appendix D. Unknown consequences were introduced into the study by permitting the order of presentation for the reference tests and the learning tasks to vary for the subjects. A testing schedule in which the order of presentation was invariant for all subjects would have required an amount of time which would have seriously interfered with the operations of the training center. The adopted schedule which minimized interference with the training program was endorsed by the Chief of Naval Personnel, who also authorized that the normal nine-week training period be extended, if necessary, to make up instruction which may have been missed.

C. Scoring and Collating Procedures

Scores on the tests in the Navy Basic Test Battery, which was administered during the recruits' processing period, and the Armed Forces Qualification Test, which had been administered prior to the subjects' entrance into military service, were obtained by permission from Naval records. The tests obtained in test booklets DETBl-5, as well as the Otis and Oral Directions Tests, were scored by the Scoring Section of Educational Testing Service. Performances on the Sidewalk Maze and the Turning and Placing Tests were scored by the subjects under close supervision from the persons administering those tasks. Performances on the Breech Block Performance Test, Meccano Assembly Test, Rotary Pursuit Test, Tapping Test, and Steadiness Test were rated by proctors or the persons administering those tasks.

The Word Code, Spatial Code, Knob Code, Sonar, Verbal Concept Formation I and II, Spatial Concept Formation I and II, and CIC Plotting Test were all scored by the subjects. These tasks represented nine of the 13 learning tasks involved in the study and the self-ratings were carefully scrutinized to insure accuracy. During the actual testing periods it was standard

procedure for the proctors to report to the test administrator the names of any subjects who for a variety of reasons were not actively participating or cooperating in the learning activity. After the answer sheets for a given task were collected, answer sheets for those individuals so reported were marked void. Answer sheets for these learning tasks, with the exception of the CIC Plotting Test, were later examined by the writer and other staff members of Educational Testing Service and rejected if the subject had failed to record his right and wrong responses or if for some other reason it was felt that the subject had not complied with the learning task. None of the answer sheets was rejected on the basis of learning. Inspection of the eight sets of answer sheets for 483 subjects produced 357 acceptable sets of data and 126 rejected sets of data (82 sets were rejected on the basis of being incomplete and included answer sheets marked void at the time of testing).

When the records for the 357 subjects who produced acceptable data on eight of the learning tasks were collated with data from the remaining learning tasks and reference variables, 42 subjects were lacking data on one or more of the variables and therefore excluded from the study. Complete and acceptable data for 315 subjects resulted from the scoring and collating procedures. No analysis--although it might be very important to do so--was made of the rejected data.

D. Computations of Learning Parameters and Correlation Coefficients

Scores for each trial and for each learning task were punched into IBM cards and the learning task parameters computed on the IBM 650 Electronic Data Processing Machine. The 28 learning parameters generated for the 13 learning tasks and scores for the reference data were punched into IBM

cards and a 67 x 67 matrix of intercorrelations computed on the IBM 650 Electronic Data Processing Machine.[1]

The resulting matrix of intercorrelations was divided into three matrices. Table IV-1, Matrix R_{11}, lists the intercorrelations among the learning parameters. The entries for elements of the principal diagonal are the squares of the multiple correlations between a given parameter and the remaining 27 other parameters. These entries served as communality estimates for the factor analysis of the learning parameters and were computed by a procedure outlined by Guttman (1953). This procedure entailed the computation of the inverse of a matrix identically equal to matrix R_{11} except for unities along the principal diagonal and was carried out by the Statistical Laboratory at Purdue University utilizing the Datatron Computer. The complements of the reciprocals of the principal diagonal elements of the resulting inverse were computed and these are the entries which appear along the principal diagonal of Matrix R_{11} in Table IV-1. Table IV-2, Matrix R_{22}, lists the intercorrelations among the reference variables. And Table IV-3, Matrix R_{12}, lists the intercorrelations between the learning parameters and the reference variables.

E. Factor Analysis of Learning Parameters

All 28 eigenvalues and roots were extracted from Matrix R_{11} using the computational facilities available for the Datatron located at Purdue University. In matrix notation the computing problem may be stated as follows (Thurstone, 1947, pp. 500-503):

> Given R_{11}, which is a matrix of intercorrelations with communality estimates in the principal diagonal.

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[1] Miss Henrietta Gallagher, Dr. Carl Helm, and Mr. Harry Garrison were responsible for the preparation of the computer programs for both the learning parameters and the matrix of intercorrelations.

Table IV-1. Matrix R_{11}: Intercorrelations of Learning Measures
(Decimals omitted)

		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
01	Word Code	32	38	32	28	27	29	15	13	24	18	17	02	03	-17	-21	-15	-02	-12	-08	-04	-09	-13	01	00	06	-07	07	00
02	Spatial Code	38	24	24	23	24	32	06	16	18	12	08	-01	10	-13	-08	-01	-02	-07	-13	-08	-13	-12	00	-01	07	-09	07	04
03	Knob Code	32	24	29	31	24	19	11	20	22	14	09	05	-04	-21	-23	07	-11	-11	-15	-03	-16	-24	-06	-01	08	-03	05	09
04	Sonar	28	23	31	31	31	11	07	16	35	15	07	-04	03	-17	-18	-22	00	-17	-10	01	-07	-25	04	-01	04	-10	10	08
05	Verbal Concept Formation I	27	24	24	31	30	28	-01	25	37	27	04	01	06	-22	-18	-13	-02	-17	-27	-02	-18	-26	-01	-03	10	-01	08	-03
06	Spatial Concept Formation I	29	32	19	11	28	26	-03	20	25	29	06	-04	09	-18	-12	-11	-17	-19	-19	-13	-14	-20	-02	-07	07	-04	12	01
07	Breech Block Performance Test	15	06	11	07	-01	-03	12	05	08	05	07	07	05	-06	-05	-03	-05	-01	-06	20	-03	-05	02	11	-04	-04	-04	01
08	CIC Plotting Test	13	16	20	16	25	20	05	33	35	28	24	12	06	-13	-21	-18	-17	-36	-22	-16	-33	-32	-11	05	-01	-17	-01	04
09	Verbal Concept Formation II	24	18	22	35	37	25	08	35	41	34	10	02	05	-31	-18	-11	-14	-36	-30	-04	-29	-43	-06	-05	02	-11	08	08
10	Spatial Concept Formation II	18	12	14	15	27	29	05	28	34	32	20	03	02	-10	-06	-12	-11	-32	-35	-10	-27	-31	00	-08	-02	-04	04	08
11	Meccano Assembly Test	17	08	09	07	04	06	07	24	10	20	22	-04	05	-06	-14	-07	-04	-14	-13	-29	-18	-07	-04	08	02	-12	13	14
12	Sidewalk Maze	02	-01	05	-04	01	-04	07	12	02	03	-04	63	01	-03	00	03	-03	-06	-05	-06	-01	01	-04	-03	-38	04	-73	-04
13	Rotary Pursuit	03	10	-04	03	06	09	05	06	05	02	05	01	22	06	-01	06	10	02	01	-05	-07	14	15	02	-04	-16	02	-30
14	Word Code	-17	-13	-21	-17	-22	-18	-06	-13	-31	-10	-06	-03	06	27	32	23	20	23	20	00	15	33	18	01	-11	01	-08	-05
15	Spatial Code	-21	-08	-23	-18	-18	-12	-05	-21	-18	-06	-14	00	-01	32	23	20	19	20	15	05	21	23	17	-01	-04	-03	-07	-01
16	Knob Code	-15	-01	07	-22	-13	-11	-03	-18	-11	-12	-07	03	06	23	20	27	20	22	19	-04	10	20	21	00	-03	06	-06	06
17	Sonar	-02	-02	-11	00	-02	-17	-05	-17	-14	-11	-04	-03	10	20	19	20	18	08	12	08	03	22	04	03	-02	-05	-01	-07
18	Verbal Concept Formation I	-12	-07	-11	-17	-17	-19	-01	-36	-36	-32	-14	-06	02	23	20	22	08	35	36	09	30	42	16	-04	-05	06	-04	01
19	Spatial Concept Formation I	-08	-13	-15	-10	-27	-19	-06	-22	-30	-35	-13	-05	01	20	15	19	12	36	31	14	16	29	18	04	04	05	-06	00
20	Breech Block Performance Test	-04	-08	-03	01	-02	-13	20	-16	-04	-10	-29	-06	-05	00	05	-04	08	09	14	25	18	01	-02	12	09	07	00	-19
21	CIC Plotting Test	-09	-13	-16	-07	-18	-14	-03	-33	-29	-27	-18	-01	-07	15	21	10	03	30	16	18	25	26	15	00	-07	10	-09	-08
22	Verbal Concept Formation II	-13	-12	-24	-25	-26	-20	-05	-32	-43	-31	-07	01	14	33	23	20	22	42	29	01	26	39	20	-05	-02	03	-04	-05
23	Spatial Concept Formation II	01	00	-06	04	-01	-02	02	-11	-06	00	-04	-04	15	18	17	21	04	16	18	-02	15	20	18	03	07	-07	05	-09
24	Meccano Assembly Test	00	-01	-01	-01	-03	-07	11	05	-05	-08	08	-03	02	01	-01	00	03	-04	04	12	00	-05	03	09	-01	-04	06	-08
25	Sidewalk Maze	06	07	08	04	10	07	-04	-01	02	-02	02	-38	-04	-11	-04	-03	-02	-05	04	09	-07	-02	07	-01	63	-02	72	06
26	Rotary Pursuit	-07	-09	-03	-10	-01	-04	-04	-17	-11	-04	-12	04	-16	01	-03	06	-05	06	05	07	10	03	-07	-04	-02	11	-12	01
27	Sidewalk Maze	07	07	05	10	08	12	-04	-01	08	04	13	-73	02	-08	-07	-06	-01	-04	-06	00	-09	-04	05	06	72	-12	81	13
28	Rotary Pursuit	00	04	09	08	-03	01	01	04	08	08	14	-04	-30	-05	-01	06	-07	01	00	-19	-08	-05	-09	-08	06	01	13	22

Table IV-2. Matrix R_{22}: Intercorrelations of Reference Variables
(Decimals omitted)

		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
29 Recognition II	(Ma)		35	06	24	37	31	38	40	29	22	35	44	37	28	12	10	15	17	15	12	31	31	17	09	06	17	14	10	13	-03	19	24	39	40	32	38	35	16	-05
30 First Names	(Ma)	35		28	40	38	32	45	37	35	21	39	44	35	27	11	03	16	08	09	03	34	42	13	17	14	27	13	17	13	00	26	26	31	36	29	47	38	28	-04
31 Word-Number	(Ma)	06	28		42	10	14	06	09	09	06	07	03	01	00	00	06	08	05	02	-06	14	12	20	14	19	18	19	17	15	-07	19	19	03	16	04	06	13	13	03
32 Picture-Number	(Ma)	24	40	42		18	19	21	19	14	15	20	10	06	07	00	04	11	04	-02	-10	24	18	10	16	16	22	04	10	15	05	26	27	09	20	09	17	32	13	05
33 Number Series	(I)	37	38	10	18		50	61	61	56	29	48	61	54	48	32	12	39	31	33	18	44	46	16	16	16	32	18	21	15	-04	26	46	40	37	55	65	60	34	03
34 Letter Sets	(I)	31	32	14	19	50		51	55	42	30	37	60	52	49	31	05	37	32	28	21	41	44	15	05	14	27	14	14	12	-09	29	45	36	34	52	58	56	36	08
35 Arithmetic	(R)	38	45	06	21	61	51		65	65	37	55	67	58	54	31	15	37	29	29	26	59	74	19	12	08	32	11	17	17	-08	35	38	41	41	64	75	53	47	06
36 Ship Destination	(R)	40	37	09	19	61	55	65		58	36	55	73	61	57	40	14	53	42	49	37	38	47	18	08	08	25	18	20	17	-18	30	51	51	45	68	72	56	41	07
37 Math Aptitude	(R)	29	35	09	14	56	42	65	58		26	41	56	51	50	22	08	40	38	33	31	47	56	20	08	10	23	11	15	10	-08	27	38	38	35	63	64	48	38	14
38 False Premises	(D)	22	21	06	15	29	30	37	36	26		39	44	35	31	15	08	18	10	13	13	21	27	15	03	12	23	07	06	10	-02	22	25	27	30	31	44	30	23	-03
39 Reasoning	(D)	35	39	07	20	48	37	55	55	41	39		58	47	40	23	21	33	22	19	10	37	46	19	13	07	25	11	16	08	-05	30	41	41	36	48	59	39	32	01
40 General Classification Test	(V)	44	44	03	10	61	60	67	73	56	44	58		82	74	33	05	43	38	49	34	39	52	21	09	18	31	19	23	14	-17	26	46	59	55	73	84	59	48	01
41 36-item Vocabulary	(V)	37	35	01	06	54	52	58	61	51	35	47	82		73	23	01	31	29	34	27	36	46	19	12	18	25	17	16	12	-13	22	38	51	47	61	75	51	44	00
42 Sentence Completion	(V)	28	27	00	07	48	49	54	57	50	31	40	74	73		21	-05	33	25	31	23	28	39	09	06	12	18	10	17	13	-12	14	30	49	40	58	69	42	40	02
43 Cards	(S)	12	11	00	00	32	31	31	40	22	15	23	33	23	21		26	41	43	51	46	15	24	29	06	11	21	20	31	29	-11	22	40	31	25	48	36	30	20	08
44 Cubes	(S)	10	03	06	04	12	05	15	14	08	08	21	05	01	-05	26		16	16	16	16	19	16	21	01	00	10	10	12	11	00	25	22	12	12	09	11	10	07	01
45 Paper Folding	(Vz)	15	16	08	11	39	37	37	53	40	18	33	43	31	33	41	16		47	49	33	12	24	27	13	-01	19	10	27	14	-22	16	42	28	26	55	46	42	23	10
46 Paper Form Board	(Vz)	17	08	05	04	31	32	29	42	38	10	22	38	29	25	43	16	47		56	47	16	20	32	05	08	16	18	21	18	-20	24	43	22	21	55	39	42	21	13
47 Mechanical	(Mk)	15	09	02	-02	33	28	29	49	33	13	19	49	34	31	51	16	49	56		71	-02	11	23	06	08	16	20	21	21	-22	16	44	26	23	64	42	37	34	14
48 G-Z Mechanical Knowledge	(Mk)	12	03	-06	-10	18	21	26	37	31	13	10	34	27	23	46	16	33	47	71		05	21	21	00	-03	14	17	17	19	-25	19	34	22	17	58	34	25	31	20
49 Addition	(N)	31	34	14	24	44	41	59	38	47	21	37	39	36	28	15	19	12	16	-02	05		73	21	08	19	37	20	26	19	-02	50	36	26	33	36	47	43	28	09
50 Division	(N)	31	42	12	18	46	44	74	47	56	27	46	52	46	39	24	16	24	20	11	21	73		18	06	12	37	12	14	11	-05	42	33	33	37	50	59	45	38	04
51 Tracing	(Al)	17	13	20	10	16	15	19	18	20	15	19	21	19	09	29	21	27	32	23	21	21	18		25	41	38	37	44	34	-25	36	37	25	24	24	20	20	16	05
52 Dotting	(Al)	09	17	14	16	16	05	12	08	08	03	13	09	12	06	06	01	13	05	06	00	08	06	25		27	29	24	23	22	04	26	21	14	06	09	10	11	11	09
53 Writing X's	(Ms)	06	14	19	16	16	14	08	08	10	12	07	18	18	12	11	00	-01	08	08	-03	19	12	41	27		49	42	33	34	-09	32	31	24	25	08	13	21	15	00
54 Writing Digits	(Ms)	17	27	18	22	32	27	32	25	23	23	25	31	25	18	21	10	19	16	16	14	37	37	38	29	49		39	35	31	-11	41	43	32	30	25	33	33	30	06
55 Tapping	(Ms)	14	13	19	04	18	14	11	18	11	07	11	19	17	10	20	10	10	18	20	17	20	12	37	24	42	39		38	40	-06	26	30	27	22	20	19	14	21	11
56 Turning	(MD)	10	17	17	10	21	14	17	20	15	06	16	23	16	17	31	12	27	21	21	17	26	14	44	23	33	35	38		53	-15	33	39	24	18	25	24	19	17	03
57 Placing	(MD)	13	13	15	15	15	12	17	17	10	10	08	14	12	13	29	11	14	18	21	19	19	11	34	22	34	31	40	53		-04	32	34	22	23	17	19	14	13	04
58 Steadiness	(PC)	-03	00	-07	05	-04	-09	-08	-18	-08	-02	-05	-17	-13	-12	-11	00	-22	-20	-22	-25	-02	-05	-25	04	-09	-11	-06	-15	-04		-08	-12	-14	-17	-20	-12	-09	-14	-10
59 Clerical Aptitude	(P)	19	26	19	26	26	29	35	30	27	22	30	26	22	14	22	25	16	24	16	19	50	42	36	26	32	41	26	33	32	-08		54	27	25	25	33	28	31	12
60 Picture Discrimination	(P)	24	26	19	27	46	45	38	51	38	25	41	46	38	30	40	22	42	43	44	34	36	33	37	21	31	43	30	39	34	-12	54		40	35	51	49	52	29	01
61 Words assoc. w/unf. house	(SA)	39	31	03	09	40	36	41	51	38	27	41	59	51	49	31	12	28	22	26	22	26	33	25	14	24	32	27	24	22	-14	27	40		66	44	55	39	25	01
62 Word Checking	(SA)	40	36	16	20	37	34	41	45	35	30	36	55	47	40	25	12	26	21	23	17	33	37	24	06	25	30	22	18	23	-17	25	35	66		41	55	39	31	-01
63 AFQT	(Int)	32	29	04	09	55	52	64	68	63	31	48	73	61	58	48	09	55	55	64	58	36	50	24	09	08	25	20	25	17	-20	25	51	44	41		70	57	43	22
64 Otis	(Int)	38	47	06	17	65	58	75	72	64	44	59	84	75	69	36	11	46	39	42	34	47	59	20	10	13	33	19	24	19	-12	33	49	55	55	70		64	48	08
65 Oral Directions Test	(Int)	35	38	13	32	60	56	53	56	48	30	39	59	51	42	30	10	42	42	37	25	43	45	20	11	21	33	14	19	14	-09	28	52	39	39	57	64		31	02
66 Education		16	28	13	13	34	36	47	41	38	23	32	48	44	40	20	07	23	21	34	31	28	38	16	11	15	30	21	17	13	-14	31	29	25	31	43	48	31		30
67 Age		-05	-04	03	05	03	08	06	07	14	-03	01	01	00	02	08	01	10	13	14	20	09	04	05	09	00	06	11	03	04	-10	12	01	01	-01	22	08	02	30	

Allison matrix

Table IV-3. Matrix R_{12}: Correlations between Learning Measures and Reference Variables
(Decimals omitted)

		Recognition II	First Names	Word-Number	Picture-Number	Number Series	Letter Sets	Arithmetic	Ship Destination	Math Aptitude	False Premises	Reasoning	General Classification Test	36-item Vocabulary	Sentence Completion	Cards	Cubes	Paper Folding	Paper Form Board	Mechanical	Mechanical	Addition	Division	Tracing	Dotting	Writing X's	Writing Digits	Tapping	Turning	Placing	Steadiness	Clerical Aptitude	Picture Discrimination	Words assoc. w/unf. house	Word Checking	AFQT	Otis	Oral Directions Test	Education	Age
		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
01	Word Code	21	22	21	26	14	18	15	12	-02	08	18	08	10	09	07	09	07	04	08	02	10	14	15	19	04	08	-02	06	10	05	19	14	05	07	08	14	15	09	02
02	Spatial Code	22	20	12	07	18	17	16	21	14	13	17	18	18	18	09	-03	06	07	11	08	08	11	11	08	05	04	07	03	09	04	10	11	09	05	14	19	18	14	-02
03	Knob Code	15	18	15	23	21	25	21	22	09	11	22	22	19	21	07	05	16	15	11	04	04	11	09	08	02	07	03	13	07	-04	12	22	16	19	14	24	27	15	-10
04	Sonar	15	10	10	18	19	14	09	15	05	09	12	12	21	13	05	-09	02	07	03	01	04	01	17	12	16	07	11	04	08	-08	05	14	10	03	10	08	18	10	-07
05	Verbal Concept Formation I	16	27	14	13	18	26	24	28	14	21	28	28	30	23	19	-02	17	15	09	05	15	16	17	22	14	17	10	19	16	-02	17	24	25	15	22	28	28	11	-05
06	Spatial Concept Formation I	13	15	14	13	18	22	15	17	07	09	17	14	10	14	07	-01	18	08	14	-01	06	11	07	11	00	09	10	02	18	01	11	19	07	03	11	16	19	12	-02
07	Breech Block Performance Test	01	02	09	11	03	06	02	03	00	-11	-05	-01	01	04	06	-10	02	-02	00	03	02	06	11	-01	16	07	04	09	07	-13	02	01	-01	00	-02	-02	01	03	-07
08	CIC Plotting Test	30	35	18	21	51	43	49	44	45	17	37	46	38	35	26	22	36	30	30	21	41	43	32	20	17	33	28	32	26	-07	36	51	35	28	45	51	43	31	09
09	Verbal Concept Formation II	30	34	14	22	41	41	37	41	24	29	30	51	50	42	23	00	23	15	23	18	19	27	21	18	21	36	18	18	23	-06	24	34	36	28	34	48	42	33	01
10	Spatial Concept Formation II	10	17	06	06	30	30	32	33	29	22	28	38	35	33	26	-01	30	24	28	16	18	27	21	29	18	26	17	22	19	-03	24	34	19	12	35	36	30	25	00
11	Meccano Assembly Test	03	01	03	09	17	17	20	31	25	01	07	17	10	14	27	06	26	36	46	42	04	10	27	11	04	12	10	19	18	-23	22	35	14	05	35	17	24	18	17
12	Sidewalk Maze	10	08	09	07	10	01	00	05	00	-03	-04	03	02	-01	02	03	-01	07	00	-03	06	01	03	-08	05	00	-02	09	-01	-02	-01	05	00	00	03	01	-01	02	-06
13	Rotary Pursuit	02	-04	00	-09	-04	02	03	-01	01	-07	02	02	06	-02	-07	-03	-10	01	-11	-02	08	06	15	06	21	10	15	07	04	-13	10	00	02	-03	-03	-01	-03	12	12
14	Word Code	-18	-40	-28	-33	-15	-12	-13	-19	-12	-06	-21	-18	-09	-11	03	-01	-11	-06	-02	04	-08	-11	-06	-16	-10	-21	-06	-08	-09	05	-12	-12	-17	-12	-04	-21	-19	-13	03
15	Spatial Code	-14	-26	-15	-33	-18	-16	-24	-27	-15	-10	-20	-22	-17	-16	-02	00	-18	-16	-14	-10	-20	-18	-11	-08	-09	-12	-03	-09	-08	05	-20	-21	-19	-18	-20	-24	-21	-15	-04
16	Knob Code	00	-19	-18	-33	-11	-02	-05	-03	-07	-03	-12	01	01	-01	07	01	-06	00	-01	12	-07	-04	-08	-10	-16	-11	-06	00	-04	-04	-14	-14	-10	-01	04	-04	-09	-07	00
17	Sonar	-03	-05	-09	-13	-10	-05	03	-07	01	-08	-11	-02	-04	-04	02	-04	02	07	-02	04	-02	03	-12	-09	-06	-08	-14	-05	-06	-07	-03	-16	-05	00	03	-06	-09	-02	13
18	Verbal Concept Formation I	-23	-27	-16	-19	-39	-28	-34	-37	-28	-19	-33	-40	-34	-33	-14	-01	-25	-18	-19	-05	-21	-26	-13	-19	-11	-20	-07	-21	-13	05	-28	-35	-32	-26	-28	-41	-28	-28	01
19	Spatial Concept Formation I	-15	-13	-18	-17	-20	-21	-20	-25	-22	-15	-21	-25	-22	-17	-20	04	-28	-20	-15	-07	-17	-18	-21	-07	-11	-17	-12	-20	-17	15	-25	-31	-20	-21	-28	-28	-21	-23	-12
20	Breech Block Performance Test	-07	-01	-02	00	-13	-11	-09	-25	-11	-04	-11	-13	-08	-01	-30	-14	-31	-39	-43	-38	04	-02	-19	-05	02	-06	-20	-18	-11	13	-09	-34	-07	-06	-38	-12	-18	-06	-07
21	CIC Plotting Test	-27	-34	-13	-20	-48	-35	-52	-49	-44	-31	-47	-50	-40	-36	-26	-09	-41	-25	-31	-22	-36	-47	-26	-02	-14	-29	-13	-21	-10	13	-27	-36	-34	-35	-47	-51	-42	-38	-10
22	Verbal Concept Formation II	-23	-30	-18	-24	-35	-34	-32	-41	-26	-20	-32	-45	-45	-42	-12	-01	-23	-09	-17	-04	-16	-23	-04	-13	-08	-20	-07	-16	-19	-03	-14	-31	-34	-26	-29	-42	-29	-19	13
23	Spatial Concept Formation II	00	-09	-08	-21	-13	-09	-11	-09	-10	-06	-10	-10	-05	-15	-05	02	-20	-09	-12	-07	-01	-03	02	-03	02	02	11	-09	-08	-06	02	-02	-02	-02	-11	-15	-01	-14	-07
24	Meccano Assembly Test	02	11	05	01	-04	00	-01	00	03	-05	-05	-02	07	00	-12	00	-05	-09	-18	-11	06	03	05	02	-02	07	-02	02	-09	-01	03	-01	03	00	-09	-02	01	-04	-12
25	Sidewalk Maze	-01	01	02	-01	-04	-01	07	00	08	05	13	00	02	03	02	00	00	-03	-05	02	02	08	08	03	01	02	03	06	05	-01	06	-03	11	09	-01	05	04	04	05
26	Rotary Pursuit	-01	01	-04	01	-13	-03	-03	-05	-05	05	01	-01	-05	00	-13	-09	-02	-09	-11	-08	00	-04	-16	-10	-20	-13	-24	-12	-16	09	-12	-14	-07	-08	-09	-05	-08	-08	-01
27	Sidewalk Maze	00	-05	06	03	-04	01	04	03	08	05	13	02	04	04	06	06	09	05	02	05	06	04	26	14	09	14	17	10	18	-04	16	08	16	12	03	04	09	03	11
28	Rotary Pursuit	01	-04	10	01	05	08	-03	17	03	13	-02	11	03	06	24	10	18	23	36	29	-02	-08	23	03	06	08	21	17	18	-11	03	12	06	06	18	06	13	09	-01

Find Λ , which is a matrix of eigenvalues and has the property

$\Lambda' \Lambda = I$, and

D , which is a diagonal matrix of eigenroots,

such that

$$R_{11}\Lambda = \Lambda D \quad . \tag{IV.1}$$

Since $\Lambda' \Lambda = I$, (IV.2)

$$R_{11} = \Lambda D \Lambda' \quad , \tag{IV.3}$$

which may be expressed as

$$R_{11} = (\Lambda D^{\frac{1}{2}})(\Lambda D^{\frac{1}{2}})' \quad . \tag{IV.4}$$

If $F \equiv \Lambda D^{\frac{1}{2}}$, then equation (IV.4) may be expressed as

$$R_{11} = FF' \quad , \tag{IV.5}$$

which is the fundamental equation in factor analysis (Thurstone, 1947, p. 78).

The rank of Matrix R_{11} is equal to its order (28 x 28) and F in equation (IV.5) would also be of order 28 x 28. The purpose of factor analysis applied specifically to this study was to find a matrix F_o which has the order 28 x k, where k is less than 28, and which when postmultiplied by F_o' closely approximated R_{11}. The rank of F_o would constitute the number of common factors represented among the intercorrelations listed in Matrix R_{11}.

One may consider the extraction of eigenvectors and roots to be a sequential process which minimizes a residual correlation matrix each time. The number of eigenvectors and roots which constitute F_o can be established on the basis of $R_{11} - F_o F_o'$ which defines an

intercorrelation matrix of residuals. Several empirical rules exist for determining the rank of F_o (Thomson, 1951, pp. 121-126). The fact that most of these methods are predicated upon the estimates used for the communalities forestalls a rigorous test of significance to determine the rank of F_o . Lawley's maximum-likelihood method of factor analysis (1940) includes a significance test for the number of common factors and generates suitable values for the communalities in the factoring process. Computing facilities were not available here to apply Lawley's method. The decision as to the rank of F_o was therefore made after an inspection of the eigenvalues, which appear in Figure IV-1. The rank of F_o was set at 12, on the belief that the "true" rank was less than 12 and that, consequently, some factors would not lend themselves to psychological interpretation.

F_o of order 28 x 12 was computed from the eigenvectors and roots based upon the 12 largest eigenroots. The resulting values which appear in Table IV-4 constitute the orthogonal, unrotated factor coefficients for the learning parameter.

To lend partial support to the decision that 12 factors were more than adequate to account for the intercorrelations contained in Matrix R_{11}, a matrix of residual correlations was computed by forming a matrix $R_{11} - F_o F_o'$. If the 12 factors were sufficient, a frequency distribution of the residual correlation coefficients should be normally distributed about a correlation of zero. Such a frequency distribution appears in Table IV-5.

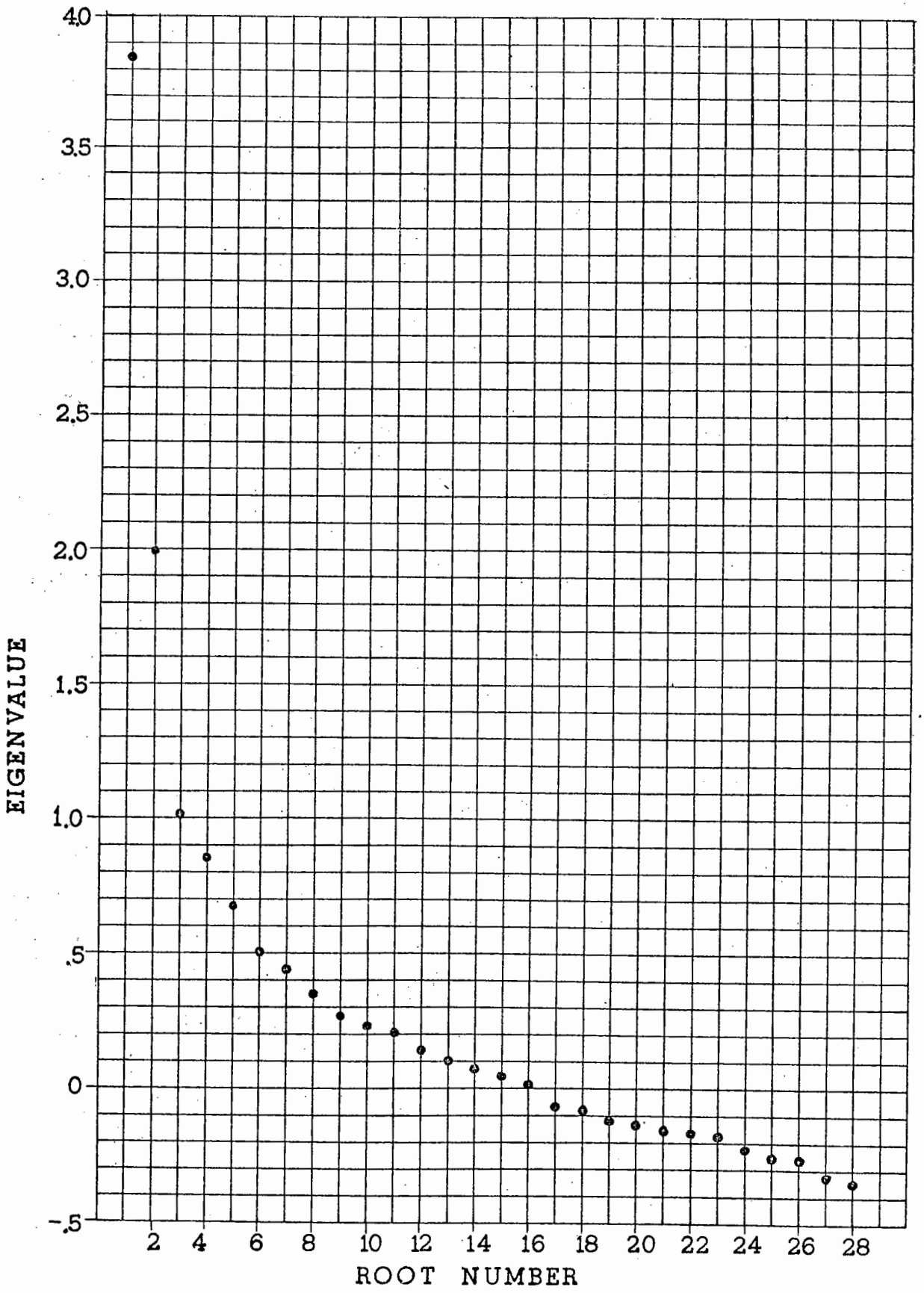

Fig. IV-1. Eigenvalue for Each of the 28 Latent Roots

Table IV-4. Matrix F_o: Unrotated Factor Coefficients of Learning Measures
(Decimals omitted)

			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
01	Word Code	c_1	-427	021	385	164	-151	-118	-109	-100	-108	-071	-129	049
02	Spatial Code		-360	044	388	036	-133	010	-118	-007	-054	-109	-040	186
03	Knob Code		-426	-003	212	181	-283	-073	116	141	005	-098	119	-079
04	Sonar		-436	042	231	220	-042	-041	185	-228	246	128	-066	-042
05	Verbal Concept Formation I		-508	006	209	114	056	211	-021	024	123	-035	-050	-082
06	Spatial Concept Formation I		-447	041	188	-045	-045	212	-277	006	-155	-007	072	148
07	Breech Block Performance Test		-100	-060	102	181	058	-238	186	-024	-299	-013	-009	-093
08	CIC Plotting Test		-539	-146	-035	-219	092	-150	058	100	005	120	039	144
09	Verbal Concept Formation II		-639	-062	046	023	078	148	216	-012	096	106	102	-019
10	Spatial Concept Formation II		-503	-085	007	-224	062	243	099	-083	-217	003	-061	-076
11	Meccano Assembly Test		-283	035	004	-355	-118	-322	001	-102	-089	-011	-062	-114
12	Sidewalk Maze		013	-758	086	031	-076	-043	004	301	-023	147	-230	-046
13	Rotary Pursuit		-009	-000	385	-183	365	-095	-137	081	072	004	110	-089
*14	Word Code	c_2	-457	-004	-160	273	-051	-074	-136	094	068	037	056	-075
*15	Spatial Code		-409	-017	-110	162	-053	-250	-196	073	117	-054	114	-143
*16	Knob Code		-325	-018	-239	169	199	-131	-242	-260	035	145	-210	059
*17	Sonar		-248	-054	-220	085	-109	-007	-204	001	-205	278	208	-018
*18	Verbal Concept Formation I		-543	-103	-227	-110	214	029	086	062	-003	-051	-099	051
*19	Spatial Concept Formation I		-481	-111	-137	-106	120	156	-041	-067	-105	-150	-094	-232
*20	Breech Block Performance Test		-166	-076	007	-500	-260	-016	-186	-029	138	050	029	-063
*21	CIC Plotting Test		-444	-024	-080	-253	042	-102	055	185	098	-127	026	086
*22	Verbal Concept Formation II		-600	-086	-255	130	060	081	159	007	-014	-005	138	111
*23	Spatial Concept Formation II		-190	-122	-368	091	-055	-089	-098	-009	079	-277	-081	095
*24	Meccano Assembly Test		-018	-038	-001	-052	-164	277	-142	-015	132	067	-062	-077
*25	Sidewalk Maze		139	-736	048	-078	016	-030	012	-361	028	-133	222	001
*26	Rotary Pursuit		-135	066	168	-192	146	-177	085	-066	066	129	-021	093
27	Sidewalk Maze	c_o	-213	942	-064	-089	037	-030	013	-008	-023	-011	001	-056
28	Rotary Pursuit		-108	083	-175	-134	-504	-000	195	-091	-004	058	-057	042

*Reflected

Table IV-5. Frequency Distribution of Twelfth Factor Residual Correlation Coefficients

Residual Coefficients	Frequency
.0600 to .0699	4
.0500 to .0599	8
.0400 to .0499	10
.0300 to .0399	29
.0200 to .0299	56
.0100 to .0199	102
+.0000 to .0099	177
-.0000 to -.0099	180
-.0100 to -.0199	128
-.0200 to -.0299	52
-.0300 to -.0399	25
-.0400 to -.0499	9
-.0500 to -.0599	4
-.0600 to -.0699	0
	Σ = 784

F. Inter-battery Factor Analysis

Tucker's recently-developed "Inter-battery Method of Factor Analysis" was employed to determine the number of common factors between the learning domain and the standard reference domain. The fundamental equations of Tucker's method are given below and discussed in terms of their application to the present study. For greater details the reader should consult Tucker's original manuscript (1958b).

Step 1. From Matrix R_{12}, which contained the correlations between the learning parameters and the reference variables, a new matrix $H_1 \equiv R_{12}R'_{12}$ was formed, so selecting R_{12} that the order of H was 28 x 28. All 28 eigenvectors and roots for H_1 were extracted by the Purdue University Statistical Laboratory using the Datatron. The eigenroots were ordered in descending order and properties of residual correlation matrices after removal of k factors were analyzed to determine the number of significant factors the two domains had in common, using Tucker's method for the number of statistically significant factors (1958b). The significant tests appear in Appendix E, and indicate that after the removal of seven factors, the residual coefficients deviated from zero on a random basis and could have arisen due to the sampling of individuals.

Step 2. Defining W_1 as a matrix of the eigenvectors for the seven accepted factors, and γ^2 as a diagonal

matrix of the eigenroots associated with H_1, matrix A_1 was defined and computed as $W_1\gamma^{\frac{1}{2}}$. In this case, matrix A_1 of order 28 x 7, which appears as Table IV-6, was the orthogonal, unrotated inter-battery factor coefficents for the learning measures. Because the scale represented by the c_2-parameters was an inverse scale, the factor coefficients were reflected and appear in reflected form in Table IV-6.

Step 3. A matrix W_2 was defined and computed as $R'_{12} W_1\gamma^{-1}$. Matrix A_2 was defined and computed as $W_2\gamma^{\frac{1}{2}}$. In this case, matrix A_2 of order 39 x 7, which appears as Table IV-7, was the orthogonal, unrotated inter-battery factor coefficient for the reference variables. Because the scale represented by scores on the Steadiness Test constituted an inverse scale, the factor coefficients for this test were reflected.

Matrices A_1 and A_2 had the properties that $R_{12} = A_1A'_2$.

G. Rotation of Axes

The unrotated factor matrices listed as Matrix F_o (Table IV-4), Matrix A_1 (Table IV-6), and Matrix A_2 (Table IV-7) were rotated to psychologically-meaningful structures. The rotational procedures which were utilized may be conveniently expressed as follows:

Let F be a generic term for the unrotated matrices,

Λ be a generic term for the transformation matrices, and

V be a generic term for the rotated matrices containing the factor coefficients.

Table IV-6. Matrix A_1: Unrotated Inter-battery Factor Coefficients of Learning Measures (Decimals omitted)

			I_1	II_1	III_1	IV_1	V_1	VI_1	VII_1
01	Word Code	c_1	-287	158	-162	-237	103	-111	-089
02	Spatial Code		-323	091	053	-045	-100	012	-025
03	Knob Code		-401	112	037	-187	-060	017	-042
04	Sonar		-258	093	-174	-067	-214	144	092
05	Verbal Concept Formation I		-508	108	-054	019	-186	-102	028
06	Spatial Concept Formation I		-309	056	-031	-151	-054	-103	-026
07	Breech Block Performance Test		-057	002	-225	-018	-011	313	154
08	CIC Plotting Test		-919	-050	-048	176	189	007	-306
09	Verbal Concept Formation II		-791	130	040	112	-262	061	100
10	Spatial Concept Formation II		-652	-106	036	156	-158	-098	112
11	Meccano Assembly Test		-466	-569	-029	-107	139	097	133
12	Sidewalk Maze		-052	034	-031	-098	031	275	-128
13	Rotary Pursuit		-036	-002	-329	353	046	136	110
*14	Word Code	c_2	-341	308	-211	-254	117	029	021
*15	Spatial Code		-436	117	-023	-155	217	044	063
*16	Knob Code		-148	225	-328	-216	190	-063	041
*17	Sonar		-107	106	-226	-121	-193	-109	-175
*18	Verbal Concept Formation I		-668	149	085	043	013	003	014
*19	Spatial Concept Formation I		-513	-074	-097	044	127	024	150
*20	Breech Block Performance Test		-364	-616	050	-209	-022	-024	-165
*21	CIC Plotting Test		-887	013	256	210	266	044	-049
*22	Verbal Concept Formation II		-657	262	214	-043	-234	014	020
*23	Spatial Concept Formation II		-182	010	183	-237	125	-043	277
*24	Meccano Assembly Test		-027	-228	103	-070	003	-125	148
*25	Sidewalk Maze		066	-049	053	-147	-078	199	-085
*26	Rotary Pursuit		-169	-195	-336	114	-085	071	-098
27	Sidewalk Maze	c_0	-167	-102	-343	159	045	-319	084
28	Rotary Pursuit		-239	-465	-132	-175	-213	-006	024

*Reflected

Table IV-7. Matrix A_2: Unrotated Inter-battery Factor Coefficients of Reference Variables (Decimals omitted)

			I_2	II_2	III_2	IV_2	V_2	VI_2	VII_2
29	Recognition II	(Ma)	-317	157	003	-064	-039	111	-140
30	First Names	(Ma)	-393	346	-023	-202	086	080	-097
31	Word-Number	(Ma)	-244	173	-223	-267	047	028	014
32	Picture-Number	(Ma)	-314	275	-175	-465	183	047	148
33	Number Series	(I)	-500	092	071	-045	-025	153	-135
34	Letter Sets	(I)	-454	077	048	-025	-125	040	-015
35	Arithmetic	(R)	-483	091	131	116	142	004	016
36	Ship Destination	(R)	-542	-038	092	-085	-058	089	-010
37	Math Aptitude	(R)	-397	-027	088	150	183	004	015
38	False Premises	(D)	-283	077	122	002	-150	-228	059
39	Reasoning	(D)	-448	176	027	007	073	-272	004
40	General Classification Test	(V)	-539	079	181	079	-126	053	052
41	36-item Vocabulary	(V)	-474	149	093	157	-252	084	041
42	Sentence Completion	(V)	-435	141	140	035	-167	000	153
43	Cards	(S)	-301	-321	051	008	-122	-010	019
44	Cubes	(S)	-073	-128	-022	-014	096	-119	-353
45	Paper Folding	(Vz)	-410	-181	122	-135	134	-109	086
46	Paper Form Board	(Vz)	-321	-352	024	-129	075	059	004
47	Mechanical	(Mk)	-367	-447	102	-243	-017	-027	008
48	G-Z Mechanical Knowledge	(Mk)	-230	-471	081	-060	-004	044	035
49	Addition	(N)	-297	134	-014	191	209	054	-114
50	Division	(N)	-374	122	068	211	221	025	-052
51	Tracing	(Ai)	-320	-193	-372	078	016	-030	-011
52	Dotting	(Ai)	-240	056	-231	-032	-129	-225	062
53	Writing X's	(Ms)	-201	048	-339	150	-062	171	139
54	Writing Digits	(Ms)	-341	059	-200	135	-027	018	-001
55	Tapping	(Ms)	-222	-181	-326	143	-161	-050	-156
56	Turning	(MD)	-301	-130	-108	034	-012	088	-010
57	Placing	(MD)	-274	-104	-191	-033	-126	-137	116
*58	Steadiness	(PC)	-107	-202	-136	091	083	263	114
59	Clerical Aptitude	(P)	-354	002	-201	080	167	-086	-012
60	Picture Discrimination	(P)	-511	-134	-099	-094	-013	008	-176
61	Words assoc. w/unf. house	(SA)	-401	104	-042	093	-027	-094	034
62	Word Checking	(SA)	-349	109	065	054	-016	-063	-010
63	AFQT	(Int)	-483	-261	163	005	023	044	-020
64	Otis	(Int)	-555	115	133	035	-002	-050	012
65	Oral Directions Test	(Int)	-490	017	-048	-060	-087	-045	-068
66	Education		-371	017	-015	067	068	081	160
67	Age		-035	-190	-017	145	322	-129	176

*Reflected

Then, from Thurstone (1947),

$$V = F\Lambda \quad \text{(IV.6)}$$

The matrix formed by pre-multiplying Λ by its transpose indicated the cosines of the angles between the reference vectors (Thurstone, 1947).

The results obtained from the rotational procedures are listed and interpreted in the next chapter.

CHAPTER V

RESULTS AND INTERPRETATIONS

This section will present the results and interpretations of the rotated oblique factor matrices.

A. The Learning Factors

The intercorrelation matrix produced from the 28 learning parameters was factor analyzed and 12 factors extracted and rotated to simple structure. The final rotated oblique structure appears in Table V-1. The cosines of the angles separating the rotated factors appear in Table V-2.

Interpretations of the rotated factors were based upon factor loadings of .25 or greater and were aided by inspections of the two-dimensional factor scattergrams. The 12 factors and interpretations are presented below. The format is arranged to give the code number for the variable, the specific learning parameter involved, the name of the learning task, and the factor coefficient; an asterisk (*) following the factor coefficient indicates that this variable had its highest factor coefficient on this factor.

Factor A

08	c_1	CIC Plotting Test	.37*
22	c_2	Verbal CF II	.32*
21	c_2	CIC Plotting Test	.30*
18	c_2	Verbal CF I	.27*
09	c_1	Verbal CF II	.25*

Interpretation: Verbal Conceptual Learning

Table V-1. Final Rotated Oblique Factor Coefficients of Learning Parameters
(Decimals omitted)

			A	B	C	D	E	F	G	H	I	J	K	L
01	Word Code	c_1	-10	06	32	02	-05	-11	05	-02	02	09	04	36
02	Spatial Code		07	01	19	04	-01	00	-07	-01	-02	-02	-04	41
03	Knob Code		-01	02	44	01	-04	-02	00	00	00	-05	-30	04
04	Sonar		01	05	46	06	-06	08	04	07	-06	-03	19	-04
05	Verbal Concept Formation I		01	-02	32	-08	14	17	-03	-05	20	06	-03	04
06	Spatial Concept Formation I		10	-05	01	-06	05	08	12	03	19	00	-04	36
07	Breech Block Performance Test		-09	07	08	-07	-04	-42	06	00	10	-01	-05	04
08	CIC Plotting Test		37	08	-06	32	03	-03	08	-05	03	03	08	05
09	Verbal Concept Formation II		25	02	22	04	02	07	02	06	20	-08	-01	-09
10	Spatial Concept Formation II		08	01	-05	02	-08	-03	-05	03	49	00	-02	07
11	Meccano Assembly Test		-03	-06	03	46	-09	-06	06	06	07	14	02	00
12	Sidewalk Maze		01	74	01	05	01	00	01	-39	-01	01	01	-03
13	Rotary Pursuit		01	-03	03	19	52	08	-04	02	-03	-08	-03	-01
*14	Word Code	c_2	-01	-02	25	-07	04	03	31	-06	02	25	-02	-06
*15	Spatial Code		-06	-03	30	10	14	05	31	03	-06	32	-07	-10
*16	Knob Code		-02	03	-04	-01	-03	-06	36	-02	03	41	48	07
*17	Sonar		01	05	-07	-05	-07	-05	49	05	08	01	02	01
*18	Verbal Concept Formation I		27	-02	-09	08	01	-06	-01	-08	25	24	08	-03
*19	Spatial Concept Formation I		-09	-02	05	-03	05	02	03	04	49	29	-05	-07
*20	Breech Block Performance Test		03	05	00	48	-04	37	04	06	01	02	-04	-02
*21	CIC Plotting Test		30	-08	00	29	07	06	-10	-05	04	13	-10	00
*22	Verbal Concept Formation II		32	01	05	-09	-10	-09	11	09	18	10	-02	-02
*23	Spatial Concept Formation II		07	04	-02	-03	-13	-03	03	03	00	44	01	03
*24	Meccano Assembly Test		-10	05	08	-04	-04	32	02	-05	09	-01	01	-03
*25	Sidewalk Maze		02	71	-01	07	01	01	00	45	00	-01	-01	-02
*26	Rotary Pursuit		17	-04	-03	29	07	-02	-04	01	-11	-09	17	03
27	Sidewalk Maze	c_0	-04	-93	04	07	-01	-01	01	00	08	04	00	-01
28	Rotary Pursuit		03	-04	07	18	-51	05	-04	03	-01	-08	-04	00

* Reflected

Table V-2. Intercorrelation Matrix of Learning Parameter Factors

		A	B	C	D	E	F	G	H	I	J	K	L
A	Verbal Conceptual Learning	1.00	.04	-.44	.22	-.09	-.04	-.26	.02	-.36	-.34	.10	.23
B	Not interpreted	.04	1.00	.05	.03	-.11	.00	.10	.01	-.12	-.08	.16	.07
C	Rote Learning for c_1 parameters: general	-.44	.05	1.00	.01	.14	.31	.03	.11	-.13	.06	-.28	-.33
D	Mechanical-Motor Learning	.22	.03	.01	1.00	.02	.25	-.01	.03	-.37	.00	.15	-.15
E	Not interpreted	-.09	-.11	.14	.02	1.00	.25	.10	.00	-.02	.08	-.21	-.28
F	Not interpreted	-.04	.00	.31	.25	.25	1.00	.00	.01	-.16	-.01	.00	-.31
G	Rote Learning for c_2 parameters	-.26	.10	.03	-.01	.10	.00	1.00	.09	-.09	.16	.26	-.12
H	Not interpreted	.02	.01	.11	.03	.00	.01	.09	1.00	.02	-.10	-.17	-.04
I	Spatial Conceptual Learning	-.36	-.12	-.13	-.37	-.02	-.16	-.09	.02	1.00	.12	-.21	-.09
J	c_2 Parameter Learning Factor	-.34	-.08	.06	.00	.08	-.01	.16	-.10	.12	1.00	.20	.00
K	Not interpreted	.10	.16	-.28	.15	-.21	.00	.26	-.17	-.21	.20	1.00	.18
L	Rote Learning for c_1 parameters: Specific to Spatial Tasks	.23	.07	-.33	-.15	-.28	-.31	-.12	-.04	-.09	.00	.18	1.00

Discussion: This factor is defined by both c_1 and c_2 parameters which may imply that subjects who learned more readily either in terms of having higher average rates of learning or learning faster during the first half of the task had more of the ability represented by Factor A than subjects who learned less readily. Variable 22, the c_2 parameters for Verbal Concept Formation II, is the most pure measure of this factor, although all of the loadings tend to be smaller than usually desired for interpretation. Verbal Concept Formation II was constructed to represent the postulated conceptual learning process. Variable 8, which has the highest loading on Factor A, also has a major loading on Factor D. Since the CIC Plotting Task was postulated to contain both conceptual and motor elements, its loading on Factor A is interpreted as stemming from conceptual processes. The tasks loading on this factor have an additional common element in that each involved the use of words. Factor A is thus interpreted as Verbal Conceptual Learning.

Factor B

27	c_0	Sidewalk Maze	-.93*
12	c_1	Sidewalk Maze	.74*
25	c_2	Sidewalk Maze	.71*

Interpretation: Not interpretable.

Discussion: Specific to Sidewalk Maze.

Factor C

04	c_1	Sonar	.46*
03	c_1	Knob Code	.44*
01	c_1	Word Code	.32
05	c_1	Verbal Concept Formation I	.32*
15	c_2	Spatial Code	.30
14	c_2	Word Code	.25

Interpretation: Rote Learning for Rate of Learning Measures: General.

Discussion: This appears to be a relatively clearly defined Rote Learning Factor for c_1 Measures. With the exception of Spatial Concept Formation I, all tasks postulated to have loadings on this factor do so. This factor is also interesting in that it is common to tasks which vary in content and sensory modality. However, in view of Factor L which appears to be a rote learning factor specific to the rate of learning spatial material, Factor C may disappear if a test battery includes additional learning situations based upon sensory modalities and verbal materials.

Factor D

20	c_2	Breech Block Performance Test	.48*
11	c_1	Meccano Assembly Test	.46*
08	c_1	CIC Plotting Test	.32
21	c_2	CIC Plotting Test	.29
26	c_2	Rotary Pursuit	.29*

Interpretation: Mechanical-Motor Learning.

Discussion: This factor is not easily interpreted. Variable 20 also has major loading on Factor F; Variable 11 is a relatively pure measure of Factor D. Although the above tasks were postulated to have loadings on the Motor Learning factor, the absence of a mechanical learning factor may warrant considering Factor D to involve both motor and mechanical components. Factor D is thus interpreted as a Mechanical-Motor Learning factor.

Factor E

13	c_1	Rotary Pursuit	.52*
28	c_0	Rotary Pursuit	-.51*

Interpretation: Not interpretable.

Discussion: Specific to Rotary Pursuit.

Factor F

07	c_1	Breech Block Performance Test	-.42*
20	c_2	Breech Block Performance Test	.37
24	c_2	Meccano Assembly Test	.32*

Interpretation: Not interpretable.

Discussion: Factor F may involve a conceptual process specific to mechanical tasks. However, this factor is not interpreted because the factor loadings for the c_1 and c_2 parameters for the Breech Block Performance Test were opposite in sign.

Factor G

17	c_2	Sonar	.49*
16	c_2	Knob Code	.36
15	c_2	Spatial Code	.31
14	c_2	Word Code	.31*

Interpretation: Rote Learning for "Early versus Late" parameters.

Discussion: Relatively clearly defined factor involving like parameters and transcending content and modality. Counterpart of Factor C.

Factor H

25	c_2	Sidewalk Maze	.45
12	c_1	Sidewalk Maze	-.39

Interpretation: Not interpretable.

Discussion: Specific to Sidewalk Maze

Factor I

10	c_1	Spatial Concept Formation II	.49*
19	c_2	Spatial Concept Formation I	.49*
18	c_2	Verbal Concept Formation I	.25

Interpretation: Spatial Conceptual Learning.

Discussion: This factor seems to represent clearly the conceptual processes. In view of the interpretation of Factor A as Verbal Conceptual Learning and in view of the high loadings originating from spatial material, Factor I is interpreted as a Spatial Conceptual Learning Factor.

Factor J

23	c_2	Spatial Concept Formation II	.44*
16	c_2	Knob Code	.41
15	c_2	Spatial Code	.32*
19	c_2	Spatial Concept Formation I	.29
14	c_2	Word Code	.25

Interpretation: "Early vs. Late" Learning Factor.

Discussion: This factor has the very desirable characteristic that like parameters from several learning tasks define it. Variable 23 is a relatively pure measure of this factor; the remaining variables also have loadings on other factors. Four of the variables were postulated to represent rote learning but Spatial Concept Formation II was designed especially to prevent learning by rote processes. Four of the tasks involve spatial abilities. It thus appears that this factor is neither rote nor conceptual but tends to be found in learning tasks with spatial

content. The underlying common element seems to be related with the c_2 parameter. Hence, Factor J is interpreted as an "Early vs. Late" learning factor, probably oriented towards spatial material. Factor J is probably a counterpart of Factor L.

Factor K

16	c_2	Knob Code	.48*
03	c_1	Knob Code	-.30

Interpretation: Not interpretable.

Discussion: Specific to Knob Code.

Factor L

02	c_1	Spatial Code	.41*
06	c_1	Spatial Concept Formation I	.36*
01	c_1	Word Code	.36*

Interpretation: Rote learning for Rate of Learning Measures: Specific to Spatial Tasks.

Discussion: Clearly defined rote learning factor associated with c_1 parameters of spatial tasks. Variables 2 and 6 are relatively pure measures of Factor L. Variable 1 also loads on Factor C.

The results and interpretations presented above suggest that learning lacks both the simplicity and clarity offered by the formulation in the opening chapter. In terms of the interpretations given to the learning factors, two of the postulated three learning processes did appear but split further factorially on the basis of at least content and parameter. Rote learning factors pointed most clearly to this probability.

B. The Inter-battery Factors

Application of the inter-battery method of factor analysis to the 28 x 39 sub-matrix of correlations between the learning parameters and the reference test produced seven factors in common between these two domains. The matrix of inter-battery factor coefficients for the learning parameters was rotated to simple structure. The rotated factor coefficients appear in Table V-3, and the cosines of the angles separating the factors appear in Table V-4. The matrix of the inter-battery factor coefficients for the reference variables was treated similarly and the results appear in Tables V-5 and V-6.

Basically, the inter-battery method provided a better method for studying possible properties of learning parameters than did a factor analysis of learning parameters. The reason for this lies in the fact that the factor analysis of learning parameters had an unknown amount of experimental dependency in the variables whereas in the inter-battery analysis of the two domains the experimental dependency within domains was mathematically non-contributory. In terms of the learning parameters, the inter-battery method yielded the factorial composition of the parameters; that is, the c_1-parameter for one task may have been a better measure of some factor than the c_2-parameter, and vice versa. In other words, the inter-battery method enabled the investigator to decide which parameter best exhibited a factor.

Factors M through S were the rotated inter-battery factors for the learning parameters. Interpretations of these factors were based upon

Table V-3. Final Rotated Oblique Inter-battery Factor Coefficients of Learning Parameters
(Decimals omitted)

			M	N	O	P	Q	R	S
01	Word Code	c_1	04	02	39	-09	05	03	-06
02	Spatial Code		29	02	05	-03	-01	-07	-04
03	Knob Code		28	08	19	-06	01	-11	-03
04	Sonar		27	11	12	21	-18	-08	-10
05	Verbal Concept Formation I		45	02	09	-02	-07	09	-07
06	Spatial Concept Formation I		18	08	19	-10	-02	03	-04
07	Breech Block Performance Test		01	13	07	40	-06	-14	01
08	CIC Plotting Test		45	07	08	01	56	00	-16
09	Verbal Concept Formation II		74	04	-04	11	-05	-03	-03
10	Spatial Concept Formation II		52	13	-12	02	05	16	04
11	Meccano Assembly Test		02	57	-04	16	33	03	17
12	Sidewalk Maze		-01	08	08	15	10	-29	-11
13	Rotary Pursuit		02	-08	-10	40	04	15	-04
*14	Word Code	c_2	12	-04	46	06	-02	-05	01
*15	Spatial Code		15	03	25	03	16	-03	16
*16	Knob Code		-10	-03	47	06	-02	10	02
*17	Sonar		09	05	25	-05	-13	02	-30
*18	Verbal Concept Formation I		49	-05	06	-01	14	-01	06
*19	Spatial Concept Formation I		23	12	07	15	17	11	15
*20	Breech Block Performance Test		-02	63	-02	-09	32	-05	-11
*21	CIC Plotting Test		53	-06	-11	-03	51	-02	19
*22	Verbal Concept Formation II		68	-06	03	-10	-08	-13	00
*23	Spatial Concept Formation II		06	07	10	-10	-03	02	36
*24	Meccano Assembly Test		-04	18	-07	-10	00	12	17
*25	Sidewalk Maze		-03	14	01	06	-01	-26	-09
*26	Rotary Pursuit		02	22	04	25	08	06	-25
27	Sidewalk Maze	c_0	-02	03	11	02	01	46	-03
28	Rotary Pursuit		04	56	02	07	00	03	-12

*Reflected

Table V-4. Intercorrelation Matrix of Inter-battery Learning Parameter Factors

	M	N	O	P	Q	R	S
M Conceptual Learning	1.00	-.19	-.32	.02	-.32	-.11	-.09
N Mechanical-Motor Learning	-.19	1.00	.12	.20	.04	-.19	-.14
O Rote Learning	-.32	.12	1.00	-.10	-.10	.03	-.13
P Control Precision	.02	.20	-.10	1.00	-.04	-.24	-.01
Q Deferred	-.32	.04	-.10	-.04	1.00	-.13	.01
R Deferred	-.11	-.19	.03	-.24	-.13	1.00	.26
S Deferred	-.09	-.14	-.13	-.01	.01	.26	1.00

Table V-5. Final Rotated Oblique Inter-battery Factor Coefficients of Reference Tests (Decimals omitted)

			T	U	V	W	X	Y	Z
29	Recognition II	(Ma)	23	-01	12	-03	-01	-05	19
30	First Names	(Ma)	19	-09	34	04	-06	-02	17
31	Word Number	(Ma)	03	01	38	-05	13	03	08
32	Picture Number	(Ma)	-02	05	63	00	02	01	-02
33	Number Series	(I)	29	10	10	02	-02	-09	20
34	Letter Sets	(I)	25	07	04	-01	03	05	06
35	Arithmetic	(R)	09	05	02	29	-04	02	-01
36	Ship Destination	(R)	23	24	09	01	00	-01	08
37	Math Aptitude	(R)	00	10	-02	31	01	-02	-02
38	False Premises	(D)	08	00	-08	02	-04	29	-10
39	Reasoning	(D)	-04	-04	07	23	02	21	-04
40	General Classification Test	(V)	31	08	-05	08	-04	05	-02
41	36-item Vocabulary	(V)	40	-05	-12	-01	06	05	-01
42	Sentence Completion	(V)	28	01	-01	03	-02	11	-13
43	Cards	(S)	06	35	-13	-04	09	04	01
44	Cubes	(S)	-12	11	-06	03	00	05	32
45	Paper Folding	(Vz)	-09	35	10	16	-05	10	-07
46	Paper Form Board	(Vz)	-05	45	07	02	05	-07	06
47	Mechanical	(Mk)	-04	59	05	-08	-01	03	05
48	G-Z Mechanical Knowledge	(Mk)	-05	50	-08	-02	04	-06	00
49	Addition	(N)	03	-10	02	30	04	-07	11
50	Division	(N)	03	-06	-01	36	-01	-04	04
51	Tracing	(Ai)	-09	15	05	08	45	05	08
52	Dotting	(Ai)	-03	-03	06	-02	27	30	-05
53	Writing X's	(Ms)	12	-09	08	04	39	-10	-05
54	Writing Digits	(Ms)	09	-05	03	10	27	04	04
55	Tapping	(Ms)	02	07	-12	-07	42	09	19
56	Turning	(MD)	07	17	03	03	18	-06	07
57	Placing	(MD)	-02	13	04	-03	27	20	-08
*58	Steadiness	(PC)	02	17	05	07	19	-27	-03
59	Clerical Aptitude	(P)	-12	03	10	25	24	09	03
60	Picture Discrimination	(P)	09	27	10	00	16	03	24
61	Words assoc. w/unf. house	(SA)	08	-03	01	14	13	15	-03
62	Word Checking	(SA)	11	-01	-01	11	00	11	01
63	AFQT	(Int)	09	38	-06	10	-02	-03	05
64	Otis	(Int)	18	06	03	17	-03	12	00
65	Oral Directions Test	(Int)	15	13	07	00	12	12	12
66	Education		08	08	08	18	10	-04	-11
67	Age		-35	13	-02	38	07	04	-22

*Reflected

Table V-6. Intercorrelation Matrix of Inter-battery Reference Test Factors

	T	U	V	W	X	Y	Z
T Intellectual Ability	1.00	-.17	-.16	-.53	-.14	-.35	.23
U Generalized Mechanical Ability	-.17	1.00	.11	-.16	-.08	-.16	.05
V Rote Memory	-.16	.11	1.00	-.04	.03	-.20	.02
W Numerical Ability	-.53	-.16	-.04	1.00	-.01	.03	-.32
X Wrist-Finger Speed	-.14	-.08	.03	-.01	1.00	.12	.00
Y Deferred	-.35	-.16	-.20	.03	.12	1.00	-.27
Z Deferred	.23	.05	.02	-.32	.00	-.27	1.00

factor loadings of .25 or more. The seven factors and their interpretations are presented below. The format is the same as outlined in Section A above.

Factor M

09	c_1	Verbal Concept Formation II	.74*
22	c_2	Verbal Concept Formation II	.68*
21	c_2	CIC Plotting Test	.53*
10	c_1	Spatial Concept Formation II	.52*
18	c_2	Verbal Concept Formation I	.49*
08	c_1	CIC Plotting Test	.45
05	c_1	Verbal Concept Formation I	.45*
02	c_1	Spatial Code	.29*
03	c_1	Knob Code	.28*
04	c_1	Sonar	.27*

Interpretation: Conceptual Learning.

Discussion: This is by far the clearest representation of the postulated conceptual learning process. With the exception of the Breech Block Performance Test and Meccano Assembly Tests, all tasks postulated to involve conceptual processes do so. There is a sharp discontinuity between the factor coefficients for conceptual and rote tasks. The failure of the two mechanical tests to load on this factor suggests the possibility of a mechanical conceptual factor. Factor M is interpreted as a Conceptual Learning Factor. It may also be noted that Factor M is defined by those variables which defined Factors A (Verbal Conceptual Learning) and I (Spatial Conceptual Learning).

Factor N

20	c_2	Breech Block Performance Test	.63*

11	c_1	Meccano Assembly Test	.57*
28	c_0	Rotary Pursuit	.56*

Interpretation: Mechanical-Motor Learning.

Discussion: This factor seems to be essentially the same factor as Factor D defined earlier as Mechanical-Motor Learning. The high loading for the c_0 parameter for the Rotary Pursuit, which represents initial ability, clarifies the motor component not only in Factor N but also Factor D.

Factor O

16	c_2	Knob Code	.47*
14	c_2	Word Code	.46*
01	c_1	Word Code	.39*
15	c_2	Spatial Code	.25*
17	c_2	Sonar	.25

Interpretation: Rote Learning.

Discussion: Clearly defined rote factor. The absence of loadings for parameters from the Verbal Conceptual Formation I and Spatial Conceptual Formation I supports the testing observation that most subjects solved these tasks using conceptual processes rather than taking advantage of the rote learning elements. This factor is essentially the same as Factor G.

Factor P

07	c_1	Breech Block Performance Test	.40*
13	c_1	Rotary Pursuit	.40*
26	c_2	Rotary Pursuit	.25*

Interpretation: Control Precision.

Discussion: Inasmuch as the c_1 parameters reflect rate of learning on an assembly task and the Rotary Pursuit task appears void of conceptual properties, this factor apparently requires precision of arm, wrist, and finger movements. This factor is interpreted as Control Precision.

Factor Q

08	c_1	CIC Plotting Test	.56*
21	c_2	CIC Plotting Test	.51
11	c_1	Meccano Assembly Test	.33
20	c_2	Breech Block Performance Test	.32

Interpretation: Deferred.

Discussion: This factor resembles Factor D described earlier as Mechanical-Motor Learning except that the mechanical tasks have smaller loadings. However, the relatively high loadings for parameters of the CIC Plotting Test may warrant interpreting Factor Q as a doublet factor specific to the CIC Plotting Test.

Factor R

27	c_0	Sidewalk Maze	.46*
12	c_1	Sidewalk Maze	-.29*
25	c_2	Sidewalk Maze	-.26*

Interpretation: Deferred.

Discussion: This factor by itself is not interpretable due to the fact that it is defined solely on the basis of the Sidewalk Maze. However, since Factor R is an inter-battery factor its interpretation may be possible by the characteristics of its counterpart among the inter-battery factors for the reference variables. Factor R is essentially the same as Factor B.

Factor S

23	c_2	Spatial Concept Formation II	.36*
17	c_2	Sonar	-.30*
26	c_2	Rotary Pursuit Test	-.25

Interpretation: Deferred.

Discussion: What these three tasks have in common is not readily apparent. One might speculate an underlying common element to involve spatial orientation but the negative loadings of variables 17 and 26 are difficult to incorporate into such an interpretation.

Factors T through Z were the rotated inter-battery factors for the reference variables. Interpretations of these factors were based upon factor loadings of .25 or more and the known factorial composition of the variables as described in Chapter II. The format is arranged to give the code number of the variable, the abbreviation of its factor composition, the name of the reference variable, and the factor coefficient; an asterisk (*) following the factor coefficient indicates that this variable had its highest factor coefficient on this factor.

Factor T

41	(V)	36-item Vocabulary	.40*
67		Age	-.35
40	(V)	General Classification Test	.31*
33	(I)	Number Series	.29*
42	(V)	Sentence Completion	.28*
34	(I)	Letter Sets	.25*

Interpretation: Intellectual Ability.

Discussion: This factor is a composite of verbal ability and induction. The emphasis for interpretation will be placed upon the tests which measure induction, a thinking activity, and treat vocabulary level as a concomitant variable which yields higher factor loadings by virtue of greater reliability.

Factor U

47	(Mk)	Mechanical Test	.59*
48	(Mk)	G-Z Mechanical Knowledge	.50*
46	(Vz)	Paper Form Board	.45*
63	(Int)	AFQT	.38*
43	(S)	Cards	.35*
45	(Vz)	Paper Folding	.35*
60	(P)	Picture Discrimination	.27*

Interpretation: Generalized Mechanical Ability.

Discussion: This factor is a composite of mechanical-visualization spatial abilities with a slight speed component. Since most mechanical assembly tests, such as found among the learning tasks, have these abilities entering into the final performance, Factor U is interpreted as a Generalized Mechanical Factor.

Factor V

32	(Ma)	Picture-Number	.63*
31	(Ma)	Word-Number	.38*
30	(Ma)	First Names	.34*

Interpretation: Rote Memory.

Discussion: Clearly defined rote factor. Three of the four reference tests of rote memory have loadings on this factor.

Factor W

67		Age	.38*
50	(N)	Division	.36*
37	(R)	Math Aptitude	.31*
49	(N)	Addition	.30*
35	(R)	Arithmetic	.29*
59	(P)	Clerical Aptitude	.25*

Interpretation: Numerical Ability.

Discussion: Although variables 37 and 35 are considered to be measures of reasoning, they also are numerical in content. The common element underlying this factor is clearly numerical ability.

Factor X

51	(Ai)	Tracing	.45*
55	(Ms)	Tapping	.42*
53	(Ms)	Writing X's	.39*
52	(Ai)	Dotting	.27
54	(Ms)	Writing Digits	.27*
57	(MD)	Placing	.27*

Interpretation: Wrist-Finger Speed.

Discussion: Clearly defined composite of several identified abilities in the field of psychomotor coordination which emphasize speed of wrist and finger coordination.

Factor Y

39	(D)	Reasoning	.31*
52	(Ai)	Dotting	.30*
38	(D)	False Premises	.29*
58	(PC)	Steadiness	-.27*

Interpretation: Deferred.

Discussion: This factor appears to involve deductive elements but the appearance of variable 52 is alarming because of its apparent lack of deduction. Clarification of this factor may be possible in terms of a related inter-battery factor defined by the learning parameters.

Factor Z

44	(S)	Cubes	.32*
60	(P)	Picture Discrimination	.24
67		Age	-.22

Interpretation: Deferred.

Discussion: This factor has a factor coefficient which is .25 or more on only the Cubes test. Addition of variables 60 and 67 does not clarify this factor's identification. Interpretation is possible only if this factor is related to a well identified inter-battery factor for the learning parameters.

With rotations to simple structure, application of the inter-battery method of factor analysis has resulted in the interpretations of two sets of inter-battery factors--namely, Factors M through S and Factors T through Z, which have been discussed above. The inter-battery method also permits the calculation of the correlations between the rotated inter-battery factors, (Tucker, 1958b). The inter-battery factor correlations, which appear in Table V-7, indicate the relationships found between the learning domain and the human ability domain. By applying multiple regression techniques, it would be possible to define each learning parameter factor as a composite of the reference factors, and vice versa.

Table V-7. Inter-battery Factor Correlation Coefficients

Reference Tests Factors		Learning Parameters Factors						
		M	N	O	P	Q	R	S
		Conceptual Learning	Mechanical-Motor Learning	Rote Learning	Control Precision	Deferred	Deferred	Deferred
T	Intellectual Ability	.7419	.1562	.3489	.0355	.3796	.1031	.1617
U	Generalized Mechanical Ability	.4959	.6008	.1542	-.0471	.4717	.1904	.1927
V	Rote Memory	.4082	-.0290	.6179	.0277	.1837	-.0971	.2952
W	Numerical Ability	.6444	.0865	.3449	.0671	.5771	.1888	.2230
X	Wrist-Finger Speed	.2175	.2636	.0674	.3484	.2175	.2745	-.1524
Y	Deferred	.6785	.1628	.4072	-.1792	.3120	.1542	.1217
Z	Deferred	.3194	.0202	.2844	-.0608	.4082	.0565	-.1162

The remainder of this section will be devoted to a comparison of the inter-battery factors in which the learning parameter factors are expressed as functions of the reference factors.

Factor M (Conceptual Learning) is related to most of the reference factors, particularly to Factor T (Intellectual Ability), Factor W (Numerical Ability), and Factor Y (Deferred). The unifying characteristic of these inter-battery factors is that the process of conceptualization or thinking is required.

Factor N (Mechanical Learning) is primarily related to Factor U (Generalized Mechanical Knowledge). Inasmuch as Factor N has low correlations with Factor T (.16) and Factor X (Finger-Wrist Speed, .26), it would appear that Factor N is specific to mechanical tasks. Its corresponding reference factor, which is Factor U (Generalized Mechanical Knowledge), does however depend in part upon conceptual processes.

Factor O (Rote Learning) corresponds to Factor V (Roté Memory) which reflects the rote process as a common element. The relationship between Factor O and Factor Y (Deferred) does not aid in the interpretation of Factor Y.

Factor P (Psychomotor Coordination) and Factor X (Wrist-Finger Speed) are corresponding inter-battery factors. The low correlation between them (.35) is probably due to the fact that the reference factor was primarily based upon speed of wrist and finger coordination whereas the learning factor involved other aspects of the general area of psychomotor coordination.

Factor Q (Deferred) is related to Factor W (Numerical Ability), Factor U (Generalized Mechanical Knowledge), and Factor Z (Deferred). The unifying characteristic between Factor Q and the reference factors is sufficiently obscure to raise doubts that Factor Q represents motor learning. Dr. Edwin A. Fleishman has commented that Factor Q may represent a "numerical facility" learning factor in view of his experience with U. S. Air Force plotting tests and their relationships with number ability. Since Factor Q was defined primarily by parameters for the CIC Plotting Test, it now appears appropriate to redefine Factor Q as not interpretable but future investigations of this factor may lend support to Dr. Fleishman's suggestion.

Factors R and S of the learning parameter factors and Factors Y and Z of the reference factors, for which interpretations were deferred earlier in this chapter, are not clarified further by the inter-battery correlations. The high correlation between Factor Y and Factor M (Conceptual Learning) suggests that Factor Y is closely related to processes which involve conceptualization, and, to a lesser degree, to rote processes as involved in Factor O (Rote Learning).

CHAPTER VI

SUMMARY AND IMPLICATIONS

A. Summary

The purpose of this study was to explore the interrelationships among learning parameters and also the interrelationships between learning parameters and measures of human abilities. Thirteen learning situations were selected to evaluate possible psychological organizations within a domain of human learning. A mathematical model was adopted which permitted each subject's performance on each learning task to be expressed by a rate parameter which described the average rate of learning and a curvature parameter which indicated whether the learning was faster during the first or second half of the situation. The nature of two of the learning tasks allowed the addition of a third parameter which described the initial ability of the subject. Thirty-nine reference variables were included in the study to assess potential relationships between the learning domain and the domain of human abilities. Factor analytic techniques were used to organize the interrelationships into more meaningful dimensions based upon common factor variances. Two general conclusions resulted from the analyses:

1. The factorial organization of the learning parameters defined herein was multidimensional. Therefore learning, within the limits of this investigation, was not a unitary trait or ability but contained several factors or abilities which were dependent upon the psychological process involved in the learning task and the content of the material to be learned.

2. Measures of learning and measures of aptitude and achievement, which have generally been treated experimentally as separate entities, have factors in common with each other. These factors were dependent upon the similarity of the psychological processes and the contents of the materials involved in the various learning tasks or reference variables.

A number of conclusions resulted from the two factor analytic techniques employed. The first technique was a conventional multiple-factor analysis of the intercorrelation matrix for the 28 learning parameters. Twelve factors were extracted and rotated to simple structure. Five of these factors were discarded because of specificity or idiosyncratic factor loadings. The seven interpreted learning parameter factors were defined as follows:

1. Verbal Conceptual Learning. This factor was based upon both rate and curvature parameters and involved situations which required the learning of relationships among words.

2. Spatial Conceptual Learning. This factor was based upon both rate and curvature parameters and involved situations which required the learning of relationships among spatial configurations.

3. Mechanical-Motor Learning. This factor was based upon both rate and curvature parameters and involved situations which required the learning of mechanical principles and psychomotor skills.

4. Rote Learning. Three rote learning factors were found. Two of these factors were defined by the rate parameter and the curvature parameter and were independent of the content of sensory modality

involved. The third rote factor was defined by the rate parameter obtained from situations which involved learning simple spatial material.

5 "Early versus Late" Learning. This factor was derived from the curvature parameter for situations which generally involved learning spatial material.

The second technique was a recently developed method which would determine the number of factors in common between the learning curve parameters and the reference variables. The inter-battery factor analysis produced seven factors which coupled the two domains and which could be described in terms of either the learning curve parameters or the reference variables. The resulting two sets of factors were each rotated to simple structure and the intercorrelations between the two sets of rotated factors were obtained. Thus, within the limits of the common factor variances, the inter-battery learning parameter factors could be expressed as functions of the inter-battery reference factors, and vice versa. Four of the seven inter-battery factors were relatively clearly defined and yielded satisfactory correspondence. The inter-battery factors which were represented by either learning parameters or reference variables may be summarized as follows:

1. Conceptual Process Factor. This is an inter-battery factor in which the process of thinking or conceptualization was dominant.

2. Rote Process Factor. This is an inter-battery factor in which a rote memory process was required.

3. Mechanical Factor. This is an inter-battery factor primarily found in activities which utilized mechanical principles. This factor also had a subtle dependency upon conceptual processes.

4 Psychomotor Coordination Factor. This is an inter-battery factor for tasks which involved precision and speed of arm, wrist, and finger movements.

B. Implications

Part of the importance of any study lies beyond the province of data and results. In the opening chapter it was postulated that human abilities are manifestations of on-going learning processes. It was stressed that human learning can be measured along many points of the learning curve itself--after one trial, after maximum performance has been reached, or even after learning has deteriorated as in forgetting or old age. Most conventional psychological and educational tests are defined by one point along their respective learning curves. The domains of human ability and learning were not conceptualized as independent and unrelated areas but as two ways of investigating essentially the same behavior. The results which were presented indicate that the two are interrelated.

Granted that overt behavior is the end-product of psychological processes whose existence is inferred, experimental support for these processes became most apparent with the inter-battery method of factor analysis. This method may prove invaluable to future investigators seeking unification of psychological functions and neurophysiological activities.

The results of this study emphasize that a theory of human learning is inadequate if it does not include the doctrine of individual differences and the multidimensional nature of learning.

Although the use of learning parameters extends the boundaries of psychometric investigations, it also presents some challenging problems. For example, since the nature of factor analytic results based upon learning parameters will depend in part upon the nature of the learning parameters, considerable explorations of different mathematical functions will be necessary. [Such studies should also include factor analyses of both within-task and between-task designs.] Although numerous difficulties would be encountered in the interpretations of factors, there is the possibility that different mathematical functions would be required to describe an individual's performances on several different learning tasks.

Another problem will arise when an attempt is made to develop a suitable concept of reliability for measures of learning. It would appear that an adequate concept should have the characteristics that, as a special case, it reduces to current concepts of reliability and that it allows for the effects of transfer of training or practice.

In summary, it appears that the ability to apply knowledge and the acquisition of knowledge have highly similar or identical properties. Further theoretical refinements are needed to bring modern learning theory and psychometric theory together.

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Appendix A: Learning Tasks and Directions

APPENDIX A

Introductory Note

The study of human learning in this project was possible only through the adoption of group-testing procedures. Descriptions of what the subjects had to do consequently required considerable augmenting as to how to record and score their performance. In order not to distract from the directions specific to each learning task employed in this study, the procedures for recording and scoring performance are committed to this introductory note and were imbedded appropriately within the directions for each learning task described later in this Appendix.

Six of the learning tasks were administered by projecting 35 mm. black-and-white slides on a screen. These tasks were Word Code, Spatial Code, Verbal Concept Formation I and II, and Spatial Concept Formation I and II. These tasks were administered in a room which was large enough to accommodate 70 subjects and which could be darkened in order that each subject could easily see what he was writing and also the learning material projected on the screen. He was told to print his name, service number, and company number on the Answer Sheet, and to stand by for specific instructions. The Revere 888 Automatic Slide Projector was used to present the learning material and allowed a stimulus slide to be projected for seven seconds and then a stimulus-response slide to be projected for seven seconds. The projector required approximately three seconds to change slides. Each task has 16 sets of stimulus and stimulus-response slides per trial. In addition to an Answer Sheet (see sample for Word Code), each subject

had a deck of color-coded 1 x 4 inch response slips which were ordered white, blue, pink, green, white, blue, pink, green, etc. The procedures for administering these six learning tasks were as follows: Stimulus Slide No. 1 was projected for the seven seconds mentioned; the subject wrote on a colored response slip the response (letter) he thought belonged to the stimulus; before or during the three-second period to change slides, he removed the response slip from the deck and placed it on a spindle located immediately in front of him; when the stimulus-response slide appeared he marked his Answer Sheet right (R) or wrong (W) as the case may have been. This procedure was continued throughout each trial. Since the subject had no prior knowledge of or practice on each learning task he had to make a guess for each response until he thought he knew what the correct response was. The person administering the task and the people who served as proctors were responsible for the subjects' keeping pace with the projector. After each trial the subjects were told to total the numbers of right and wrong responses and to record these numbers in the appropriate spaces on their Answer Sheets. The Answer Sheets and response slips were collected after each learning task had been completed.

The Knob Code learning task was administered in a large room which contained eight tables which were approximately 4 1/2 x 9 x 4 feet. For this task the subjects had to learn the names of eight knobs and were given eight trials to accomplish this. The tables "corresponded" to trials--that is, eight knobs were presented one at a time at one

table; the next table contained the same eight knobs but presented in a different order; the next table had the knobs presented in another order, etc. With eight tables each containing eight stations, as many as 64 subjects could be assessed at the same time. (Note that this arrangement meant that the order of presentation of the material to be learned varied for each subject.) Each station consisted of a cardboard box (approximately 16 x 24 x 10 inches) with a black cloth hanging down in front and a stimulus knob located inside opposite the black curtain. The subjects were thus able to feel but not to see each stimulus knob. On top of each box but underneath a 5 x 8 inch card was printed the correct identity of the knob. After printing his name, service number, company number and station number on an Answer Sheet, the subject was informed of the nature of the learning task. Then on command of the test administrator the subject inserted his hand into a box, felt the knob, printed what he thought to be the correct identification on his Answer Sheet, lifted the card exposing the correct answer, marked his answer sheet right (R) or wrong (W), and shifted to the next station. This procedure was repeated for each of the eight stations; after which, the subject recorded the total numbers of right and wrong answers on the bottom of his Answer Sheet. The eight subjects at each table moved to the next table and took up the same station positions which they had at the beginning of the first trial. This procedure of shifting around each table and to another table continued for the eight trials. Answer Sheets were collected at the end of the eight trials.

The Sonar learning task was conducted in two large rooms which could each seat a company of recruits. The stimulus sounds were presented by a tape recorder which contained two 5-inch speakers for use in one of the rooms and an external 12-inch speaker for use in the second room. It was felt that the differences in the two speaker systems would have trivial consequences upon the performance scores for this task. Except for directions, this task was entirely programmed on the tape recording. The subjects were told that they would hear a stimulus sound of 10-seconds' duration and that during that period and the silence period of 10 seconds which followed, they were to indicate on their Answer Sheets the identity of the sound. The correct identification then appeared on the tape recording and they marked their Answer Sheet right (R) or wrong (W) accordingly. They repeated this procedure for 10 stimulus and response sounds per trial. The tape recording contained 60-seconds of silence between trials which was ample time for the subjects to record the total numbers of right and wrong responses for each given trial on their Answer Sheets. Answer Sheets were collected at the completion of the task.

The Breech Block Performance Test was also administered in a large room of which one end had been set aside for projecting a 16 mm. training film with sound depicting the assembly operations and the other end had been set up with 32 private stalls within which the subjects could attempt to put the parts of the breech block together. The subjects spent two minutes viewing the training film and then reported to one of the stalls, filled out the Answer Sheets, and stood

by for the start signal. One proctor observed and rated the performances of two subjects. After a three-minute assembly period the subjects were told to stop and return to the other end of the room to see the training film a second time. While the subjects watched the film for the second time, the proctors recorded the subjects' scores, disassembled their work, and set the parts out once again in the standard layout positions. The subjects returned to the same stalls and the second assembly period started. This procedure was continued for six trials.

The Meccano Assembly Test was administered in a manner paralleling the Breech Block Performance Test. The subjects sat at one end of the room and observed the instructional material which consisted of a set of 35 mm. slides and an accompanying sound track. After the instructional material the subjects took their positions in the stalls at the other end of the room and were given five minutes to construct the specified apparatus. As in the case for the Breech Block Performance Test, this procedure was repeated for a number of trials.

The Combat Information Center Plotting Test was administered to a company of men at a time. The testing material consisted of a test booklet containing ten trials and a sheet of carbon paper which the subject inserted between the response grids and the scoring sheets. The directions and stimulus locations were presented by tape recording which included a sample set to help convey the directions and to acquaint the subject with the use of the carbon sheet and scoring

procedures. After each trial the subject counted up the number of crosses which appeared within the red circles on the scoring sheet and recorded this number on the face sheet of the test booklet.

The Sidewalk Maze was administered to four men at a time. Each subject received a test packet containing seven identical mazes with scoring sheets under each maze. The sidewalk maze along which the subject traced had a carbon underlay which transmitted a tracing to the Answer Sheet as long as the subject remained within the 1/4-inch pathway. The subject was given 30 seconds to trace through the maze as fast as he could. The subject then determined how far he travelled before getting off the path or having to retrace from the distance grid indicated on the scoring sheet. He copied his score for that trial on the face sheet of the test packet and was given another 30-second trial. This procedure continued for the remaining trials.

The Rotary Pursuit Test was administered to four men at a time. Each test unit was connected to a console panel which contained recording clocks for each subject's performance. The clocks were calibrated to indicate the amount of time in thousandths of a minute the stylus was in contact with the revolving disc. The test equipment normally is programmed to give the subjects five 20-second trials with 10-second rest periods in between trials. A slight temporary modification was made in this study to produce fifteen 20-second trials with 10-second rest periods. Proctors were trained to read and record the time during each rest period, one proctor was responsible for two clocks. Cumulative time scores per trial were recorded during the test administration and were later converted to the amount of time in contact per trial.

DIRECTIONS FOR WORD CODE

"I'm going to project sixteen slides with words on them similar to this one." (Project Stimulus Slide No. 1.) "Each word has a letter assigned to it--like this." (Project Stimulus-Response Slide No. 1.) "You are to learn which letter goes with each word. This task is very similar to learning semaphore except words are used instead of arm positions. Tear off the white sheet of paper from Deck 1 and place it on the spindle. On your Answer Sheet under Trial 1 for Number 1 draw a circle around the letter W for a wrong response. I will show you another slide." (Project Stimulus Slide No. 2.) "This time I want you to guess which letter you think goes with this slide. Print this letter as a capital letter on the next sheet of paper which is blue. Tear off that sheet of paper and put it on the spindle. I will now show you the correct letter that goes with this slide." (Project Stimulus-Response Slide No. 2.) "If you guessed correctly, circle the R on your Answer Sheet for Number 2 under Trial 1. If you got it wrong, circle the W. The rest of the test is done in the same way. The drawings will be shown on the screen for 7 seconds. During that time you should record a letter on a colored sheet, tear it off, and put it on the spindle. Then when the correct answer is shown, mark your Answer Sheet either right or wrong for that slide. If you have not written a letter before the slide with the correct answer is shown, tear off the colored slip and place it on the spindle anyway. This way you will have a sheet of colored paper on the spindle for each word. The colors are also indicated on your Answer Sheet for each slide number. Do not get the colors out of order. Are there any questions? Stand by for Slide No. 3 under Trial 1."

(These directions were supplemented as per introductory note to Appendix A.)

WORD CODE

(Sample of Stimulus-Response Slides for Trial 1)

1	2	3	4
DESTROYER	ACTION	STATIONS	BRIDGE
K	I	E	Z
5	6	7	8
RELAY	ENEMY	RANGE	TORPEDO
U	B	D	C
9	10	11	12
BEARING	SPEED	SUBMARINE	CLEAR
W	X	A	S
13	14	15	16
DAMAGE	CONVOY	DECOY	CONDUCT
T	L	P	M

(Sample of Word Code Answer Sheet)

NAME_____ SERVICE NUMBER_____

(Print) Last First Middle

COMPANY NUMBER_____

Trial 1		Trial 3		Trial 5		Trial 7		Trial 9	
1. white	R W	1. white	R W	1. white	R W	1. white	R W	1. white	R W
2. blue	R W	2. blue	R W	2. blue	R W	2. blue	R W	2. blue	R W
3. pink	R W	3. pink	R W	3. pink	R W	3. pink	R W	3. pink	R W
4. green	R W	4. green	R W	4. green	R W	4. green	R W	4. green	R W
5. white	R W	5. white	R W	5. white	R W	5. white	R W	5. white	R W
6. blue	R W	6. blue	R W	6. blue	R W	6. blue	R W	6. blue	R W
7. pink	R W	7. pink	R W	7. pink	R W	7. pink	R W	7. pink	R W
8. green	R W	8. green	R W	8. green	R W	8. green	R W	8. green	R W
9. white	R W	9. white	R W	9. white	R W	9. white	R W	9. white	R W
10. blue	R W	10. blue	R W	10. blue	R W	10. blue	R W	10. blue	R W
11. pink	R W	11. pink	R W	11. pink	R W	11. pink	R W	11. pink	R W
12. green	R W	12. green	R W	12. green	R W	12. green	R W	12. green	R W
13. white	R W	13. white	R W	13. white	R W	13. white	R W	13. white	R W
14. blue	R W	14. blue	R W	14. blue	R W	14. blue	R W	14. blue	R W
15. pink	R W	15. pink	R W	15. pink	R W	15. pink	R W	15. pink	R W
16. green	R W	16. green	R W	16. green	R W	16. green	R W	16. green	R W

Trial 2		Trial 4		Trial 6		Trial 8		Trial 10	
1. white	R W	1. white	R W	1. white	R W	1. white	R W	1. white	R W
2. blue	R W	2. blue	R W	2. blue	R W	2. blue	R W	2. blue	R W
3. pink	R W	3. pink	R W	3. pink	R W	3. pink	R W	3. pink	R W
4. green	R W	4. green	R W	4. green	R W	4. green	R W	4. green	R W
5. white	R W	5. white	R W	5. white	R W	5. white	R W	5. white	R W
6. blue	R W	6. blue	R W	6. blue	R W	6. blue	R W	6. blue	R W
7. pink	R W	7. pink	R W	7. pink	R W	7. pink	R W	7. pink	R W
8. green	R W	8. green	R W	8. green	R W	8. green	R W	8. green	R W
9. white	R W	9. white	R W	9. white	R W	9. white	R W	9. white	R W
10. blue	R W	10. blue	R W	10. blue	R W	10. blue	R W	10. blue	R W
11. pink	R W	11. pink	R W	11. pink	R W	11. pink	R W	11. pink	R W
12. green	R W	12. green	R W	12. green	R W	12. green	R W	12. green	R W
13. white	R W	13. white	R W	13. white	R W	13. white	R W	13. white	R W
14. blue	R W	14. blue	R W	14. blue	R W	14. blue	R W	14. blue	R W
15. pink	R W	15. pink	R W	15. pink	R W	15. pink	R W	15. pink	R W
16. green	R W	16. green	R W	16. green	R W	16. green	R W	16. green	R W

TOTAL	R	W	TOTAL	R	W
Trial 1	_____	_____	Trial 6	_____	_____
Trial 2	_____	_____	Trial 7	_____	_____
Trial 3	_____	_____	Trial 8	_____	_____
Trial 4	_____	_____	Trial 9	_____	_____
Trial 5	_____	_____	Trial 10	_____	_____

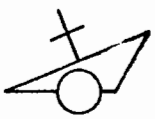
DIRECTIONS FOR SPATIAL CODE

"I'm going to project sixteen slides with drawings on them similar to this one." (Project Stimulus Slide No. 1.) "Each drawing has a letter assigned to it--like this." (Project Stimulus-Response Slide No. 1.) "You are to learn the letter that goes with each drawing. This is very similar to learning semaphore only drawings are used instead of arm positions. Tear off the white sheet of paper from Deck 1 and place it on the spindle. On your Answer Sheet under Trial 1 for Number 1 draw a circle around the letter W for a wrong response. I will show you another slide." (Project Stimulus Slide No. 2.) "This time I want you to guess which letter you think goes with this slide. Print this letter as a capital letter on the next sheet of paper which is blue. Tear off that sheet of paper and put it on the spindle. I will now show you the correct letter that goes with this slide." (Project Stimulus-Response Slide No. 2.) "If you guessed correctly, circle the R on your Answer Sheet for Number 2 under Trial 1. If you got it wrong, circle the W. The rest of the test is done in the same way. The drawings will be shown on the screen for seven seconds. During that time you should print a letter on a colored sheet, tear it off, and put it on the spindle. If you have not written a letter before the drawing with the correct answer is shown, tear off the colored sheet and place it on the spindle. This way you will have a sheet of colored paper on the spindle for each drawing you have to learn. Do not get the colored sheets out of order. Are there any questions? Stand by for Slide No. 3 under Trial 1."

(These directions were supplemented as per introductory note to Appendix A. See the Word Code task for a sample of the Answer Sheet.)

SPATIAL CODE

(Sample of Stimulus-Response Slides for Trial 1)

1  L

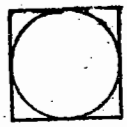
2  X

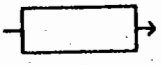
3  W

4  Z

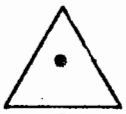
5  C

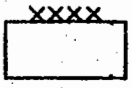
6  M

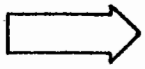
7  B

8  A

9  T

10  S

11  K

12  P

13  U

14  I

15  D

16  E

DIRECTIONS FOR KNOB CODE

(On the blackboards surrounding the room on three sides print the following words: AIR, HEAT, GAS, FIRE, WATER, SIREN, CHOKE, PUMP. Have each subject take a position in front of any one of the sixty-four stations, insert an Answer Sheet in a clip board, and write his name, service number, and company number on the sheet.)

"Step back from the tables. In front of each one of you is a box. Inside each box is a knob. The knob is fastened to the back of the box about one quarter of the way up from the bottom. In this test you will reach inside each box, feel the knob, and try to identify the knob. There are eight different kinds of knobs and each kind has been given a name. When you feel a knob you are to guess what the name of the knob is. The eight possible names are written on the blackboards." (Examiner indicates locations of the lists.) "This is how the test will proceed: On the command REACH you will reach inside the box and locate and feel the knob. Then I will say RECOVER and you will take your hand out of the box. You will then guess what the name of the knob is and write it in the appropriate place on your Answer Sheet. When you have done this I will say CHECK. Then, and not before, you will lift the card on the top of the box. Under this card is the correct name of the knob. When you have read the name you will know whether your answer is right or wrong. If it is right you circle the R on the Answer Sheet following your answer. If it is wrong you will circle the W. Then I will say SHIFT. When I say SHIFT each man will move to the box to his right. The men on the right hand ends of the

tables will move around the table to the box that is directly opposite them. That is, the man at Station 4 will move to Station 5, and the man at Station 8 will move to Station 1. When you have made a complete circuit of a table--when you have been at every station at a table--I will tell you to CHANGE TABLES. You will do it this way. The men at this table will go to that table; the men at this table will go to that table, and so on." (Examiner indicates changes.) "In no case will you look into the box. You will not touch the card on the top of the box until I say CHECK. Are there any questions? Stand by for Number 1 under Trial 1."

(These directions were supplemented as per introductory note to Appendix A.)

(Sample of Knob Code Answer Sheet)

Name _____
(Print) Last First Middle

Trial 1		Trial 3		Trial 5		Trial 7		Trial 9	
1. _____	R W	1. _____	R W	1. _____	R W	1. _____	R W	1. _____	R W
2. _____	R W	2. _____	R W	2. _____	R W	2. _____	R W	2. _____	R W
3. _____	R W	3. _____	R W	3. _____	R W	3. _____	R W	3. _____	R W
4. _____	R W	4. _____	R W	4. _____	R W	4. _____	R W	4. _____	R W
5. _____	R W	5. _____	R W	5. _____	R W	5. _____	R W	5. _____	R W
6. _____	R W	6. _____	R W	6. _____	R W	6. _____	R W	6. _____	R W
7. _____	R W	7. _____	R W	7. _____	R W	7. _____	R W	7. _____	R W
8. _____	R W	8. _____	R W	8. _____	R W	8. _____	R W	8. _____	R W
9. _____	R W	9. _____	R W	9. _____	R W	9. _____	R W	9. _____	R W
10. _____	R W	10. _____	R W	10. _____	R W	10. _____	R W	10. _____	R W
11. _____	R W	11. _____	R W	11. _____	R W	11. _____	R W	11. _____	R W
12. _____	R W	12. _____	R W	12. _____	R W	12. _____	R W	12. _____	R W
13. _____	R W	13. _____	R W	13. _____	R W	13. _____	R W	13. _____	R W
14. _____	R W	14. _____	R W	14. _____	R W	14. _____	R W	14. _____	R W
15. _____	R W	15. _____	R W	15. _____	R W	15. _____	R W	15. _____	R W
16. _____	R W	16. _____	R W	16. _____	R W	16. _____	R W	16. _____	R W

Trial 2		Trial 4		Trial 6		Trial 8		Trial 10	
1. _____	R W	1. _____	R W	1. _____	R W	1. _____	R W	1. _____	R W
2. _____	R W	2. _____	R W	2. _____	R W	2. _____	R W	2. _____	R W
3. _____	R W	3. _____	R W	3. _____	R W	3. _____	R W	3. _____	R W
4. _____	R W	4. _____	R W	4. _____	R W	4. _____	R W	4. _____	R W
5. _____	R W	5. _____	R W	5. _____	R W	5. _____	R W	5. _____	R W
6. _____	R W	6. _____	R W	6. _____	R W	6. _____	R W	6. _____	R W
7. _____	R W	7. _____	R W	7. _____	R W	7. _____	R W	7. _____	R W
8. _____	R W	8. _____	R W	8. _____	R W	8. _____	R W	8. _____	R W
9. _____	R W	9. _____	R W	9. _____	R W	9. _____	R W	9. _____	R W
10. _____	R W	10. _____	R W	10. _____	R W	10. _____	R W	10. _____	R W
11. _____	R W	11. _____	R W	11. _____	R W	11. _____	R W	11. _____	R W
12. _____	R W	12. _____	R W	12. _____	R W	12. _____	R W	12. _____	R W
13. _____	R W	13. _____	R W	13. _____	R W	13. _____	R W	13. _____	R W
14. _____	R W	14. _____	R W	14. _____	R W	14. _____	R W	14. _____	R W
15. _____	R W	15. _____	R W	15. _____	R W	15. _____	R W	15. _____	R W
16. _____	R W	16. _____	R W	16. _____	R W	16. _____	R W	16. _____	R W

TOTAL	R	W	TOTAL	R	W
Trial 1	_____	_____	Trial 6	_____	_____
Trial 2	_____	_____	Trial 7	_____	_____
Trial 3	_____	_____	Trial 8	_____	_____
Trial 4	_____	_____	Trial 9	_____	_____
Trial 5	_____	_____	Trial 10	_____	_____

DIRECTIONS FOR SONAR

(Print on the blackboard the following words: PORPOISE, CROAKER, WHALE, ICEBERG, SUBMARINE, TORPEDO, DRUMFISH, TOADFISH, SEA CATFISH, COWFISH, SCORPION, SHRIMP.)

"Do you all know what Sonar is? For those of you who are not sure, Sonar is a means of locating objects underwater such as submarines. It works very much like Radar except sound is used instead of radio waves. Anyway, the sonar apparatus includes a sensitive microphone for hearing sounds made under water. With it you can hear submarines, the screws of ships, and even fish--in fact, any sound which is made under water if it is loud enough. Now in this test you will hear recordings made of under water sounds which were picked up on sonar apparatus. Your task will be to learn to recognize and identify these sounds. The sounds were made by twelve different things and the names of these things are printed on the blackboard." (Examiner points to lists on the blackboards.) "Here is how the test will work. You will hear one of the sounds for about ten seconds. Then there will be a period of silence. During this period you should decide which of the twelve things made the sound. You will then print the first three letters of the names of that thing on the appropriate line of your Answer Sheet. Then you will be told the correct name that goes with the sound and you will mark your Answer Sheet right or wrong by circling the R or the W following your answer. Then you will hear another sound for ten seconds and you will guess again--and so on. If you cannot decide what made the sound--if you can't even guess--put three X's on the line and circle the W. At first you will have

to guess but gradually you will come to recognize the sounds. Are there any questions? Stand by for Trial Number 1."

(These directions were supplemented as per introductory note to Appendix A. See Knob Code for a sample of the Answer Sheet.)

DIRECTIONS FOR VERBAL CONCEPT FORMATION I

(Print on blackboard the following information.)

1	CHICAGO	BOSTON
	NEW YORK	LONDON
	X	

3	ORANGE	CAT
	FOR	AT
	Y	

2	SEATTLE	PARIS
	BALTIMORE	BERLIN
	X	

4	READ	QUICKLY
	STOP	BANANA
	Y	

5	MIAMI	DETROIT
	ROME	PORTLAND

6	APPLE	HAPPY
	RUNNING	CAR

"Look at the blackboard. Here are four sets of words. Each set has four words. Sets 1 and 2 (examiner points to sets) both have something in common with each other. The capital letter X stands for this relationship--that is, it represents what sets 1 and 2 have in common, or why they belong together. So they both fall in group X. Now look at sets 3 and 4. They both fall into group Y--the letter Y stands for the relationship between sets 3 and 4. Now look at sets 5 and 6. Which group would set 5 fall into? X or Y? Which group for set 6? (Pause) Set 5 belongs to group X because all of the words are names of cities. Set 6 belongs to group Y. What Y stands for is more difficult to figure out than X but group Y always contains the name of a fruit. Note that X was based on all four words but Y

was based on only one of the four words. That was an example of how this test works. Remember it was only an example. These words will not be used, and neither will the groups X and Y be used."

"The test you are asked to take is more difficult than the examples. You will be shown 16 slides, one at a time, first without a letter, and then with the correct letter. These 16 slides belong to one of 4 groups, A, B, C, or D. I repeat, only capital letters A, B, C, and D are used. Your task is to learn which letter goes with which slide. Four slides go with letter A, four with letter B, four with letter C, and four with letter D. You use the colored paper and the Answer Sheet the same way as you have before. Slide Number 1 will come on the screen for about 7 seconds. During that time you are to choose or guess A, B, C, or D and print that capital letter on the right slip of colored paper. Tear it off and put it on the spindle before the correct answer is shown. Then circle that item number right or wrong on your Answer Sheet. After each trial, add up the number right and wrong for each trial and record that in the box below. Keep up with the projection machine. Don't get the colored slips out of order. Are there any questions? Stand by for Number 1 under Trial 1. We'll begin with Slide Number 1, Trial 1. You begin with the white slip of paper labeled Deck 1." (Project Stimulus Slide 1.) "Here is Slide 1. Guess a letter--A, B, C, or D and print that letter on the white slip of paper; tear it off and put on the spindle." (After Stimulus-Response Slide 1 appears on the screen.) "Now mark your Answer Sheet right or wrong as the case may be."

(These directions were supplemented as per introductory note to Appendix A. See Word Code for a sample of the Answer Sheet.)

VERBAL CONCEPT FORMATION I

(Sample of Stimulus-Response Slides for Trial 1)

1

RIFLE WHAT

COURSE ONE

A

2

MUZZLE RIGHT

WRITE LEGIBLE

C

3

ROUGH CLEAR

AFTER GOLF

B

4

DOZEN MONTH

KNOT CUP

D

5

AWAY TRAY

WAY WEIGH

C

6

MARK FOUR

FIRE CANE

A

7

INCH FOOT

YARD MILE

D

8

TRACK HOCKEY

TRAIL COOK

B

9

MIGHT PURPLE

NIGHT MITE

C

10

SEVEN LIFT

SLOP MASK

A

11

COAL SEND

BASEBALL LIKE

B

12

BLANK HIM

THREE CORK

A

13

METER BUSHEL

DOLLAR ACRE

D

14

DELAY SUM

SOME DIFFERENT

C

15

TENNIS CONVEY

BLAST WEAK

B

16

SECOND MINUTE

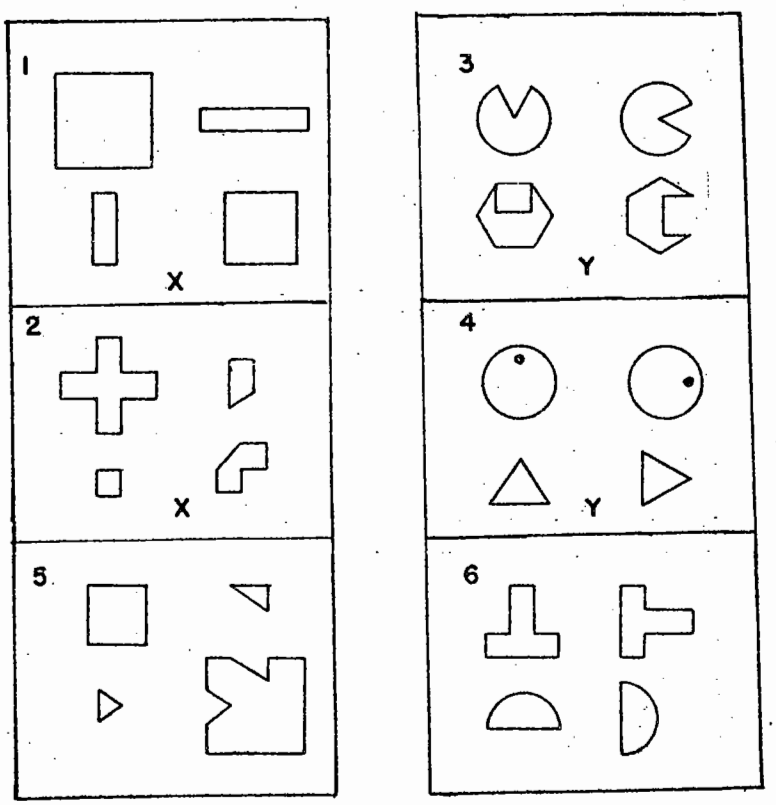
HOUR DAY

D

DIRECTIONS FOR SPATIAL CONCEPT FORMATION I

Note: This learning task was administered four days after Spatial Concept Formation II.

(Draw on blackboard.)



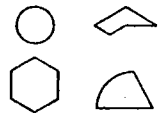
"This learning task is very similar to the one you took several days ago. Sets of drawings from that test appear on the blackboard. One concept represented on the blackboard as letter code X was that three of the parts made one of the four figures--parts which made up the whole. Concept Y in our example corresponds to rotation--the left hand figures have been rotated 90 degrees. The material you are

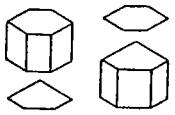
to learn today contains more sets of figures to be assigned to letter groups A, B, C, or D. Different slides and different rules apply however. The slides are not different for each trial as before, but will be presented in a different order each trial. Therefore, you will be able to learn the letter codes by either figuring out the rules or by memorizing the slides. Use the colored slips as before. Are there any questions? Stand by for Number 1 under Trial 1."

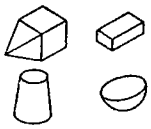
(These directions were supplemented as per introductory note to Appendix A. See Word Code for a sample of the Answer Sheet.)

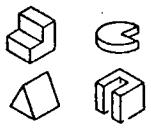
SPATIAL CONCEPT FORMATION I

(Sample of Stimulus-Response Slides for Trial 1)

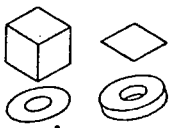
1  B

2  A

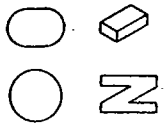
3  C

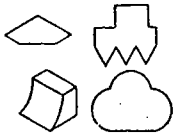
4  C

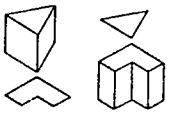
5  D

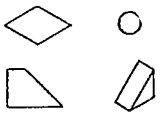
6  A

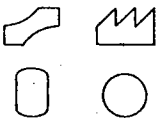
7  D

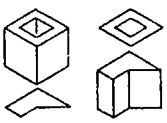
8  B

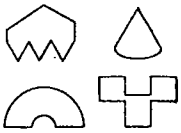
9  D

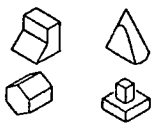
10  A

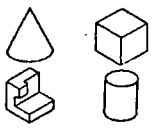
11  B

12  B

13  A

14  D

15  C

16  C

DIRECTIONS FOR BREECH BLOCK PERFORMANCE TEST

"The purpose of this task is to investigate your ability to learn how to assemble the breech block of a 40 mm. antiaircraft gun. First, you will be shown a film describing the step-by-step assembly of the breech block. Following this you will be given three minutes to assemble as much of the breech block as you can in this period. Since most of you will not be able to complete the assembly the first time, the film will be projected a second time and you will then be given another three-minute assembly trial. The film and test sequence will be repeated for a total of six times, at the end of which practically everyone will be able to assemble the breech block. After you have seen the film for the first time, take a station in front of the breech block gear, give the proctor the card with your name, and other information, and stand by for the timekeeper to tell you when to begin. In the event you complete the assembly within the time limit stand by until the timekeeper stops the group. Each time after the film report to the same station. Do not discuss the assembly with your neighbor because the only instructions should be those contained in the film. Are there any questions?"

(These directions were supplemented as per introductory note to Appendix A. A sample Record Sheet is attached.)

Record Sheet

40 mm Breech Block Performance Test

Name _____ Class _____

Task: Assembly of breech block.

Steps:

		Trials					
		1	2	3	4	5	6
1.	Inserts sear and sear spring into block.	☐	☐	☐	☐	☐	☐
2.	Presses sear in until flush with block.	☐	☐	☐	☐	☐	☐
3.	Inserts notched end of inner cocking lever into groove of sear.	☐	☐	☐	☐	☐	☐
4a.	Properly aligns hole of inner cocking lever with block.	☐	☐	☐	☐	☐	☐
4b.	Inserts outer cocking lever in 12 o'clock position.	☐	☐	☐	☐	☐	☐
5.	Moves outer cocking level to fired position using slight pressure on sear.	☐	☐	☐	☐	☐	☐
6.	Inserts firing pin, firing pin spring into firing pin chamber and places firing pin cover on firing pin spring.	☐	☐	☐	☐	☐	☐

If subject is proceeding to step 7 <u>without</u> completing step 5, say:

"STOP, YOUR ASSEMBLY TO THIS STEP IS NOT CORRECT, RECHECK YOUR WORK."

7a.	Lifts block to protect firing pin.	☐	☐	☐	☐	☐	☐
7b.	Inserts wrench in firing pin cover and locks firing pin cover in correct position.	☐	☐	☐	☐	☐	☐

	1	2	3	4	5	6
Total steps completed						
Time						
(Leave blank)						

Proctor's comments

Proctor

DIRECTIONS FOR COMBAT INFORMATION CENTER PLOTTING TEST

Note: The directions for this learning task were recorded.

"One very important activity carried out aboard ship is the mission assigned to the Combat Information Center. This center has to keep track of all planes and ships, both enemy and friendly, within a given range. The Combat Information Center Plotting Test is only a sample of some of the activities handled by the Combat Information Center. This test will teach you how to plot enemy planes and ships. Open the book to page A. (Pause) Your ship is located at the center of the plotting sheet. This sound track will give you the position of the objects you are to plot. Aboard ship, this information would be coming to you over a set of headphones from your radarman. He gives you the location of the plane or ship in terms of its bearing in degrees, which run from zero degrees at the top of your sheet around clockwise to 090 degrees, 180 degrees, 270 degrees, and 360 or zero degrees again. The radarman also gives the distance of the object in miles from your ship. The inside solid ring is 10 miles from your ship--the outer solid ring is 100 miles from your ship. Each circle of dots in between represents a distance of 10 miles. For example, the dotted circle labeled 2 is 20 miles from your ship. The next dotted ring, labeled 3, is 30 miles from your ship. And so on out to the outer solid ring which is 100 miles from your ship.

To make a plot for a plane or ship this is what you do. First, the radarman gives the location in terms of degrees or bearing. Run around the outer ring until you come to this bearing. Next he gives the distance in miles from your ship. Come in on the given bearing

from the outer ring to the correct range from your ship. At this point make a small cross like you see on page A. Now let's try some plots. But first place the sheet of carbon paper between page A and page B like this. (Examiner demonstrates.) Each time you make a plot correctly the X or cross will fall inside one of the red circles on the second sheet. That is all there is to plotting except that it has to be done fast and accurately.

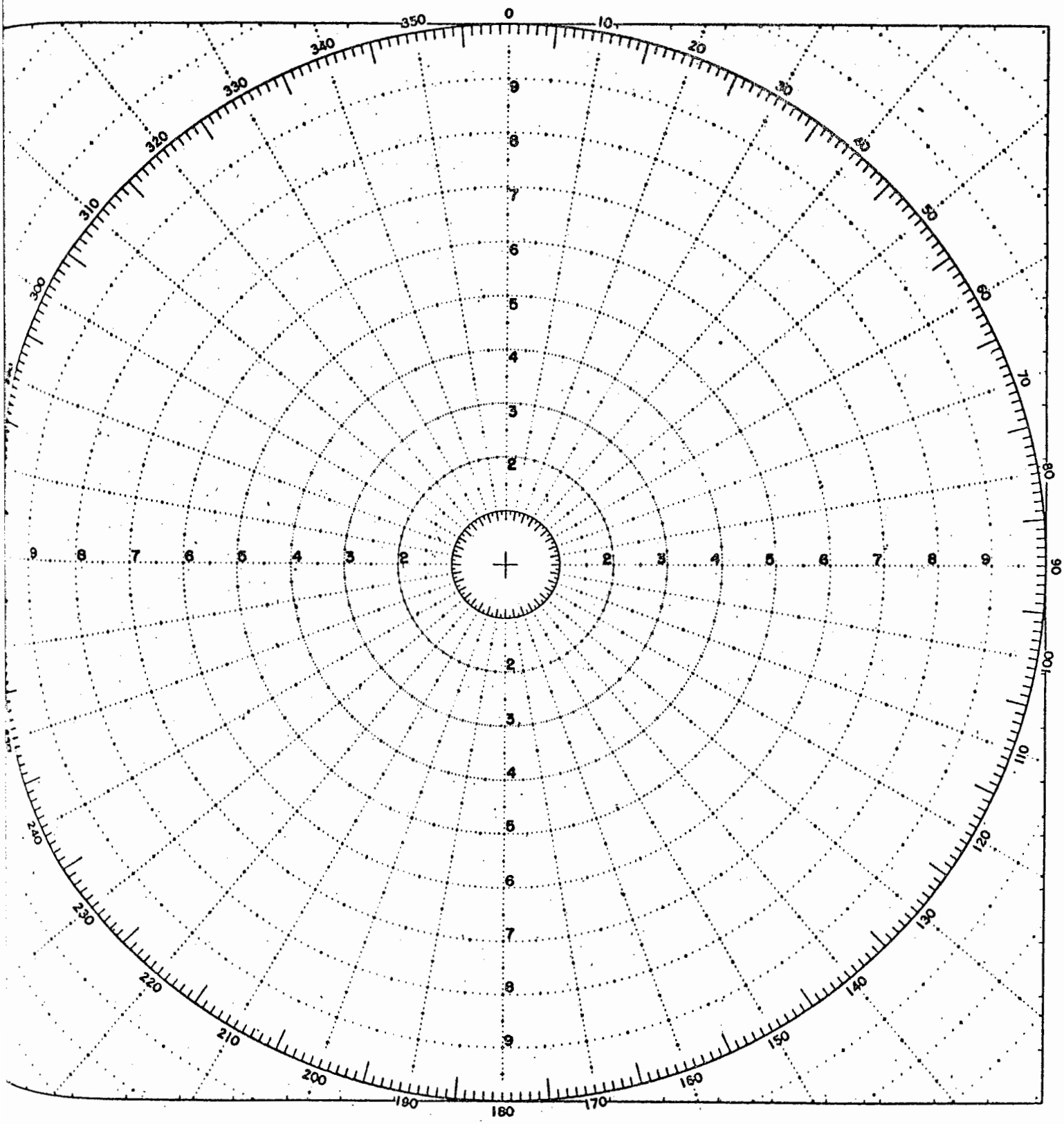
Here is how the radarman would give you the information for the plots already made on page A. He will give you enough time between plots that you can check the ones already made. Afterwards he will give you three more to plot yourself on this page. Stand by.

Bearing 350, range 84 miles. To make this plot, come around the outer circle to 350. Now come in toward the center to 84, make a cross here. This cross should be right in line or on top of the printed cross. Do the same for this one. Now try this one. Bearing 110, range 32 miles. Now try this one. Bearing 224, range 62 miles. You should make the following plots on page A. Stand by. Bearing 050, range 56. (Pause) Bearing 142, range 80. (Pause) Bearing 318, range 46. (Pause) Now remove the carbon paper between pages A and B. Look at page B. Each time you made a plot correctly, you should find the center of your cross within a red circle. Count up the number of crosses you have in the red circles. Record the number you got right in the box at the lower rgt. corner. A perfect score is 6. Now insert your carbon sheet between pages 2 and 3, that is between the black print for Trial 1 and the red circles for Trial 1.

The plots will be given to you very fast. Get as many as you can. If you miss one go on to the next plot. As you learn to make the plots you should be able to get more done each trial. You have ten trials.

Stand by."

(Sample of Combat Information Center Plotting Grid)



DIRECTIONS FOR VERBAL CONCEPT FORMATION II

Note: This learning task was administered two days after Verbal Concept Formation I.

(Print on blackboard.)

1	CHICAGO	BOSTON	
	NEW YORK	LONDON	
		X	

3	ORANGE	CAT	
	FOR	AT	
		Y	

2	SEATTLE	PARIS	
	BALTIMORE	BERLIN	
		X	

4	READ	QUICKLY	
	STOP	BANANA	
		Y	

5	MIAMI	DETROIT	
	ROME	PORTLAND	

6	APPLE	HAPPY	
	RUNNING	CAR	

"Look at the blackboard. This learning task is very similar to the one you took two days ago. The example, for that test, is written again on the blackboard. As you recall, you learned to assign each set of words to a certain letter by figuring out what the sets had in common. The task before us again has sets of words to be assigned to one of the four letter groups, A, B, C, or D. Only this time the sets of words are different and the letter codes stand for different relationships than in the test of two days ago. Also, instead of seeing the same slides each trial although the order was changed, the slides in this test are different each trial. However, the rules for assigning

the slides to A, B, C, or D will apply to any slide in any trial once you figure them out. Use the colored slips as before. Are there any questions? Stand by for Number 1 under Trial 1."

At the beginning of Trial 2 say, "Remember that in Trial 2 and each trial thereafter the slides will be different--but what each letter stands for is the same."

(These directions were supplemented as per introductory note to Appendix A. See Word Code for a sample of the Answer Sheet.)

VERBAL CONCEPT FORMATION II

(Sample of Stimulus-Response Slides for Trial 1)

1

HANDS TO

QUARTERS ALL

A

2

FASTEN TAUT

ATTACH SLACK

B

3

TOMAHAWK TIE

LOVE TOO

D

4

FORK IRON

TIRE SWITCH

C

5

DISCLOSE REVEAL

RIGHT WRONG

B

6

COMPANY IN

FALL ABLE

A

7

FAN PENCIL

HOE JACK

C

8

WET VEER

SWERVE DRY

B

9

FLIP SEE

PISTOL SCISSORS

D

10

JOKE BOMB

COURSE HEAR

D

11

TABLET SKATE

MUFFLER SHOVEL

C

12

OVERBOARD SIDE

PORT MAN

A

13

CLOTHING RAISE

APPAREL LOWER

B

14

BUTTON SPOON

RULER RAKE

C

15

THE SECURE

TAUT LINE

A

16

THINK CHALK

FILM BAZOOKA

D

DIRECTIONS FOR SPATIAL CONCEPT FORMATION II

Note: This was the first concept formation learning task which was administered. The Spatial Code had been administered several days earlier however.

(Print on blackboard.)

1	CHICAGO	BOSTON
	NEW YORK	LONDON
	X	

3	ORANGE	CAT
	FOR	AT
	Y	

2	SEATTLE	PARIS
	BALTIMORE	BERLIN
	X	

4	READ	QUICKLY
	STOP	BANANA
	Y	

5	MIAMI	DETROIT
	ROME	PORTLAND

6	APPLE	HAPPY
	RUNNING	CAR

"This is another learning task, only this time there is a relationship between the slides and the letters which go with them. Your task is to figure out what the relationships are. Look at the blackboard. Here are four sets of words. Each set has four words. Sets 1 and 2 (examiner points to sets) both have something in common with each other. The capital letter X stands for this relationship--that is, it represents what sets 1 and 2 have in common, or why they belong together. So they both fall in group X. Now look at sets 3 and 4. They both fall into group Y--the letter Y stands for the relationship between sets 3 and 4. Now look at sets 5 and 6. Which group would set 5 fall into? X or Y? Which group for set 6? (Pause) Set 5 belongs to group X

because all of the words are names of cities. Set 6 belongs to group Y. What Y stands for is more difficult to figure out than X but Y always contains the name of a fruit. Note that X was based on all four words but Y was based on only one of the four words. That was an example of how this test works. Remember, it was only an example. These words will not be used, and neither will the groups X and Y be used. Each slide has four figures on it--instead of words--and belongs to one of four letter groups, A, B, C, or D. You are to learn which of the four letters goes with each. For example, all of the slides that go in Group A have something in common. What they have in common is up to you to figure out--the relationships, or what they have in common, may be based upon one, two, three, or all four figures on a slide. You will never see the same slide more than twice--once without the letter code at the bottom and once with the letter code. Therefore, you will have to find out what A, B, C, and D stand for."

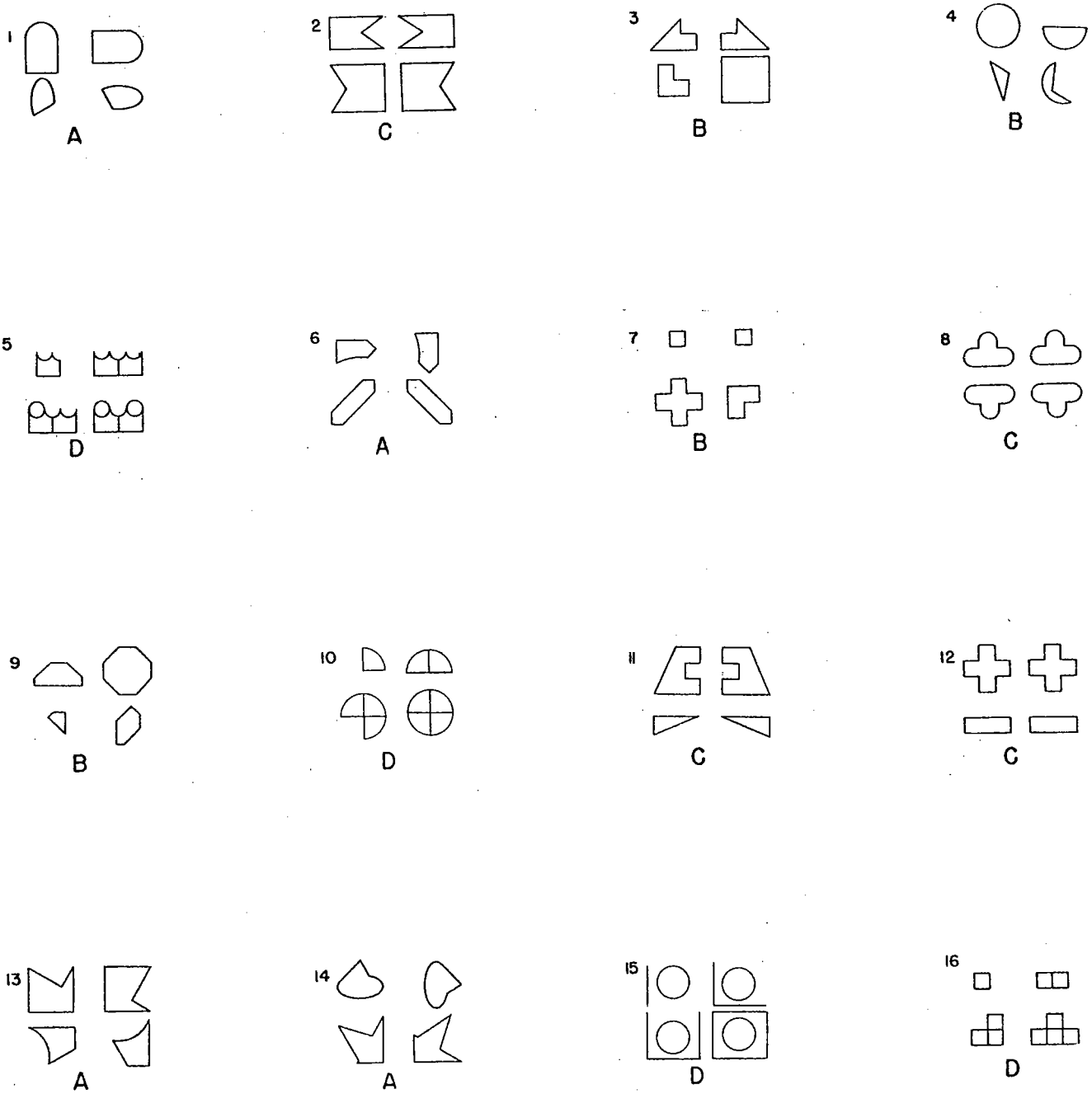
"You use the slips of colored paper and the Answer Sheet the same way as you have before. Slide number 1 will come on the screen for about 7 seconds. During that time you are to choose or guess A, B, C, or D and print that capital letter on the right slip of colored paper. Tear it off and put it on the spindle before the correct answer is shown. Then circle that item number right or wrong on your Answer Sheet. After each trial, add up the number right and wrong for each trial and record that in the box below. Keep up with the projection machine. Don't get the colored slips out of order. Are there any questions? Stand by for Number 1 of Trial 1. (Project Stimulus Slide 1) "Here is slide 1. Guess a letter--A, B, C, or D and print

that letter on the white slip of paper, take it off and put it on the spindle." (After Stimulus-Response Slide 1 appears on the screen.) "Now mark your answer sheet right or wrong as the case may be."

(These directions were supplemented as per introductory note to Appendix A. See Word Code for a sample of the Answer Sheet.)

SPATIAL CONCEPT FORMATION II

(Sample of Stimulus-Response Slides for Trial 1)



DIRECTIONS FOR MECCANO ASSEMBLY TEST

(Have the subjects first sit on the stools in front of the test apparatus.)

"In working on this test, your task will be to put together various gears, axles, and collars in such a way that for each six turns of the crank the rubber-covered wheel will make almost one complete turn in the same direction. All of the parts you will need are in the small box. However, you may not need to use all the parts; you may have one or more parts left over. The only tool you will need is a screwdriver. Do not take apart any of the pieces that have already been assembled. If you assemble the gears correctly, they will mesh smoothly and turn easily. Do not force them. Your finished product should be put together so that the gears will not get out of mesh simply because they turn."

"Before you begin the task, you will be shown some slides and hear a recording dealing with basic mechanisms. You will then have a five-minute period in which to work on your task. After this you will again see the slides and hear the recording. Then once again you will try the assembly, starting from scratch. There will be a total of five trials. After each we will check to see how many of the ten steps in the assembly you have done correctly. We will record this on the sheet you see alongside your test apparatus, so that you will know how well you are progressing on learning how to put this mechanical device together. Then, we will take your work apart so that all of you will start each new trial from the same starting point. We will now show the slides and play the tape recording." (Have the subjects move to

where they can see the screen. After the slides and recording are over, have the subjects move back to the test apparatus.) "Before you open the box of parts and begin work on Trial 1, let me give you a few more words of instruction. To make the crank turn the rubber-covered wheel correctly, you will need to use one axle somewhere in the red uprights and another axle somewhere in the tall thin green uprights. To get ahead with the task, try putting the gears on these axles in various ways so you can figure out where they belong. If one idea doesn't work, try another. Now, open the box and begin work."

(After a period of five minutes.) "Stop work. Cover your work with the piece of black cloth. (Pause briefly) Now move back to the other part of the room to see the slides again." (The proctors will now score the performances and take apart what the subjects have assembled. After the subjects return from the slides say) "Remember to use one axle somewhere in the red uprights and the other axle somewhere in the thin green uprights. Go ahead!"

(At the end of Trial 5.) "Stop work. Now move to the arm chairs while the proctors score your final performances. After the scores are ready, we shall call you back so that you can see how well you have done, and can copy the scores on the record cards." (After the proctors have finished.) "Now return to your test stations. Copy your five scores onto the record card in the appropriate spaces."

(These directions were supplemented as per introductory note on Appendix A.)

MECCANO ASSEMBLY TEST

Scoring Instructions

In scoring a recruit's performance on the Meccano Assembly Test, each of the following is to be given one point:

1. 1. Short axle in correct position
   2. Collar to hold short axle in place
   3. Large spur gear on shaft with crank
   4. Small pinion meshed with large spur gear
   5. Long axle in correct position
   6. Worm in correct position
   7. Small pinion meshed with worm
   8. One bevel gear on axle with rubber-covered wheel
   9. Other bevel gear on long axle
   10. Collar on long axle to maintain position of bevel gear
   11. Total assembly operates with correct direction and speed
   12. Assembly operates smoothly and continuously

The following explanations may be helpful in guiding your giving of credit:

Points 1,5 — 1. For an axle to be scored as in the correct position, <u>both</u> ends of the axle should be in the appropriate supports.

Points 3,4,6, 7,8,9 — 2. For a gear to be considered to be in the correct position, it need <u>not</u> be tightened on the shaft.

Point 11 — 3. Credit for point number 11 depends on having all the gears correctly placed and fastened. However, for credit to be allowed, the collars need not be in the correct position, and the set-up may be hard to operate because things are too "tight."

Point 12 — 4. Credit for point number 12 depends on having all of the above <u>plus</u> having the collars so placed that the device will continue to operate, and having parts so adjusted that the operation is smooth and easy.

Scoring Instructions (Contd)

Point 2

5. Note that the collar on the short axle can be placed <u>either</u> on the outside of the red upright opposite to the end on which the small pinion is mounted, <u>or</u> on this axle <u>inside</u> the red upright that has the small pinion on the other side.

Point 10

6. Note also that there are similarly two positions in which the collar can be correctly placed so as to hold the long axle properly. One position is between the pinion that meshes with the worm and the thin green upright nearer the red uprights. The second (and more frequently given response) is between the bevel gear and the far green upright, next to this upright.

Points 3,4, 6,7

7. Except for the bevel gears, the way in which the gears "face" is not material and does not affect the scoring.

Name _____
Last First Middle

Company Number _____ Service Number _____

MECANNO ASSEMBLY TEST

Remember this: Six turns of the crank are to turn the rubber-covered wheel almost one turn in the same direction.

Total possible score: 12 points

Your scores:

First trial ☐

Second trial ☐

Third trial ☐

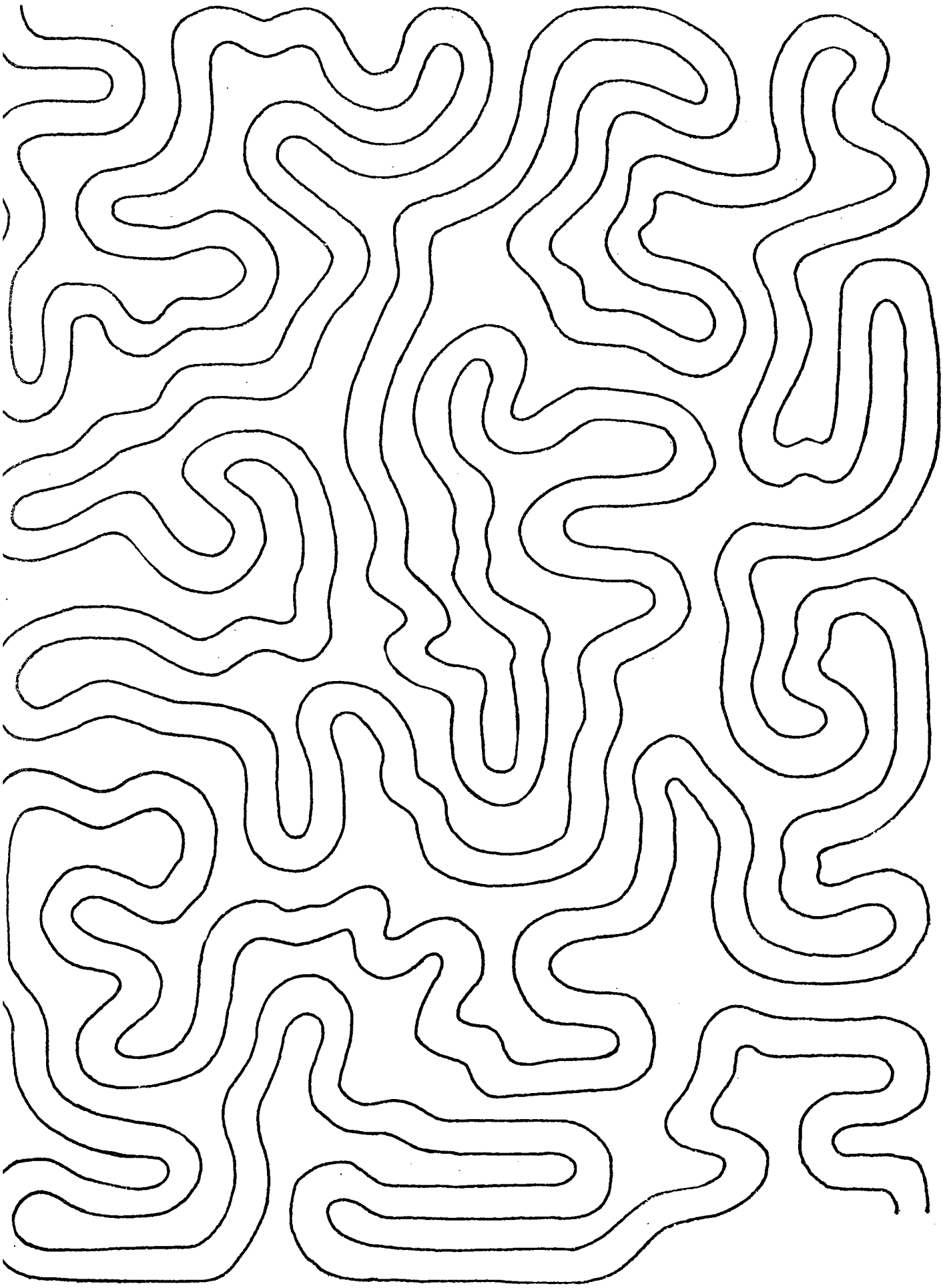
Fourth trial ☐

Fifth trial ☐

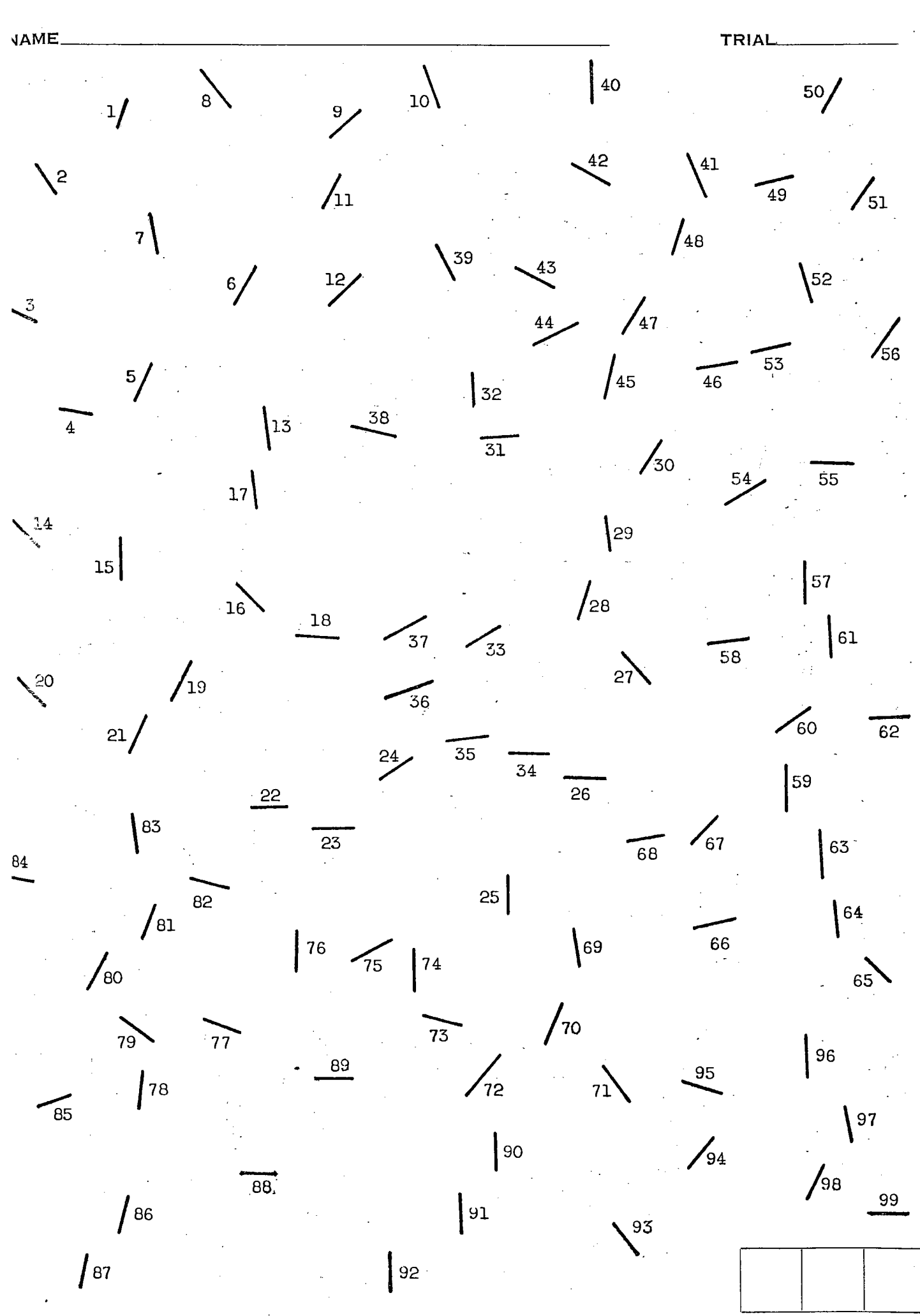
DIRECTIONS FOR SIDEWALK MAZE

"This is a sidewalk maze. Take the first copy from your stack and put it on your clip board just like this." (Examiner demonstrates.) "You are to trace through this maze as fast as you can without going off the sidewalk and without picking up your pencil to make a new start. Your score will be the distance you travel before you go off the sidewalk once or before you make your first 'new start'. You will be given seven thirty-second trials at this. For each trial be sure you hold the clip board flat on the table and slant it just like you would for writing. Always start in the upper right hand corner and be sure to press hard enough so that the pencil will record through the carbon. Any questions? Ready, go!" (After 30 seconds.) "Stop. Now remove the maze from the clip board and open it out. In the upper right hand corner where it says "Trial" put the number 1. Now look at the line you just traced. Follow it along with your eye looking for a break like this." (Examiner shows example.) "If you have one that means you went off the sidewalk. Also, look for a double line like this." (Examiner shows example.) "If you have one of these it means you picked up your pencil and made a new start. Your score is the number of the last black line you went through before your first break or your first new start. If you have neither a break nor a new start your score is the number the last black line you went through. When you have found your score put it in the first box at the bottom of the sheet. And then where it says, 'Trial 1' on the yellow card. Now put this maze aside and get a new one ready to go."

(These directions were supplemented as per introductory note to Appendix A.)



NAME_____ TRIAL_____


1
8
9
10
40
50
2
42
41
49
51
11
7
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52
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92

DIRECTIONS FOR ROTARY PURSUIT

(Examiner takes up position in front of one of the test units.)

"This is a test of your ability to follow a moving target. Your task is to keep the point of this stylus (examiner lifts the stylus and points to the tip) on the little round metal target as it goes around. You hold the stylus like this and follow the target as it goes around. (Examiner demonstrates the correct grip and follows the target for a regular test period during which time he makes the following statement.) You will find that if you develop a smooth motion of your whole arm and shoulder and follow the target as it goes around, you will get the best results."

"When you come over here, I want you to stand in an erect position and put your hands on the corner of the box and then step back until your arms are straight. This gives you the right distance away. Then, you pick up the stylus in whichever hand you prefer and put it on the target. (Examiner picks up the stylus and puts it on the target.) And when you do that, the whole thing should be level, like this. (Examiner passes his hand through the horizontal plane of the stylus rod and handles.) You don't want to turn it on the side like this, or hold it up in the air like this, or turn the handle like this (examiner demonstrates the various incorrect positions.) The reason for that is the tip of this stylus makes an electrical contact with the round metal plate and it makes that contact best if you have it on its level. Now I don't want to see anyone turning the handle up like this (examiner demonstrates holding the handle at right angles to the rod) because if you do that,

you are going to run into the turntable as it goes around and damage the motor. Now come and take your positions and pick up the stylus. (Corrects any incorrect grips.)

Lift the stylus about an inch off the target while I finish the directions. You will be given a series of test periods with short rest intervals between. There is no practice, your score begins to count when the first buzzer sounds. When the second buzzer sounds, lift your stylus off the target and keep it off until it starts to move again. Do you have any questions? Remember, your score is the amount of time you stay on the target, so if you get off, get right back on again. You will find that the rest periods are very short and the disc starts again without warning so keep your eyes on the apparatus. Ready." (Examiner turns on the switch.)

(These directions were supplemented as per introductory note to Appendix A.)

Appendix B: Weights for Computing Learning Parameters

(Note: To compute any learning parameter enter that section of Table B-1 which pertains to the learning task and multiply the score earned on trial t by the appropriate weight for that trial. Sum the cross-products over the K trials and add the pertinent constant. The result is the desired learning parameter.)

APPENDIX B

Table B-1. Weights for Computing Learning Parameters

Task: Meccano Assembly Test

c_0: Set equal to zero

Trial	Trial Weights for c_1	Trial Weights for c_2
1	-.02981	-.05280
2	-.02857	-.07143
3	.00373	-.05590
4	.06708	-.00621
5	.16149	.07764
Additive constant:	0.	0.

Task: Breech Block Performance Test

c_0: Set equal to zero

Trial	Trial Weights for c_1	Trial Weights for c_2
1	-.02120	-.02790
2	-.02567	-.04130
3	-.01339	-.04018
4	.01562	-.02455
5	.06138	.00558
6	.12388	.05022
Additive constant:	0.	0.

Table B-1. Weights for Computing Learning Parameters (Cont.)

Task: Sidewalk Maze

c_0: Variable

Trial	Trial Weights for c_0	Trial Weights for c_1	Trial Weights for c_2
1	1.28571	-.16667	.05952
2	.42857	-.07143	0.
3	-.14286	0.	-.03571
4	-.42857	.04762	-.04762
5	-.42857	.07143	-.03571
6	-.14286	.07143	0.
7	.42857	.04762	.05952
Additive constant:	0.	0.	0.

Task: Knob Code

c_0: Set equal to 1

Trial	Trial Weights for c_1	Trial Weights for c_2
1	-.01147	-.00994
2	-.01682	-.01616
3	-.01606	-.01868
4	-.00917	-.01747
5	.00382	-.01256
6	.02294	-.00393
7	.04817	.00841
8	.07951	.02446
Additive constant:	-.10092	.04587

Table B-1. Weights for Computing Learning Parameters (Cont.)

Task: Verbal Concept Formation I
Spatial Concept Formation I

c_0: Set equal to 4

Trial	Trial Weights for c_1	Trial Weights for c_2
1	-.01147	-.00994
2	-.01682	-.01616
3	-.01606	-.01868
4	-.00917	-.01747
5	.00382	-.01256
6	.02294	-.00393
7	.04817	.00841
8	.07951	.02446
Additive constant:	-.40368	.18348

Task: Verbal Concept Formation II
Spatial Concept Formation II

c_0: Set equal to 4

Trial	Trial Weights for c_1	Trial Weights for c_2
1	-.00873	-.00646
2	-.01346	-.01081
3	-.01417	-.01303
4	-.01087	-.01315
5	-.00357	-.01114
6	.00775	-.00702
7	.02308	-.00078
8	.04242	.00758
9	.06578	.01805
Additive constant:	-.35296	.14704

Table B-1. Weights for Computing Learning Parameters (Cont.)

Task: Word Code

c_0: Set equal to zero

Trial	Trial Weights for c_1	Trial Weights for c_2
1	-.00873	-.00646
2	-.01346	-.01081
3	-.01417	-.01303
4	-.01087	-.01315
5	-.00357	-.01114
6	.00775	-.00702
7	.02308	-.00078
8	.04242	.00758
9	.06578	.01805
Additive constant:	0.	0.

Task: Spatial Code

c_0: Set equal to zero

Trial	Trial Weights for c_1	Trial Weights for c_2
1	-.00679	-.00438
2	-.01084	-.00748
3	-.01216	-.00931
4	-.01073	-.00986
5	-.00657	-.00913
6	.00033	-.00712
7	.00997	-.00383
8	.02234	.00073
9	.03746	.00657
10	.05531	.01369
Additive constant:	0.	0.

Table B-1. Weights for Computing Learning Parameters (Cont.)

Task: Sonar

c_0: Set equal to 1

Trial	Trial Weights for c_1	Trial Weights for c_2
1	-.00679	-.00438
2	-.01084	-.00748
3	-.01216	-.00931
4	-.01073	-.00986
5	-.00657	-.00913
6	.00033	-.00712
7	.00997	-.00383
8	.02234	.00073
9	.03746	.00657
10	.05531	.01369
Additive constant:	-.07831	.03012

Task: Combat Information Center Plotting Test

c_0: Set equal to zero

Trial	Trial Weights for c_1	Trial Weights for c_2
1	-.00741	-.00524
2	-.01193	-.00899
3	-.01356	-.01126
4	-.01231	-.01204
5*	0.	0.
6	-.00114	-.00916
7	.00878	-.00549
8	.02158	-.00033
9	.03727	.00631
10	.05585	.01444
Additive constant:	0.	0.

* Note: An error in administration occurred in the fifth trial for the task and the weight vectors were readjusted to ignore trial 5. Otherwise, the weight vectors would have been the same as those for Spatial Code.

Table B-1. Weights for Computing Learning Parameters (Cont.)

Task: Rotary Pursuit Test

c_0: Variable

Trial	Trial Weights for c_0	Trial Weights for c_1	Trial Weights for c_2
1	.60000	-.03235	.00735
2	.42857	-.02563	.00420
3	.27912	-.01939	.00154
4	.15165	-.01364	-.00065
5	.04615	-.00837	-.00234
6	-.03736	-.00359	-.00356
7	-.09890	.00071	-.00428
8	-.13846	.00452	-.00452
9	-.15604	.00785	-.00428
10	-.15165	.01070	-.00356
11	-.12527	.01306	-.00234
12	-.07692	.01493	-.00065
13	-.00659	.01632	.00154
14	.08571	.01723	.00420
15	.20000	.01765	.00735
Additive constant:	0.	0.	0.

Appendix C. Means and Standard Deviations of Variables

APPENDIX C

Table C-1. Means and Standard Deviations of Variables

	Variable	Mean	Standard Deviation
c_1 parameters:			
01	Word Code	1.55	.37
02	Spatial Code	1.48	.24
03	Knob Code	.69	.19
04	Sonar	.64	.24
05	Verbal Concept Formation I	1.11	.44
06	Spatial Concept Formation I	1.17	.38
07	Breech Block Performance Test	1.40	.23
08	CIC Plotting Test	.52	.34
09	Verbal Concept Formation II	.69	.39
10	Spatial Concept Formation II	.49	.52
11	Meccano Assembly Test	1.21	.78
12	Sidewalk Maze	2.04	2.15
13	Rotary Pursuit	3.97	2.75
c_2 parameters:			
14	Word Code	-.12	.14
15	Spatial Code	-.15	.12
16	Knob Code	-.09	.09
17	Sonar	-.08	.06
18	Verbal Concept Formation I	-.13	.19
19	Spatial Concept Formation I	-.16	.14
20	Breech Block Performance Test	-.35	.24
21	CIC Plotting Test	-.10	.09
22	Verbal Concept Formation II	-.16	.12
23	Spatial Concept Formation II	-.02	.11
24	Meccano Assembly Test	-.11	.30
25	Sidewalk Maze	-.30	1.00
26	Rotary Pursuit	-.20	.48
c_0 parameters:			
27	Sidewalk Maze	22.18	15.30
28	Rotary Pursuit	32.32	34.36
Reference Variables:			
29	Recognition II	38.03	5.04
30	First Names	4.69	3.34
31	Word-Number	4.68	3.07
32	Picture-Number	7.95	4.07
33	Number Series	7.89	5.19
34	Letter Sets	6.18	3.68
35	Arithmetic	45.14	8.60
36	Ship Destination	15.90	12.44
37	Math Aptitude	5.14	3.22
38	False Premises	13.30	3.02
39	Reasoning	12.61	5.33
40	General Classification Test	45.80	10.08

Table C-1. (Cont.)

	Variable	Mean	Standard Deviation
41	36-item Vocabulary	12.58	7.87
42	Sentence Completion	3.27	3.05
43	Cards	25.36	11.02
44	Cubes	19.67	4.88
45	Paper Folding	3.43	3.17
46	Paper Form Board	6.66	3.53
47	Mechanical	45.91	8.82
48	G-Z Mechanical Knowledge	7.83	4.40
49	Addition	23.95	8.74
50	Division	18.35	11.64
51	Tracing	131.65	28.87
52	Dotting	94.13	26.24
53	Writing X's	120.00	20.17
54	Writing Digits	173.12	30.54
55	Tapping	738.26	76.94
56	Turning	101.95	9.87
57	Placing	81.92	6.60
58	Steadiness	18.83	14.10
59	Clerical Aptitude	46.43	8.15
60	Picture Discrimination	44.65	9.75
61	Words assoc. w/unf. house	21.11	9.07
62	Word Checking	29.62	10.12
63	AFQT	45.09	10.00
64	Otis	35.27	12.05
65	Oral Directions Test	30.08	4.62
66	Education	2.22	1.34
67	Age	17.77	1.06

Appendix D: Testing Schedules

APPENDIX D

Table D-1. Master Testing Schedule

Date (1955)	6-2	6-3	6-7	6-8	6-9	6-10	6-13	6-14	6-15	6-16	6-17	6-20	6-21	6-22	6-23
Hours of Testing	6	6	7	7	7	7	7	7	7	7	2	2	2	2	1
CO. 207	Ref		Dog								SCF II	VCF I CIC	Sonar SCF I	Knob VCF II	Word
CO. 208	Ref			Dog							SCF II	VCF I CIC	Sonar SCF I	Knob VCF II	Word
CO. 209	Ref				Dog						SCF II	VCF I CIC	Sonar SCF I	Knob VCF II	Word
CO. 210	Ref					Dog					SCF II	VCF I CIC	Sonar SCF I	Knob VCF II	Word
CO. 211		Ref					Dog				SCF II	VCF I CIC	Sonar SCF I	Knob VCF II	Word
CO. 212		Ref						Dog			SCF II	VCF I CIC	Sonar SCF I	Knob VCF II	Word
CO. 213		Ref							Dog		SCF II	VCF I CIC	Sonar SCF I	Knob VCF II	Word
CO. 214		Ref								Dog	SCF II	VCF I CIC	Sonar SCF I	Knob VCF II	Word
No. Proctors	10	10	30	30	30	30	30	30	30	30	5	5	5	5	5
No. Examiners	2	2	7	7	7	7	7	7	7	7	4	4	4	4	2

Code:
- Ref = Reference Tests explained Table D-2
- Dog = Schedule explained in Table D-3
- SCF II = Spatial Concept Formation II
- VCF I = Verbal Concept Formation I
- CIC = Combat Information Center Plotting Test
- SCF I = Spatial Concept Formation I
- Knob = Knob Code
- VCF II = Verbal Concept Formation II
- Word = Word Code

Table D-2. Schedule for Reference Tests

Time	Book	Test	Other	Adm. Time	Test Time	Total Time
0730			Introductory Remarks			15'
	DETB1	Mech. Knowl.		3'	10'	13'
	DETB1	Ship Dest.		5'	15'	20'
	DETB1	Vocab.		3'	10'	13'
	DETB1	Number Series		5'	8'	13'
	DETB1	Rec. II		3'	4'	7'
			Collection of DETB1			5'
			5' break			5'
	DETB2	Writing X's		3'	30"+90"	5'
	DETB2	Addition		3'	3'	6'
	DETB2	Cards		3'	6'	9'
	DETB2	Tracing		3'	30"+90"	5'
	DETB2	First Names		3'	90"+ 8'	12½'
			Collection of DETB2			5'
			2' break			2'
	DETB3	Writing Digits		3'	30"+90"	5'
	DETB3	Division		3'	3'	6'
	DETB3	False Premises		3'	8'	11'
	DETB3	Word-Number		3'	90"+ 8'	12½'
	DETB3	Reasoning		3'	6'	9'
	DETB3	Cubes		3'	5'	8'
			Collection of DETB3			5'
1105			Dismissed for lunch			
1230	DETB4	Math Apt.		3'	10'	13'
	DETB4	Paper Folding		5'	10'	15'
	DETB4	Sentence Compl.		3'	7'	10'
	DETB4	Letter Sets		3'	8'	11'
			Collection of DETB4			5'
			5' break			5'
	DETB5	Dotting		3'	30"+90"	5'
	DETB5	Picture-Number		3'	6'	9'
	DETB5	w/a unf. house		3'	2½'	5½'
	DETB5	Paper Form Board		3'	7'	10'
	DETB5	Pict. Disc.		3'	3'	6'
	DETB5	Word Checking		3'	2'	5'
			Collection of DETB5			5'
1430			Dismissed			

Table D-3. "Dog Days" Testing Schedule

Time Period	0745-0905	0910-1010	1015-1115	1300-1400	1405-1515
Group A (N=16)	Delta	Otis-ODT	Meccano	BBPT	Spa. Code
Group B (N=16)	Meccano	Delta	Otis-ODT	BBPT	Spa. Code
Group C (N=16)	Spa. Code	Meccano	Delta	Otis-ODT	BBPT
Group D (N=8)	Spa. Code	Meccano	Otis-ODT	Delta	BBPT
Group E (N=8)	Spa. Code	Otis-ODT	Meccano	Delta	BBPT

Code: Delta = Schedule explained in Table D-4
Otis-ODT = Otis Mental Ability Test and Oral Directions Test
Meccano = Meccano Assembly Test
BBPT = Breech Block Performance Test
Spa.Code = Spatial Code

Table D-4. Delta Testing Schedule

Delta Time Period	1	2	3	4
Sub-Group I (N=4)	RP	S&T	T&P	Maze
Sub-Group II (N=4)	S&T	T&P	Maze	RP
Sub-Group III (N=4)	T&P	Maze	RP	S&T
Sub-Group IV (N=4)	Maze	RP	S&T	T&P

Code: RP = Rotary Pursuit Test
S&T = Steadiness Test and Tapping Test
T&P = Turning Test and Placing Test
Maze = Sidewalk Maze

Appendix E: Tests of Statistical Significance for Inter-battery Factors

APPENDIX E

Tests of Statistical Significance for Inter-battery Factors*

$N = 315$ $n_1 = 28$ $n_2 = 39$

1. f, u	0	1	2	3	4	5	6	7
2. $n_1 - u$	28	27	26	25	24	23	22	21
3. $n_2 - u$	39	38	37	36	35	34	33	32
4. $(d.f.) = (n_1 - u)(n_2 - u)$	1092	1026	962	900	840	782	726	672
5. γ_f^2		29.5804	1.9359	.7378	.5317	.3746	.2077	.1752
6. $A \equiv \sum_j \sum_k r_{jk}^2 - \sum_{f=1}^{u} \gamma_f^2$	34.4406	4.8602	2.9243	2.1865	1.6548	1.2802	1.0725	.8973
7. $S_{f1}^2 = W_{f1}' R_{11} W_{f1}$		4.1771	1.5587	1.1952	1.4422	1.0385	1.6405	1.0064
8. $C \equiv n_1 - \sum_{f=1}^{u} S_{f1}^2$	28	23.8229	22.2642	21.0690	19.6268	18.5883	16.9478	15.9414
9. $S_{f2}^2 = W_{f2}' R_{22} W_{fz}$		12.2618	2.6533	2.8125	1.3689	1.2768	.8158	1.0407
10. $D \equiv n_2 - \sum_{f=1}^{u} S_{f2}^2$	39	26.7382	24.0849	21.2724	19.9035	18.6267	17.8109	16.7702
11. $B \equiv C \times D$	1092	636.9815	536.2310	4448.1882	390.6420	346.2387	301.8556	267.3405
12. $\phi_u = \frac{N(d.f.)(A)}{(B)}$	10711.0	2434.6418	1631.5691	1365.5008	1106.6397	899.2270	802.229	701.4594
13. $Z = \sqrt{2\phi_u} - \sqrt{2(d.f.) - 1}$	99.64	24.49	13.27	9.84	6.07	2.87	1.96	.81
14. p	<.01	<.01	<.01	<.01	<.01	<.01	.025	.209

* See Tucker (1958b) for additional clarifiction of notation.