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This investigation examined in the laboratory the type of learning commonly found in the school situation--the formalized acquisition of concepts. A verbal concept-learning task suitable for college students was devised which permitted the externalizing and quantifying of behavior at 6 points in the learning process. A pilot study evaluated the effects of 4 experimental conditions on learning. One of the conditions, described as "postulates removed, no feedback" was employed in the factor-analytic study. The learning task and 16 nonarbitrarily selected ability tests purporting to measure reasoning, memory, and verbal factors were administered to 102 college women. Two major conclusions were (1) that the psychological constructs underlying the learning task are an ability to make multiple discriminations and an ability to respond to stimulus items as representatives of a class rather than as individual entities and (2) that the pattern of loadings on each task factor is evidence of an occurrence of learning. The type of learning is specific to the learning task and the abilities isolated by it. (Author)

RELATIONSHIPS BETWEEN CONCEPT LEARNING AND SELECTED ABILITY TEST VARIABLES FOR AN ADULT POPULATION

WISCONSIN RESEARCH AND DEVELOPMENT

CENTER FOR COGNITIVE LEARNING

Technical Report No. 51

RELATIONSHIPS BETWEEN CONCEPT LEARNING AND SELECTED ABILITY TEST VARIABLES FOR AN ADULT POPULATION

By Dorothy L. Jones

Report from the Project on Situational Variables and Efficiency of Concept Learning
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PREFACE

This technical report is based upon the dissertation of Dorothy Lois Jones. The examining committee consisted of Professors C. W. Harris, (chairman), H. J. Klausmeier, R. E. Davidson, T. A. Cleary and H. J. Keisler.

One major program of the Wisconsin R and D Center for Cognitive Learning is Program 1 which is concerned with fundamental conditions and processes of learning. This program consists of laboratory-type research projects, each independently concentrating on certain basic organismic or situational determinants of cognitive learning, but all united in the task of providing knowledge which can be effectively utilized in the construction of instructional systems for tomorrow's schools.

Of critical importance to the field of human learning is the area of concept learning, an area which enjoys vigorous experimentation most of which is designed primarily to reveal task or situational determinants of performance. Miss Jones continues these empirical investigations by analyzing the performance of college women on a concept learning task. The results of elaborate factor analyses permit Miss Jones to make significant statements concerning specific cognitive abilities related to this type of learning, including relative differences in the cognitive abilities of learners and nonlearners.

Harold J. Fletcher
Director, Program 1

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ABSTRACT

The purpose of the investigation was to examine in the laboratory the type of learning commonly found in the school situation—the formalized acquisition of concepts. A verbal concept-learning task suitable for college students was devised which permitted the externalizing and quantifying of behavior at six points in the learning process. A pilot study evaluated the effects of four experimental conditions on learning; one of these conditions described as "postulates removed, no feedback" was employed in the factor-analytic study. The learning task and sixteen nonarbitrarily selected ability tests purporting to measure reasoning, memory, and verbal factors were administered to 102 college females. Data for the total group were analyzed by both alpha factor analysis and incomplete image analysis. Alpha factor analyses were also reported for two subgroups, achievers and nonachievers. Six alpha and twelve image factors were extracted and orthogonally rotated in the total population analyses, seven alpha factors in each subgroup analysis. Four areas of cognitive ability were associated with mathematically deduced factors in all analyses. These abilities were identified as meaningful memory, multiple discrimination, a classifying or categorizing ability, and verbal comprehension. Reasoning factors were less clearly defined and test alignments on isolated factors (in the total group, achiever, and nonachiever analyses) differed. Two major conclusions of the study were: (1) that the psychological constructs underlying the learning task are an ability to make multiple discriminations and an ability to respond to stimulus items as representatives of a class rather than as individual entities; and (2) that the pattern of loadings on each task factor is evidence of an occurrence of learning; the type of learning is specific to the learning task and the abilities isolated by it.

I

THE PROBLEM AND RELATED RESEARCH

THE PROBLEM

A paramount goal of educators is the improvement of instruction. Such enhancement is often determined by evaluating effects of varied instructional methods in controlled experiments. That method A is significantly superior to B and C is a statistically derived statement; it may be that A reflects the best application and exploitation of the subjects' acquired or trained intellectual aptitudes. The more fundamental problem would seem to be the identification of those intellectual skills which are related to efficient learning. The next step would be to develop the students' level of proficiency with respect to these intellectual skills (if it be possible to train for such skills). Under these circumstances the statistically derived statement that "method A is significantly superior to B and C" implies a "true best" since the dependent measures obtained on Ss (subjects) which determined A's superiority reflect efficiency in learning. With these ideas in mind and assuming that "school-type" learning is predominantly conceptual in nature, the most rudimentary question, which is the major concern of this study, is; What intellectual abilities are related to conceptual learning?

In the middle 1930's researchers (Perl, 1934; Edgerton and Valentine, 1935; Woodrow, 1938) began examining the changes in the factorial structures of test and/or task variables measured at successive stages of practice to ascertain whether or not there was an univocal factor suggestive of an "ability to learn" or an "ability to improve with practice." Although patterns in loadings exhibited in the extracted factors of intercorrelation matrices of practice variables were first observed by Perl,[1] Woodrow (1939a) specified that, for any practice matrix,

> ...as practice proceeds, the first factor loadings progressively decrease and the second factor loadings progressively increase....The two factors (which may be complex) are not necessarily the same, as Perl assumed, in the case of different practice tests [p. 460].

Understanding the structural principle underlying an arbitrary practice matrix (i.e., factor analytic reduction to at least two factors) gives meaning to Woodrow's (1939a) comment:

> ...if by learning ability is meant the ability to improve one's score with practice, beginning with whatever might happen to be one's initial score, then certainly there is no general learning factor [p. 457].

If investigative interests were bent toward isolating a general ability to learn, factor analyzing practice matrices would be fruitless. Employing methods which compactly express overall learning performance within one score has been recommended as a way to avoid the multiple task factors. Woodrow (1939a, 1946), Thurstone (1919), and Gulliksen (1934) suggested fitting learning curves to the data and computing learning parameters (e.g., the maximum slope of the curve representing rate of learning) as measures for factor analyzing. Both Stake (1961) and Allison (1960) have used this approach.

The aim of this study, however, was not the isolation of an unique "ability to learn" but the establishment of observable evidence

[1]Perl (1934) first described what is now termed a practice matrix: "The intercorrelations of scores on these different trials of the same task were computed, and we found that for each test they tended to be arranged in a hierarchy; i.e., the 1st trial correlated higher with the 3rd than it did with the 6th trial, it correlated higher with the 6th than the 12th, and so on. The nearer together in the series trials fall, the higher the intercorrelations of score on these trials [p. 210]."

(in the form of ability test loadings) which would permit attaching "surplus" meaning to the two or more mathematically deduced task factors defined by measures taken on a particular learning task for a particular population at a sufficient number of practice points. In this study a factor is a principle of classification, a resultant of the reorganization of the concomitant variation of an empirical set of data. Interpretation of factors as hypothetical constructs[2] is not to be confused with the mathematical model representing the data. The latter is a tool which not only helps establish the former by confirming (or disconfirming) an experimenter's presumptions but also generates hypotheses for future research. Factor analysis, as employed in this investigation, is concerned with construct validation.[3]

In this study, an intellectual ability has the status of a hypothetical construct. Although the term "intellectual abilities" is used freely with respect to "factors," the above distinction is to be understood.

Specific Statement of the Problem

Measures at six points (or stages) of a specially devised concept-learning task for college students were factor analyzed along with scores on sixteen nonarbitrarily selected ability tests primarily to answer (or, at least, guide direction to an answer for) the question;[4] What hypothetical constructs account for the variance in performance on the concept-learning task?

Objectives of the Study

The objectives of the investigation were:

A. The task
   1. To devise a task that parallels in the laboratory the type of concept learning most prevalent in the school situation, i.e., the formal acquisition of second-level concepts.[5]
   2. To administer the task in a manner which permits the externalizing and quantifying of behavior at selected points in the learning process.

B. The factor analysis
   1. To isolate and identify intellectual abilities associated with or dissociated from successful performance on a concept learning task.
   2. To compare the factorial structure of the laboratory task at successive stages of proficiency.
   3. To examine and compare the results of separate analyses corresponding to two subgroups of the total population.[6]

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[2] A hypothetical construct implies an entity not directly reducible to the observable and that to which "surplus meaning" has been attached (MacCorquodale and Meehl, 1948). Accordingly, empirical data and laws are necessary but not sufficient conditions for establishing or confirming a hypothetical construct. An intervening variable, on the other hand, summarizes observable objects or events in the form of an empirical law. No surplus meaning is implied; it is directly reducible to observables and empirical laws. A factor as a classification is best denoted as an intervening variable, with surplus meaning attached, a hypothetical construct. More realistically, when reference is made to "the third factor" or "the factor which loads substantially on the task variables," an intervening variable is specified; when reference is to a "memory factor" or "induction factor" a hypothetical construct is implied.

[3] The Standards for Educational and Psychological Tests and Manuals states: "Construct validity is evaluated by investigating what quantities a test measures, i.e., by determining the degree to which certain explanatory concepts or constructs account for performance on the test [1966, p. 13]."

[4] Cronbach and Meehl (1955, p. 282) cite the question with the word "hypothetical" deleted. They refer to a construct as "some postulated attribute of people, assumed to be reflected in test performance [p. 283]."

[5] By "second-level concepts" is meant concepts which have other concepts as their denotation as contrasted with first-level concepts which have objects as referents. Frege (1960, p. 50) is more specific: "Second-level concepts, which concepts fall under, are essentially different from first-level concepts, which objects fall under. The relation of an object to a first-level concept that it falls under is different from the (admittedly similar) relation of a first-level to a second-level concept. (To do justice at once to the distinction and to the similarity we might perhaps say: An object falls under a first-level concept; a concept falls within a second-level concept). The distinction of concept and object thus still holds, with all its sharpness."

[6] The total population was dichotomized at the median score of the final stage of the task.

THEORETICAL CONSIDERATIONS

Definitions

For this study, the term "learning" has the status of an intervening variable (Note 2). Couched in S–R terminology, the word functions as a label for "the relationship between a set of stimulus conditions (repeated presentation of stimulus material) and a set of response conditions (the acquired behaviors) [Staats and Staats, 1964, p. 21]." Staats schematized the relationship as follows:

Learning
Practice (Repeated Trials) → Change in behavior

Inherent in the operational definition is the relative permanence of behavioral change which eliminates behavioral modifications due to motivation or fatigue. Maturational changes are excluded by identifying conditions (repetition, practice, experience) for learning.

Gagné (1965) identified "types" of learning according to conditions which determine the occurrences of learning. Two types are particularly relevant to this investigation (and to school learning):

> Multiple discrimination learning—the individual becomes capable of making different responses to the different members of a particular collection.
>
> Concept learning—the learner becomes able to respond in a single way to the collection as a class, which then extends beyond the particular members that were originally present [p. 114].

Rationale for the Experimentally Sampled Behavior

Typically, in the school situation (primarily high schools and colleges), S receives a definition or description of an entity. His capability of either correctly employing the concept when used denotatively[7] or correctly categorizing instances and noninstances indicates whether he does or does not "have" the concept. The latter categorizing behavior, commonly studied in the laboratory, is not an infrequent occurence in formalized or school-type learning. For example, in mathematics, S categorizes objective stimuli as positive or negative instances of the concept of "function" according to defining attributes given by the teacher. In English, S displays his acquisition of the concept of "pronoun" by his categorizing behavior which in turn is determined by defining characteristics presented to him. Repeatedly, in the school situation, the rules of the game are given to S; he demonstrates his understanding via publicly observable behavior.

The task employed in this study, however, did not sample behavior customarily observed by the teacher or experimenter. Although attempting to parallel school learning, the task was primarily aimed at "slowing down," externalizing and quantifying S's covert behavior within a defined "interval of learning."

The Domain of Definition of the Task

Consider the hypothetical learning curve displayed in Figure 1. Two intervals on the X-axis have been indicated. Let (X_0, X_p) be the open interval where each X_i, $i = 1, 2, \ldots, n$, $n < p$, represents a trial or stage at which S is given new information about the concept. Let $[X_p, X_c]$ be the closed interval representing stages of learning where no new information is presented; S continues to assimilate (process) information and overtly shows "improvement with practice." The endpoint X_c indicates that point or stage where the criterion of performance defined by the experimenter was met.

The portion of the total behavior pattern explored in the study falls in the interval $(X_0, X_p]$. The laboratory task measured S's categorizing behavior at six stages; five were sampled from the interval (X_0, X_p), the sixth was X_p.

It should be clear why no informative feedback was provided.[8] As S normally processes information gleaned from a definition or description, there is no externally applied feedback.

Structure-of-Intellect Model

Guilford's structure-of-intellect (SI) model provided theoretical framework for selecting ability tests. The model in its present formulation (Guilford and Merrifield, 1960) espouses 120 separate intellectual abilities defined within a three-dimensional system, the latter identified as contents, operations, and products. Information is defined as "that which the

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[7] The idea of using a concept denotatively is drawn from B. Russell (1937). For example, the statement, "An integer is either odd or even," is not about the concept of "integer"; instead the concept represented by the word "integer" is used to denote "entities" which are either odd or even.

[8] In the pilot study, however, effects of feedback were studied (Chapter III).

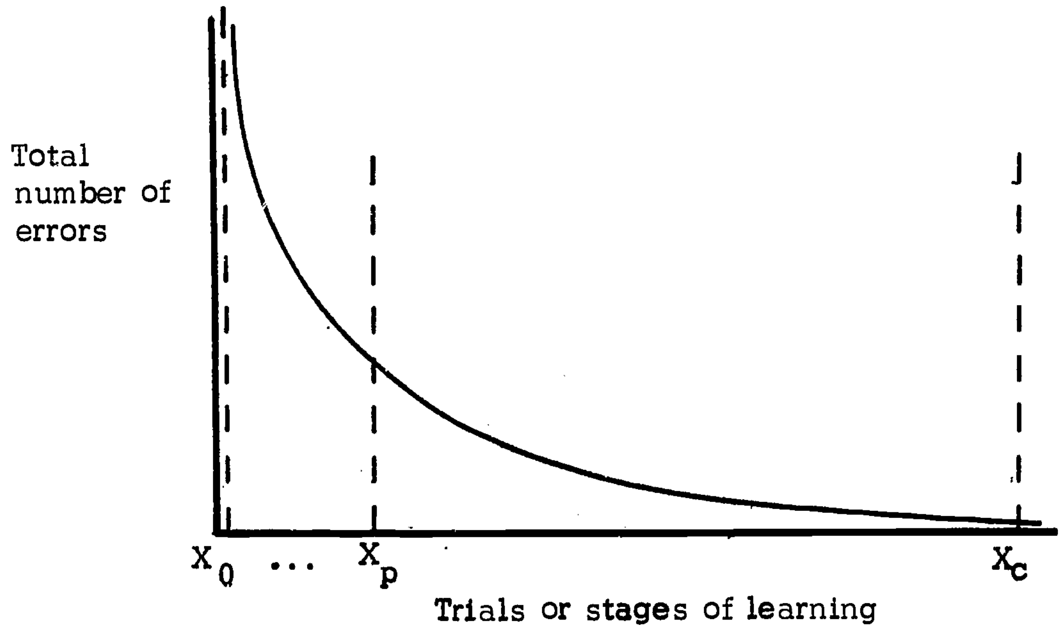

Figure 1. Hypothetical Learning Curve

organism discriminates." The following definitions describe the model (Guilford and Merrifield, 1960, p. 5):

Operations: Major kinds of intellectual activities or processes: things that the organism does with the raw materials of information.
Cognition: Discovery, awareness, rediscovery, or recognition of information in various forms; comprehension or understanding.
Memory: Retention of information in any form.
Divergent production: Generation of information from given information, where the emphasis is upon variety of output from the same source.
Convergent production: Generation of information from given information, where the emphasis is upon achieving unique or conventially accepted or best outcomes.
Evaluation: Reaching decisions or making judgments concerning the goodness (correctness, suitability, adequacy, desirability) of information in terms of criteria of identity, consistency, and goal satisfaction.

Contents: General varieties of information.
Figural content: Information in concrete form, as perceived or as recalled in the form of images. The term "figural" implies some degree of organization or structuring.
Symbolic content: Information in the form of signs, having no significance in and of themselves, such as letters, numbers, musical notations, etc.
Semantic content: Information in the form of meanings to which words commonly become attached, hence most notable in verbal thinking; involved in doing verbal tests, where the things signified by words must be known.
Behavioral content: Information, essentially non-verbal, involved in human interactions, where awareness of the attitudes, needs, desires, intentions, thoughts, etc. of other persons and of ourselves is important.

Products: Results from the organism's processing of information.
Units: Relatively segregated or circumscribed items of information having "thing" character.
Classes: Aggregates of items of information grouped because of their common properties.
Relations: Recognized connections between units of information based upon variables that apply to them.
Systems: Organized or structured aggregates of items of information; complexes of interrelated or interacting parts.
Transformations: Changes in existing or known information or in its use, as in production.
Implications: Extrapolations of information, in the form of expectancies, predictions, antecedents, and consequents.

Guilford's concrete representation of the SI model as a rectangular prism appears in Figure 2. Each of the 120 intellectual abilities occupies a unique cell in the rectangular solid and is denoted by a trigram symbol; e.g., CPU represents cognition of figural units (see Figure 2 for letter designations).

RELATED RESEARCH

Factor-Analytic Studies Involving "Practice" Variables

Exploration of the relationship between measures of learning over practice series was

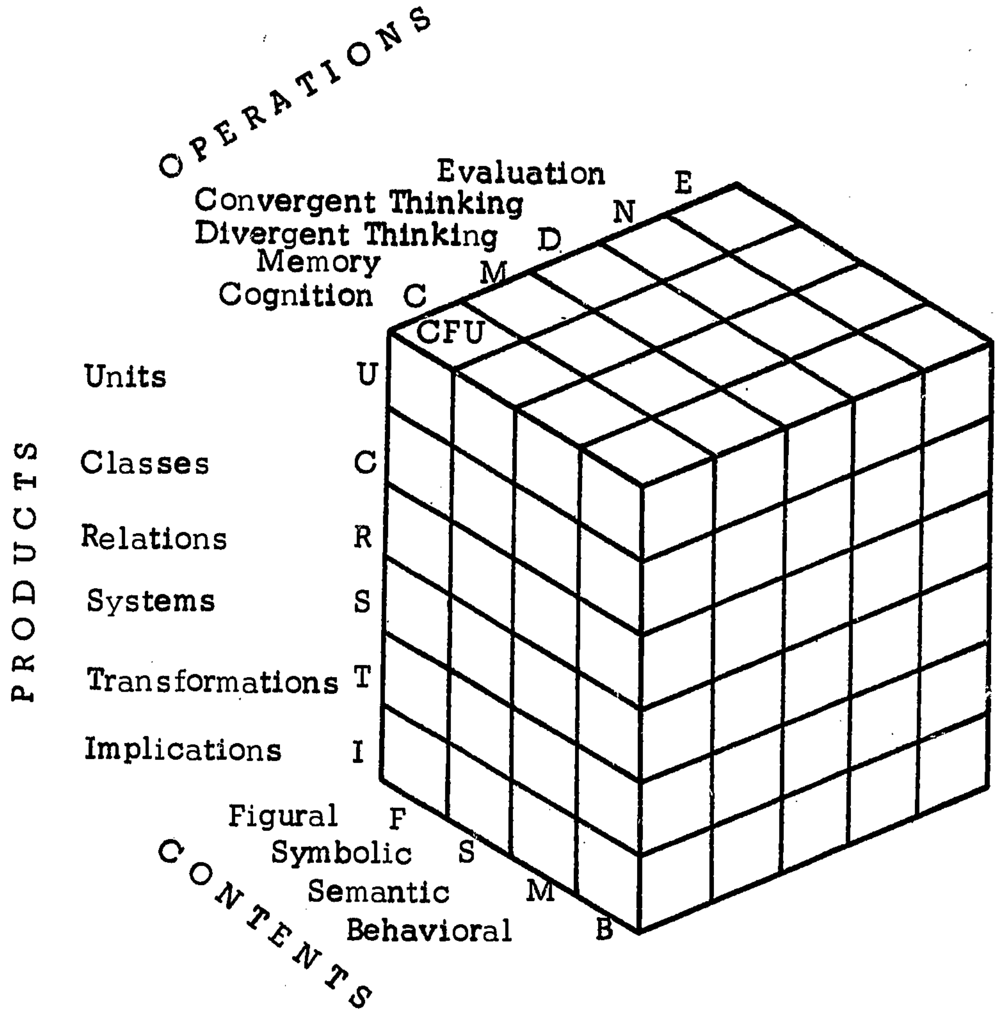

Figure 2. Geometrical Representation of the Structure-of-Intellect Model

first reported by Ruth Perl (1934). Thurstone's multiple factor method was used to examine the factorial structure of four different tasks at five practice stages selected from twenty trials. The first of two factors extracted was interpreted as "something like 'proximity'" reflecting the hierarchical arrangement typical of a practice matrix. Loadings increased with successive trials to a maximum point and then dropped. The second factor loadings likewise displayed a hierarchy and were thought to indicate the learning that took place over the practice series.

Edgerton and Valentine (1935) also applying Thurstone's factor analytic technique isolated three factors explanatory of the underlying structure of the intercorrelations of time series for ten successive trials on mirror drawing.

Woodrow (1938) factor-analyzed initial, final, and gain scores of seven performance tests practiced by 56 subjects for 39 days together with scores on "end-tests" (tests given either before or after practice). Marked changes in the factor loadings of the seven performance tests over practice and absence of such changes for end-tests given before and after practice were reported. Although "no sign of any general improvement factor" appeared, several factors did load on more than one practice test with respect to gain score. Woodrow (1939a) identified and discussed problems associated with practice: (1) the existence of a general ability to learn, (2) what abilities are increasingly sampled as the result of practice, (3) the relationship between the observed factorial change and improvement in task performance with practice. In another study, Woodrow (1939b) failed to isolate any factor common to gain scores which would be indicative of a general ability to improve with practice. With respect to practice, Woodrow (1946, pp. 148-149) generalized:

> Improvement with practice correlates importantly with group-factors, that is, relatively narrow abilities, and also with specific factors.
>
> Even the group-factors involved in learning are not unique to learning but consist of abilities which can be measured by tests given but once.

Greene (1943) factor analyzed separately data collected on the first and fourth trials of six motor tests and six nonverbal tests given four times. He suggested that the change in a test's factorial structure might indicate something other than error associated with the lowering of reliabilities on retesting.

Fleishman (1953) began the first in a series of factor analyses designed to explore and describe the organization of abilities associated with psychomotor learning at different stages of practice.

Fleishman and Hempel (1954) factor analyzed the intercorrelation matrix of scores for 197 airmen at eight stages of practice on the Complex Coordination Test together with scores on eighteen reference tests. Using Thurstone's centroid method of factor analysis, ten factors (nine interpretable) were extracted. Results indicated that as practice increased, the factorial structure of the Complex Coordination Test became less complex; the "nature" of the factors contributing variance at early and late stages of practice likewise showed a shift. "By the final stage of practice, the non-motor factors account for only 10.5 per cent of the variance while the motor factors now account for 74.5 per cent [page 247]."

The results of a similarly designed study (Fleishman and Hempel, 1955) employing a different psychomotor practice task confirmed the earlier findings of systematic change in a test's factorial structure over practice. This task, however, did not exhibit a factorial pattern of decreasing complexity but "there was an increase in the contribution of a factor common only to the practice task [p. 312]."

Fleishman (1957a) carried out two independent factor analyses on seven psychomotor tasks and eight reference tests. Both analyses employed measures taken at four practice stages of the Complex Coordination Task and scores on the eight reference tests. Early versus late stage scores for the remaining six psychomotor tasks discriminated between the two analyses. Results indicated identification of the same eight factors in both analyses and no appearance of new factors upon substitution of more proficient measures (in Analysis 2). The author stated, "The question was one of 'degree of involvement' of particular factors already identified [p. 270]." The "within-task" factor (the factor specific to practice on the Complex Coordination Task) appeared in both analyses and showed the typical pattern of increased loadings with practice.

Later studies (Fleishman, 1958, 1960) continued the same line of research but varied the type of psychomotor task analyzed over practice stages. In a study exploring the relationship of certain abilities and task difficulty, Fleishman's (1957b) comment "As a corollary of these findings, the results suggest that subjects of varying ability levels may solve the same task by using different processes [p. 531]" is relevant to results reported in Chapter IV.

Recently reported investigations (Bunderson, 1967; Dunham, Guilford, and Hoepfner, 1966) have examined performance on learning tasks at successive stages of practice with respect to carefully selected intellectual abilities; these studies are discussed in the next section.

Factor-Analytic Studies Involving Learning Tasks

Two of the earliest factor-analytic studies which specifically named a factor "concept formation" were Adkins and Lyerly (1952) and Corter (1952). Both studies, however, primarily investigated reasoning abilities, the Adkins and Lyerly study using 200 adult subjects, the Corter study, 100 high school students.

Matin and Adkins (1954) reported a second-order factor analysis of the 13 interpretable factors extracted in the Adkins and Lyerly study. Six second-order factors appeared. M', the concept formation factor of the original study, was described as the "ability to formulate abstract or precise verbal concepts." Three tests (whose titles adequately suggest task requirements) identifying the factor were Picture-Group Naming, Word-Group Naming, and Verbal Analogies. Factor 1, a second-order factor, was "Precision in Formation and Use of Verbal Concepts." It loaded substantially and positively on both Concept Formation and Verbal Relations and negatively on Perceptual Speed. Two comments were noteworthy: firstly, several tests of Verbal Relations stressed the perception and manipulation of the verbal relations rather than understanding the meanings of "high-level" vocabulary; secondly, a suggested interpretation of bipolarity was that subjects might be employing "alternative or even antagonistic processes" in test performance. The first comment has relevance to the type of analogies tests used in this investigation, one representing Guilford's MMR factor, the other, EMR.

The Corter (1952) study analyzed scores on five subtests of the Science Research Associates version of the Primary Mental Abilities Test and sixteen individually administered tests. One of the seven interpreted factors was "weakly identified" as a concept ability. The author stated, "It apparently involves the ability to recognize essential similarities, to abstract and to generalize, to think inductively [p. 28]."

Stake (1961) studied individual differences among learners (240 seventh graders) to ascertain whether there was a general ability to learn or whether there were multiple learning abilities specific to types of task. Twelve "short-term" learning tasks were specially devised to parallel scholastic-type learning situations. Half of the tasks were of the rote-memory type; the other required the child to discover relationships. Word Groups was the only task requiring categorizing behavior; cards bearing four words each had to be placed in one of four boxes. The experimenter indicated the correct box if the child erred.

A hyperbolic learning curve was fitted to scores taken at successive stages of practice for each person for each task. Three parameters were used to define task performance. Two of these calculated from the learning curve were the asymptote (total errors for perfect learning) and the curvature (the minimum distance from the intersection of asymptotes to the hyperbole). The third parameter employed was the standard error of fit (a goodness-of-fit or parameter of performance).

A total of 72 variables (learning tasks, ability tests, achievement tests, intelligence test, race, and course marks) were factor analyzed by Thurstone's multiple group method and the results rotated obliquely to approach simple structure. Four of the extracted factors were identified as learning factors. Two were related to learning tasks described as memory type; the third, to tasks requiring use of numbers; the fourth was loaded on the goodness-of-fit parameter for four of the tasks. The last factor was interpreted as a concentration factor. Results supported the hypotheses that there is no unitary ability to learn and that learning ability can be specific to type of task. No factors were isolated which differentiated rote learning performance from relational learning performance. Other findings indicated that learning-curve parameters did correlate significantly with intelligence, aptitude, and achievement measures whereas the correlation between the marks factor and the learning factors was negligible.

Allison (1960) also employed the "fitted learning curve" technique to derive learning measures suitable for subsequent task analysis. Thirteen learning tasks, 34 reference tests, and three intelligence tests were administered to 315 adults. Included in the groups of learning tasks (hypothesized as representing conceptual, rote, and memory learning) were four concept formation tasks. These tasks required S to assign a letter (A, B, C or D) to presented sets of four words of four figures. Immediate feedback was provided.

Twenty-eight learning measures obtained from the 13 learning tasks were factor-analyzed by application of the principal component algorithm to the intercorrelation matrix with communality estimates as diagonal elements. Seven of the 12 extracted and rotated factors were interpreted as follows: verbal conceptual learning, spatial conceptual learning, mechanical-motor learning, three rote-learning factors (two defined by the rate and curvature parameters independent of content and one defined by the rate parameter but specific to spatial tasks), early versus late learning. The author concluded that

> 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 [p. 89].

An interbattery factor analysis (Tucker, 1958) yielded seven factors common to the set of learning-curve measures and the reference-test battery. After rotation four factors represented by learning parameters corresponded satisfactorily with four reference-test interbattery factors. They were interpreted as a conceptual process factor, rote process factor, mechanical factor, and a psychomotor coordination factor.

Duncanson (1966) reported another investigation of interrelationships of learning measures and ability scores. Nine different tasks, systematically evolved by combining each of the three types of material (verbal, numerical, and figural) with each of three types of task (concept formation, paired associates, and rote memory), were administered to 102 sixth-grade children. Concept formation tasks were patterned after the Wisconsin Card Sorting Task (Berg, 1948). Individualized raw scores obtained over stages of practice for every task were converted into a set of learning measures assumed to describe an individual's learning performance by a method developed by Tucker (1960). For a given task, there were as many derived learning measures as there were "significant" characteristic roots (and vectors) of the crossproduct matrix formed from the raw scores matrix. Factor scores (on the unrotated factors) were computed for each person. The derived learning measures for all tasks were factor analyzed along with scores on 15 ability tests, one intelligence test, and six achievement tests. Seven factors were extracted and rotated to an equamax solution. One factor, a speed factor, was unrelated to task variables. Three other factors interpreted as ability factors (verbal, reasoning, and rote memory) loaded substantially on task variables permitting the conclusion that learning is related to measured abilities. The remaining three factors were restricted to task variables and were interpreted as a concept formation factor, a verbal learning factor, and a nonverbal learning factor. Results indicated that the concept formation task used in the study did not exhibit interrelationships with the abilities measured as did the paired-associates and rote memory tasks. The author commented, "Whether the lack of interrelationships lies in the battery of ability tests or in the specially devised learning tasks or both remains at present a puzzle [p. 228]."

Lemke (1965) investigated the relationships among 18 conceptual learning measures and scores on 17 selected ability tests. An underlying motive of the study was to isolate and identify variables suitable for blocking purposes in experiments involving strategies of learning. Two concept-attainment tasks and an information processing task (Tagatz, 1963) administered to 94 female college students provided the 18 learning measures. All tasks used figural "dimensionalized" stimulus materials patterned after the Wisconsin Card Sorting Task. Variant I of the concept attainment tasks exemplified the Bruner et al. (1956) selection paradigm; Variant II (reception mode) presented a minimally sufficient set of cards simultaneously to S for concept determination. The information processing task required S to specify the inclusion, exclusion, or indeterminateness of a given card in accordance with simultaneously presented exemplars and/or nonexemplars. Learning measures obtained from two Variant I problems were time-to-criterion, number of cards-to-criterion, and an index of manifested information (defined as "that amount of information manifested in the first hypothesis from that potentially obtained [p. 6]"). Four reception-type concept attainment problems yielded time-to-criterion scores. Number-correct scores measured performance on eight subtests of the information processing task. Ability test selection was based on the following eight psychological factors hypothesized as "underlying the concept attainment and information processing tasks": Verbal Comprehension, General Reasoning, Induction, Deduction, Rote Memory, Span Memory, Perceptual Speed, and Spatial Scanning.

Both incomplete image and alpha solutions were reported by Lemke. Only the alpha results (rotated obliquely with the Harris-Kaiser analytic criterion) are summarized here. The twelve extracted and interpreted factors included all hypothesized factors except Perceptual Speed. The remaining five factors were identified as Information Processing (Negative-Affirmative Decisions), Selection I (Concept 2), Presented Information, Selection II (Concept 1), and Information Processing (Can't Tell).

The matrix of factor intercorrelations indicated that the General Reasoning and Induction factors were correlated with all five task factors. Coefficients were low but consistent, ranging from .22 to .46. The Verbal Comprehension factor showed two correlations with task variables in that range.

Tagatz, Lemke, and Meinke (1966) studied the relationship between concept learning in the laboratory and achievement in selected curricular areas for a population composed of seventh-, eighth-, and ninth-grade students. The same set of figural dimensionalized stimulus cards as described above was employed. S was required to solve four concept attainment problems involving only two concepts; each concept was to be deduced from two different stimulus card presentations. One case displayed only positive instances of the concept; the other showed an exemplar focus card along with three nonexemplars. The process yielded four time-to-criterion scores. Two groupings of the same information processing task (Tagatz, 1963) scores dictated two separate factor analyses. In the first analysis the 30 item-responses within each of two subtests were grouped according to type of stimulus card presentation. i.e., exemplars or nonexemplars. This approach accounted for four task variables. The second analysis employed scores obtained by grouping test items (for each of two subtests varying in complexity) according to response options (yes, no, or can't tell), determining a total of six different task variables. Scores on 16 achievement tests representing five curricular areas (mathematics, reading, social studies, science, and spelling) were included in both analyses. Measures on four concept attainment problems were only included in the first analysis.

Comparison of an alpha solution (rotated obliquely by the Harris-Kaiser method) for each battery showed interesting results. Four factors were extracted from the first intercorrelation matrix: a general achievement factor loading highest on the language arts tests, lowest on mathematics tests; an information processing factor showing loadings on the four task variables described in the preceding paragraph; and two concept attainment factors related to the four concept attainment problems. The intercorrelation matrix showed the general achievement factor correlating .60 with the information processing factor and .54 with one of the concept attainment factors. The second analysis, which did not include the four concept attainment measures and which interpreted the information processing task as six response-option variables, produced three factors: a language arts factor, a bipolar information processing factor (response option "No" for Subtests 1 and 2 loaded negatively and response option "Can't Tell" for both subtests loaded positively), and a factor loading heavily on both information processing variables and arithmetic (reasoning- and application-type) tests. The last factor and the language arts factor correlated .73. The authors attributed the change in factor structure to "the similarities in the convergent reasoning common to mathematics achievement and Information Processing Tests arranged by response option. Inductive reasoning was required by these two types of tests...[pp. 74–75]." This relationship supported Lemke's (1965) findings concerning relationship between concept atainment and inductive reasoning.

Incomplete image solutions likewise supported the conclusion that successful performance on concept attainment and information processing tasks is related to success in curricular areas.

Manley (1965) investigated individual differences common to three different concept attainment tasks and 16 ability tests for a population of 119 ninth-grade boys and two subpopulations, concept solvers and nonsolvers. The three concept attainment tasks employed were Goldstein's tasks (Goldstein and Galef, 1965), Allison's task (1960), and a card sorting task patterned after the New York University Card Sorting test (Kendler and D'Amato, 1955). Learning measures analyzed were total errors for Allison's task and total errors with respect to a criterion of 20 consecutive correct trials for the Goldstein and Card Sort tasks.

Both learning measures and ability test scores were factor analyzed together for each of the three groups of Ss. Eleven factors were extracted and rotated to an equamax solution. Five factors were isolated by ability tests and interpreted as numerical ability, reasoning, verbal ability, memory, and selective attention. The largest loadings identified two factors not clearly defined, namely general reasoning and syllogistic reasoning. Three factors loaded on both ability tests and concept attainment tasks. Concept Attainment A was isolated by Allison's four concept attainment problems and described as a verbal concept attainment factor; deductive reasoning tests showed weak loadings (ranging from .19 to .35 in the three groups of Ss) on this factor. Concept Attainment B was specific to the Card Sort tasks for solvers but showed additional substantial loadings on an induction test for the total population and nonsolvers. Concept Attainment C was primarily defined by the Goldstein tasks. The remaining factor was interpreted as order of presentation of concept tasks. It was concluded that there are few communalities existing among tasks employed in the study, that nonsolvers use abilities in attempting to solve concept attainment tasks that solvers do not use, and that relations do exist between certain concept attainment and reference test abilities.

A recent report from the Guilford laboratory (Dunham et al., 1966)[9] empirically verified hypothesized factors associated with "classes" in the SI model. Additionally, three concept learning tasks employing three types of content (figural, symbolic, semantic) were included in the ability test battery. All three tasks required S to assign one of four letters to 96 successively presented stimuli. Immediate feedback (the correct answer) followed each response. Three types of learning measures were analyzed: stage scores, verbalization scores, and mastery scores. A stage score represented the number of correct responses to a block of 8 successively presented stimuli. The 96 stimuli in each task booklet provided 12 stage scores for each S for each task. Verbalization scores specified the number of concepts S was able to describe after responding to each set of 96 stimuli. A mastery score represented the number of trials needed to reach a predefined criterion of mastery. Mastery scores (based on 24 stimuli) were computed for the four concepts within each of three tasks.

The matrix of intercorrelations (with squared multiple correlation coefficients on the diagonal) was factor analyzed using the principal-axes algorithm. The factors were rotated to an orthogonal solution by an iterative process (Cliff, 1966) which at any one point in the sequence provided a least-squares approximation of an obtained (rotated) factor matrix to a target matrix. The loadings of task variables on factors common to the ability tests were derived by an extension procedure (Dwyer, 1937; Mosier, 1938).

Fifteen factors (excluding a sex factor) based on test scores of 177 high-school students were identified: CFC, CSC, CMU, CMC, CMS, MSC, MMC, DFC, DSU, DMC, NFC, NSC, NMU, NMC.[10] Results indicated that the factorial patterns of the three different types of task scores tended to be similar. Factorial complexity of task measures was somewhat difficult to assess since loadings

[9] Although the report was not available at the time this investigation was executed, results are summarized because of their relevance.

[10] See page 4 for explanation of Guilford's trigrams.

were not sizable. Only 5 factors— MSC, MMC, DSC, NMC, and CMC— showed loadings of .30 or higher on task variables, the first 4 factors showing significant loadings on stage scores, the CMC factor on verbalization scores. That factorial complexity of the concept learning tasks could not be judged by the 15 factors represented in the analysis was clearly pointed out by the authors. The communality means on three "within task" factor analyses of stage scores were .61 (figural), .64 (symbolic), and .60 (semantic) whereas the corresponding communality means derived by the extension procedure were .26, .21, and .34. These differences were attributed to two general sources: 1) factors common to the learning scores only and 2) factors common to both learning scores and ability tests which were not brought out by factor analyzing only ability tests.

Although factor loadings (in the ability test common factor space) on stage score variables were low, changes in factorial structure over practice were reported. For the figural task, trends were primarily observed on MSC, MMC, and NMC; for the symbolic task, CMS, MMC, and DSC; for the semantic task, CSC, MSC, MMC, and NMC. The two memory factors, MMC and MSC, showed some of the highest loadings on stage scores, and this was, as the authors reported, "one of the surprises of the results [p. 23]."

Bunderson (1967) examined the factorial structure of learning measures over six stages of practice within the common factor space defined by 30 ability tests. Each of 18 concept learning problems consisted of eight sequentially presented slides, each slide displaying eight bivalued (white or black) geometrical figures. A "Yes" or "No" accompanying the stimulus slide indicated to S whether it was an exemplar or nonexemplar of the concept. The first slide was always an exemplar; the next six included three exemplars and three nonexemplars. The last card determined the problem type. Complex negative problems employed a "No" slide for the eighth instance; complex positive used a "Yes" slide. The former could not be solved without using the information in the negative instances. Complex positive problems needed only the information in the five "Yes" instances for solution. Two types of learning measures were collected. "Rules scores" indicated the problem at which S began to use the focus rule and the rules for handling positive and negative instances. "Process scores" (positive process, negative process, and solution process) represented response totals (of positive slides, negative slides, and last slide respectively) over blocks of three problems.

From a task analysis, five factors (constraint factors) were hypothesized as relevant abilities: perceptual speed, spatial scanning, memory span, associative memory, and chunking memory. A conceptual model constructed for the task described a problem analysis process, search processes, and an organization process. Four factors (rational factors) hypothesized as being relevant to the model were verbal reasoning, general reasoning, induction and figural adaptive flexibility.

Thirty ability tests serving as markers for the hypothesized factors were administered to 143 university undergraduates. Subsequent factor analysis and equamax rotation produced 10 interpretable factors. Extension loadings on the 10 factors were computed for the 25 learning measures. Results showed relationships between task variables and 3 reasoning factors in addition to perceptual and memory abilities. The higher order processes postulated by the conceptual model were supported. The cycle, analyze → search → organize, appeared for positive process scores only. The transfer of abilities followed the hypothesized pattern: verbal reasoning, induction and figural adaptive flexibility, and general reasoning. Verbal reasoning and chunking memory showed strong relationships with learning the use of negative concept instances.

Factor-Analytic Studies Involving Reasoning Abilities

The following summaries of factor-analytic studies involving reasoning factors are presented chronologically and focus on tests employed in the present research as well as the precursors of these tests, namely Locations (adapted from Thurstone's Marks and analogous to Blakey's Circle Reasoning), Letter Sets (suggested by Thurstone's Letter Grouping), Necessary Arithmetic Operations, Ship Destination, Verbal Analogies III, Best Trend Name, Nonsense Syllogisms (suggested by Thurstone's False Premises), and Logical Reasoning.

The reasoning domain is still not clearly understood factorially. Thurstone originally described three reasoning factors: induction, the ability to discover rules or principles; deduction, the ability to apply rules or principles; restrictive thinking, the ability to reach solutions with given restrictions.

In Thurstone's (1938) study of the primary mental ability tests (administered to 218 college students), 13 orthogonal factors were extracted and 9 interpreted. Two tests, False Premises and Reasoning, showed largest loadings on a deduction factor and next largest on a verbal relations factor (which had as its leading test Verbal Analogies). Arithmetic

Reasoning isolated a restrictive task ability, and Syllogisms appeared factorially complex.

Zimmerman (1953), in a revised orthogonal rotational solution of the Thurstone (1938) study, identified a general reasoning factor (Arithmetic Reasoning with loading .64) as closest correspondent to Thurstone's restrictive reasoning. False Premises and Reasoning (both syllogistic-type reasoning tests) showed larger loadings on a deduction factor in the rerotation than in the Thurstone study. Syllogisms loaded .43 (versus .33 on Thurstone's induction factor) on a factor called "Classification." Finally, Thurstone's uninterpreted Factor 11 on rerotating was described as the ability to educe relationships. Verbal Analogies which had a loading of .31 on Factor 11 showed .59 in the revised solution.

Thurstone's (1940) study involving 36 tests administered to 286 high-school seniors identified two of the seven interpreted oblique factors as reasoning factors, namely deduction and induction. Both Letter Grouping and Marks loaded significantly on the induction factor.

In studying intelligence of children, Thurstone and Thurstone (1941) reported two factor analyses which included Letter Grouping. The first study analyzed 60 test scores (and three organismic variables) obtained from 710 eighth graders. Of the seven interpreted oblique factors, only one reasoning factor (induction) was identified. In the second study, scores for 437 eighth-grade children on 21 tests, 3 tests representing each of the seven factors found in the first study, were factor analyzed. Seven oblique factors were isolated; interpretation was in harmony with the first study. In both, Letter Grouping (along with Letter Series) identified the inductive reasoning factor.

Letter Grouping and Marks also appeared in a battery of 34 tests which were administered to 223 high-school seniors in a study (Coombs, 1941) primarily designed to investigate number ability. Ten factors were extracted. After oblique rotation, Marks (with a communality of .48) showed loadings of .29 and .30 on factors interpreted as deductive and inductive respectively. Letter Grouping (with a communality of .37) loaded on the perceptual speed factor (.28) and a factor labeled "alphabet test triplet" (.30). The latter factor was isolated by the same test given three times with rest periods interspersed.

Blakey (1941) administered 10 nonverbal reasoning tests to 286 high-school students. Five extracted and obliquely rotated factors were interpreted as perceptual speed, perceptual discrimination, induction, general reasoning, and deductive reasoning. Circle Reasoning, which required S to discover the rules by which one circle in each of four given rows of circles and dashes was blackened and then blacken a circle in the fifth row, is analogous to Locations. It loaded .56 on the induction factor and .52 on the general-reasoning factor.

Goodman (1943) tested 170 male first-year college students in a factor-analytic study of Thurstone's 16 primary mental abilities tests. Two of the seven orthogonal factors were interpreted as induction and reasoning. Letter Grouping and Marks with loadings of .49 and .50 respectively identified the induction factor. Corresponding communalities (.42 and .32 respectively) indicated that much of the variance was still unexplained.

In Botzum's (1951) study, tests purporting to measure three reasoning factors (Thurstone's deductive, inductive, and restrictive thinking factors) and five closure factors were administered to 237 college men. Nine factors were extracted. Letter Grouping helped identify the induction factor which the author suggested was not limited to type of material. Inductive-type tests involving numbers, letters, words, forms and figures loaded on the factor.

In a factor-analytic study of reasoning abilities by Green, Guilford, Christensen, and Comry (1953), 34 tests were administered to 283 Air Force men. Two separate orthogonal rotations (denoted as X and Y solutions) of 12 extracted factors (centroid method) were reported. Seven factors associated with reasoning tests were identified as general reasoning (GR), logical reasoning (LR), eduction of perceptual relations (PR), eduction of conceptual relations (CR), eduction of conceptual patterns (CP), eduction of correlates (EC), and symbol substitution (SS). In both X and Y solutions Ship Destination appeared as a leading test on GR; factorial complexity was indicated, however, by a significant loading on the PR factor. The authors suggested that PR together with CR and CP described the inductive area. All three factors involved educing relations and patterns. Circle Reasoning showed the biggest loading in both solutions on CP. Syllogism Test and False Premises identified with LR. The authors pointed out that although the factor primarily involved deductive reasoning, the tests isolating the factor did not require S to draw his own conclusion. His task was to evaluate or judge conclusions presented to him. The last two tests also showed significant loadings on GR in the Y solution. False Premises appeared on an induction factor (PR) in the X solution. Although classification tests had been included in the battery, no factor was isolated which could be described as a classifying ability (identified by Zimmerman, 1953).

Guilford, Christensen, Rettner, Green, and Hertzka (1954) administered a battery of 54 tests to 395 Air Cadets and 343 Student Officers in a study primarily aimed at clarifying the nature of reasoning abilities. Sixteen factors were extracted by an iterative procedure for determining principal components and rotated to an orthogonal solution. Four factors were classified in the reasoning domain: general reasoning (GR), eduction of correlates (EC), eduction of conceptual relations (CR), and eduction of perceptual relations (PR). It was suggested that two other factors, logical reasoning (LR) and judgment (J), might be better classified as evaluative abilities than reasoning abilities. Ship Destination was a leading test on GR which supported the Green et al. (1953) findings. The test's lack of purity was likewise verified; the secondary (but substantial) factorial component was LR as compared to PR in the Green et al. study. Syllogism Test served to identify LR. Circle Reasoning did not appear on any reasoning factor.

In studying mental abilities and personality traits, Denton and Taylor (1955) found a relationship between memory tests and reasoning tests. Eight different mental ability indices were derived by combining with equal weights scores on two tests measuring the ability. The reasoning index was defined by Letter Grouping and Letter Series. Factor analysis of the eight ability indices and five personality measures yielded six factors. After rotation to an oblique solution, factor B loaded on the memory index .47, on reasoning, .36.

Kettner, Guilford, and Christensen (1956) investigated the nature of the general-reasoning factor. Twenty-three tests including Circle Reasoning, Logical Reasoning, Necessary Arithmetic Operations, and Ship Destination were given to 170 entering Coast Guard Academy cadets. Three hypotheses were presented in an attempt to define general reasoning: (1) defining problems, (2) handling complicated procedures, and (3) trial and error manipulation. Ten factors were extracted (Thurstone's centroid method) and rotated to an orthogonal solution. Nine were interpreted as verbal comprehension, numerical facility, visualization, logical evaluation, eduction of patterns, general reasoning, handling complicated procedures, trial-and-error manipulation, and mathematical achievement. The authors concluded that "defining problems" best fit the general reasoning factor. Ship Destination and Necessary Arithmetic Operations were the leading tests on the general-reasoning factor. Factorial complexity was indicated for both tests; the factor described as "handling complicated procedures" loaded on Ship Destination and "numerical facility" on Necessary Arithmetic Operations. Logical Reasoning was a prime identifier of the logical-evaluation factor. Circle Reasoning helped isolate the eduction-of-patterns factor (defined as "the ability to discover patterns or sets of relationships").

Harris and Liba (1965) employed both alpha factor analysis and incomplete image analysis in reanalyzing the Kettner et al. (1956) data. A derived orthogonal solution of the image model produced eleven factors, four of which were singlets. Ship Destination appeared on Factor 1 which seemed to be a mixture of three factors of the Kettner study interpreted as visualization, general reasoning, and handling complicated procedures. Necessary Arithmetic Operations identified a factor which appeared to be part of the reasoning factor in the original analysis. Logical Reasoning loaded on Factor 4 which was analogous to Kettner's logical-evaluation factor. Factor 5 reproduced the eduction-of-patterns factor with Circle Reasoning as one of the leading tests.

Kettner, Guilford, and Christensen (1959) investigated 11 factors previously identified in one or more studies associated with reasoning, creativity, or evaluation. Fifty-seven different tests were represented in three overlapping batteries; one included 28 tests, the other two 26 each. Each battery was administered to a different sample. The three groups of subjects were 219 naval air cadets and two groups of aircrew trainees totaling 201 and 210 each. Three separate Thurstonian centroid analyses were performed followed by rotations to orthogonal solutions. From the 12 factors extracted in each analysis, 20 different factors were interpreted. Nine of the 11 factors being investigated were verified; one of these factors, eduction of patterns, had Circle Reasoning as leading test and appeared similar to one of the inductive factors (eduction of conceptual patterns) in the Green et al. (1953) study. Letter Grouping had its largest loading on a newly identified factor, eduction of structural (symbolic) relations. Ship Destination was prime identifier for the general-reasoning factor.

Harris and Liba (1965) reported three incomplete image solutions (each rotated to orthogonal solution) of the Kettner et al. (1959) data. In all three analyses correspondence to Kettner factors was good for at least four factors, suggestive for two others. Observed discrepancies were the appearance of from two to four singlet factors and an apparent coalescing of Kettner factors in all three factor matrices. Tests of interest to the present research gave evidence of some invariance. In the analysis of battery A, Circle Reasoning was leading test on factor 8, a "good" correspondent to Kettner et al.'s "eduction of patterns." Ship Destination identified factor 7, a partial reproduction of the general reasoning factor. In each of the other two analyses, Letter Grouping helped identify a factor which was considered a "good" correspondent to Kettner et al.'s newly isolated "eduction of structural relations."

Guilford et al. (1960) investigated the symbolic factors of cognition and convergent production defined by the structure-of-intellect model. Thirty tests were administered to 240 Naval Air Cadets and Aviation Officer Candidates. Subsequent factor analysis by Thurstone's centroid method yielded 15 factors, 13 of which were interpreted after rotation to an orthogonal solution. The relevant identified factors were CMS (general reasoning) with Ship Destination as leading test, CSS[11] (eduction of patterns) with both Circle Reasoning and Letter Grouping as identifiers, and CSC (cognition of symbolic classes) with Letter Grouping showing a relationship just slightly less than that with the CSS factor.

Reanalysis of the above data by Harris and Liba (1965) indicated more extreme discrepancies than previously cited. An imcomplete image analysis, orthogonal solution, produced 12 factors, 5 of which were singlets. Guilford's CSC factor was 1 of 3 factors reproduced in the second analysis. Several of Guilford's factors appeared to have been collapsed into factors 1 and 2. Factor 1 loaded substantially on 17 tests, the relevant ones being Ship Destination, Letter Grouping, and Circle Reasoning. Letter Grouping loaded significantly on factors 1, 2, and 3.

Merrifield, Guilford, Christensen, and Frick (1962) investigated the relationship of intellectual abilities and problem solving in adults. Both Ship Destination and Logical Reasoning were included in the test battery. Thurstone's centroid factor analysis and orthogonal rotation yielded 10 interpretable factors. The two aforementioned tests identified the CMS (general reasoning) factor. Logical Reasoning, however, showed a larger loading on CMR (eduction of conceptual relations). The authors pointed out that its communality was only .48 in comparison with a reliability of .80. Ship Destination likewise had a sizable portion of variance not accounted for by factors common to the test battery. Reanalysis by Harris and Liba (1965) yielded fairly consistent results with the above analysis. Of 8 common factors, only 2 could not be identified with Merrifield et al. factors. Logical Reasoning loaded on factor 2 which appeared somewhat broader than the eduction-of-conceptual-relations factor isolated in the Merrifield et al. analysis. Ship Destination appeared on one of the 12 singlet factors.

Circle Reasoning was included in another study emerging from the Guilford laboratory (Hoepfner, Guilford, and Merrifield, 1964) primarily designed to analyze symbolic-evaluation abilities. The test only showed a loading of .26 on the CSS factor and was not reported as an identifier of any other factor. Communality was .44; reliability estimate, .67.

A recent study from the Guilford laboratory (Nihira, Guilford, Hoepfner, and Merrifield, 1964) investigated semantic-evaluation abilities. Three separate factor analyses were reported involving data obtained on 474 eleventh-grade students. The analysis for Group A (202 students) included scores on all test variables; for Group B (272 students), a subset of the test variables; for Group C (all 474 students), the same test variables included in the Group B battery. Sixteen principal axes were extracted and rotated to an orthogonal solution for Group A, 14 for each of the remaining groups. Five of the hypothesized semantic-evaluation factors emerged. The two tests designed to isolate the missing factor (EMT—evaluation of semantic transformations) loaded on EMU. Best Trend Name and Verbal Analogies III isolated the EMR (evaluation of semantic relations) factor. Best Trend Name also showed a significant loading on CMS. In previous research involving the structure-of-intellect model, EMR was identified with the logical-evaluation factor whose identifiers were syllogistic-type reasoning tests. Results indicated that the factor identified by syllogistic or inference tests should be assigned to the EMI cell of the SI model. Logical Reasoning whose biggest loading was on the EMI factor exhibited factorial complexity. Ship Destination was the leading test on CMS.

Six reasoning tests employed in the present research also appeared in the Lemke (1965) study discussed earlier. In the alpha analysis, orthogonal solution, factor X was isolated by Logical Reasoning (.75) and Nonsense Syllogisms (.39), factor XI by Ship Destination (.71) and Necessary Arithmetic Operations (.87). However, both Nonsense Syllogisms and Locations showed significant loadings on the latter factor (.53 and .63 respectively). Factor XII had Letter Sets as leading test (.81 loading); Locations only showed a loading of .20.

The study by Manley (1965) reviewed in the previous section likewise provided evidence of the ambiguous nature of certain reasoning

[11] CSS is the eduction-of-patterns factor isolated in the Kettner et al. (1959) study.

tests. Nonsense Syllogisms and Logical Reasoning were each leading tests on different factors. Locations identified a factor called "Selective Attention" with Logical Reasoning showing bigger loadings than Letter Sets.

Factor-Analytic Studies and Memory Abilities

Several recent studies (Games, 1962; Kelley, 1964) were specifically concerned with memory abilities. The former investigated certain memory abilities and performance on verbal-learning tasks. The latter identified three memory factors: Rote Memory, Meaningful Memory, and Span Memory. Other investigations (dating back to the 1930's) have included memory tests in the test batteries. The only study which is relevant to the present research comes out of the Guilford laboratory.

In a study designed to investigate semantic memory abilities, Brown, Guilford, and Hoepfner (1966) factor analyzed scores obtained from 175 eleventh-grade students on 50 ability tests. Nine additional nonaptitude measures were correlated with the derived factors by an extension process. A principal-component type analysis with squared multiple correlation coefficients as diagonal entries of the correlation matrix extracted 30 factors corresponding to positive eigenvalues. The first 17 components accounted for 95.1 % of the total variance. Sixteen components were rotated orthogonally by an iterative process which matched the factor matrix to a target matrix at each phase (Cliff, 1966). The seventeenth component was rotated by hand. Six of the 16 interpreted factors were identified as semantic-memory abilities: MMU (memory for semantic units), MMC (memory for semantic classes), MMR (memory for semantic relations), MMS (memory for semantic systems), MMI (memory for semantic implications), and MMT (memory for semantic transformations). Tests loading high on MMC, MMR, and MMT were included in the battery analyzed in the present research. Tests for both MMS and MMT appeared factorially complex. The authors suggested that transformations may not occur apart from other products; i.e., answering test items correctly may require S to remember units of information as well as transformations. Homonyms was the only univocal test of MMT.

SUMMARY

The first part of the chapter specified the precise nature of the problem to be investigated and pointed out its limitations. The study of conceptual learning was restricted to the formal acquisition of verbally represented concepts by young adults. The portion of the total learning process explored by factor-analytic techniques was carefully delineated.

A major portion of the chapter was devoted to summaries of research considered relevant to the problem. Factor-analytic studies involving measures taken over successive stages of practice, learning tasks, and reasoning and memory abilities were reviewed. Results in general indicated that there is no general ability to learn. Relationships between learning task variables and measured abilities were reported. Allison (1960) and Stake (1961) employed parameters of fitted learning curves as learning measures; Duncanson (1966) used a factor-analytic method by Tucker for determining learning measures. Manley (1965) studied three types of concept tasks; results were reported for two subgroups (concept solvers and nonsolvers) in addition to the total group analysis. Lemke's (1965) oblique factor solution showed positive relationships between abilities and task factors. Bunderson (1967) examined the factorial structure of learning measures over stages of practice within the factor space defined by ability measures. Dunham et al. (1966) studied abilities pertaining to classes (SI model) and the learning of concepts; extension procedures were employed to include learning task measures in the factor space defined by ability tests. Factor analytic studies involving learning variables have exhibited an assortment of learning tasks, a variety of learning measures, and different factor-analytic techniques, but, in general, results indicated relationships between performance on learning tasks and measured abilities.

The following outline provides a historical review of the ability tests relevant to the present research:

Test	Study	Name of Factor
Letter Grouping	Thurstone (1940)	Induction
	Thurstone (1941)	Induction
	Coombs (1941)	Alphabet Test Triplet; Perceptual Speed
	Goodman (1943)	Induction
	Botzum (1951)	Induction
	Kettner et al. (1959)	Eduction of Structural Relations
	Harris and Liba (1965) (Reanalysis of Kettner [1959])	Eduction of Structural Relations
	Guilford et al. (1960)	CSS CSC
	Harris and Liba (1965) (Reanaly-	Factors 1, 2, and 3

Test	Study	Name of Factor
	sis of Guilford et al. [1960])	
Letter Sets	Lemke (1965)	Induction
	Manley (1965)	General Reasoning (Solvers) Concept Attainment B (Nonsolvers and total population) Selective Attention
Marks	Thurstone (1940)	Induction
	Coombs (1941)	Induction Deduction
	Goodman (1943)	Induction
Circle Reasoning	Blakey (1941)	Induction and General Reasoning
	Green et al. (1953)	Eduction of Conceptual Patterns
	Kettner et al. (1956)	Eduction of Patterns
	Harris and Liba (1965) (Reanalysis of Kettner et al. [1956])	Eduction of Patterns
	Kettner et al. (1959)	Eduction of Patterns
	Harris and Liba (1965) (Reanalysis of Kettner et al. [1959])	Eduction of Patterns
	Guilford et al. (1960)	CSS
	Harris and Liba (1965) (Reanalysis of Guilford et al. [1960])	Factor 1
	Hoepfner et al. (1964)	CSS (.26 loading)
Locations	Lemke (1965)	General Reasoning, Induction
	Manley (1965)	Selective Attention
Nonsense Syllogisms	Lemke (1965)	Deduction, General Reasoning
	Manley (1965)	Syllogistic Reasoning Verbal Ability (Solvers)
False Premises	Thurstone (1938)	Deduction
	Zimmerman (1953)	Deduction
	Green et al. (1953)	Logical Reasoning (Y solution) Eduction of Perceptual, Relations (X solution)
Syllogisms	Zimmerman (1953)	Classification
Syllogisms Test	Green et al. (1953)	Logical Reasoning
	Guilford et al. (1954)	Logical Reasoning
Reasoning	Thurstone (1938)	Deduction
	Zimmerman (1953)	Deduction
Necessary Arithmetic Operations	Kettner et al.	General Reasoning Numerical Facility
	Harris and Liba (1965) (Reanalysis of Kettner et al. [1956])	In part, Kettner et al.'s General Reasoning
	Lemke (1965)	General Reasoning
	Manley (1965)	General Reasoning Reasoning (Solvers)
Ship Destination	Green et al. (1953)	General Reasoning Eduction of Perceptual Relations
	Guilford et al. (1954)	General Reasoning Logical Reasoning
	Kettner et al. (1956)	General Reasoning Handling Complicated Procedures
	Harris and Liba (1965) (Reanalysis of Kettner et al. [1956])	Factor 1, a mixture of Kettner et al.'s Visualization, General Reasoning, and Handling Complicated Procedures
	Kettner et al. (1959)	General Reasoning
	Harris and Liba (1965) (Reanalysis of Kettner et al. [1959])	Factor 7, partial reproduction of Kettner et al.'s General Reasoning
	Guilford et al. (1960)	CMS
	Harris and Liba (1965) (Reanalysis of Guilford et al. [1960])	Factor 1
	Merrifield et al. (1962)	CMS
	Harris and Liba (1965) (Reanalysis of Merrifield et al. [1962])	Singlet Factor
	Nihira et al. (1964)	CMS
	Lemke (1965	General Reasoning
Logical Reasoning	Kettner et al. (1956)	Logical Evaluation

Test	Study	Name of Factor
Logical Reasoning	Kettner et al. (1956)	Logical Evaluation
	Harris and Liba (1965) (Reanalysis of Kettner et al. [1956])	Logical Evaluation
	Merrifield et al. (1962)	CMR CMS
	Harris and Liba (1965) (Reanalysis of Kettner et al. [1956])	Broader factor than CMR
	Nihira et al. (1964)	EMI
	Lemke (1965)	Deduction General Reasoning
	Manley (1965)	General Reasoning Selective Attention (Nonsolvers)
Verbal Analogies III	Nihira et al. (1964)	EMR
Best Trend Name	Nihira et al. (1964)	EMR CMS

The six memory tests employed in the investigation had been analyzed in a study of semantic memory abilities (Brown et al. 1966).

II
THE METHOD

This chapter intends to (a) exhibit a sufficient portion of the learning task to make unambiguous its underlying rationale, (b) describe selected intellectual abilities (factors) hypothesized to be either associated with or dissociated from successful performance on the learning task, (c) report the experimental events in the order of occurrence, (d) describe the subjects, and (e) specify the univariate and multivariate models employed in the analysis of the data.

INSTRUMENTS

The complete set of postulates, stimulus sentences, and instructions for the learning task used in the pilot study and the revised version used in the factor analysis are given in the original report (Jones, 1967) as are the cover pages of all ability tests.

The Task

The concept of "perceptual situation" was selected for the learning task. The defining characteristics of this concept were presented as postulates, these being a condensed version of those given by C. D. Broad (1960).[12] The first five postulates each asserted new information about the concept; the last was for review purposes only. The words "perceptual situation" were never used; the concept was denoted as "the situation" in all postulates. The task was composed of six stages. Each stage was defined by two activities: (1) S received a new postulate; (2) S sorted a deck of 50 cards.

S was instructed that in the card sorting part of the task meaningful sentences would serve as exemplars and nonexemplars of the concept since presentation of actual cases for his judgment was an impossibility. Accordingly, 50 sentences were composed and individually typed on 3 x 5 cards. Sentences represented situations involving thinking, remembering, imagining, and perceiving.[13] Some examples are:

1. I see a pink elephant.
2. I can see the man as a little boy.
3. I can see clearly.
4. I hear the baby crying.
5. I heard about the baby crying.
6. I am aware of the baby crying.
7. I feel the baby is crying.
8. I am aware of my hearing the bell.

Seventeen of the sentences were exemplars, 33 were nonexemplars. S sorted the same 50 cards six times—once after the reading of each new postulate.

The first postulate said:

> The situation is sensuous; that is, sensation plays an absolutely necessary part in it. A sentence that represents an example of the situation is: "I am aware of a red flash."

An arbitrary S might place sentence 1 above on the "No" pile, all others on the "Yes" pile in the first card sort.

The second postulate stated that the situation involved a relation between a subjective element (the "I" in the sentence) and an objective element (a something other than ourselves). Further, this "something" other than

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[12] The fourth postulate of the revised version of the task was a reinterpretation of C. D. Broad's views according to suggestions offered by Professor F. I. Dretske of the Philosophy Department at the University of Wisconsin.

[13] A complete accounting of all stimulus sentences with respect to postulates satisfied and postulates violated is given in Jones (1967).

ourselves might be hallucinatory. Two exemplars were given: "I hear a bell" and "I see a ghost." With this added information S should put sentences 1 and 3 on the "No" pile.

The third postulate clarified ambiguities concerning the objective element in the situation saying it "must be of the physical kind rather than mental (or psychical)" — explaining that in hallucinations, the object was truly of the physical kind. The nonexemplar "I notice that I am acting spitefully" was given. On sorting the eight sample cards this time, "I am aware of my hearing the bell" should be a "No."

Postulate four declared the situation to be intuitive rather than discursive. "I hear a bell" was given as an example of the situation whereas "I think about the bell" represented a nonexemplar. In sorting the above cards for the fourth time, "I feel the baby is crying" and "I heard about the baby crying" should now be classified as "No."

Postulate five, which asserted that the object must be revealed as it was at the time the situation was going on, eliminates "I can see the man as a little boy."

The sixth postulate was a review of the other five.

The Ability Tests

Although the structure-of-intellect model dominated factor selection, reference tests were drawn from both the Guilford Laboratory and the Kit of Reference Tests for Cognitive Factors, Educational Testing Service. The final choice was determined by the findings of previous studies, consideration of the nature of the learning task, and the reliability estimates of the reference tests for a college population. The test battery was further restricted by a three-hour time limit.

The factors and associated tests selected were:

MMC: Memory for semantic classes
- Picture Class Memory
- Classified Information

MMR: Memory for semantic relations
- Remembered Relations
- Recalled Analogies

MMT: Memory for semantic transformations
- Double Meanings
- Homonyms

I: Induction
- Letter Sets
- Locations

RS: Syllogistic Reasoning
- Nonsense Syllogisms
- Logical Reasoning

CMS: Cognition of semantic systems
- Necessary Arithmetic Operations
- Ship Destination

EMR: Evaluation of semantic relations
- Verbal Analogies III
- Best Trend Name

CMU: Cognition of semantic units
- Advanced Vocabulary V-4
- Advanced Vocabulary V-5

MMC—Memory for semantic classes. Within the structure-of-intellect model, this factor classification is described as:

> the ability to maintain in storage ideas of common attributes whereby two or more items of information are assigned to the same group of class [Brown et al., 1966, p. 9].

In the learning task, S was never required to "discover" the common attribute or attributes of the concept being learned. Such properties were asserted of the concept in postulate form and presented to S at the beginning of each new phase. However, since the postulates were unavailable to S during the card sorting activity, the successful sorter (i.e., the S who showed improvement by reduction in the total number of misclassifications) might employ aspects of behavior analogous to those utilized in the tests purporting to represent this factor classification. For example, the postulate which asserted the compresence of a subjective element (the "I" part of the stimulus sentence) and some other element (the "something" other than ourselves) obviously had not been stored (or, at least, not recalled) by S if S classified the situation exemplified in the statement "I feel sick" as a "Yes."

The two tests chosen to serve as markers for this factor were those recommended by Guilford and Hoepfner (1966). Picture Class Memory presented pictures of three objects each to S; his instructions were "to learn the class concept of the picture groups." On a subsequent test page, S was required to decide whether the pictured groups of two objects each implied concepts given on the study page. Classified Information was essentially the same type of test except classes of three words each were presented instead of pictures. Both tests required S "to choose test-page classes that were similar to classes presented on the study page." The test items were contrived so that correct responses were determined by recognizing the concept underlying the group of words (or objects), not the similarity of particular class members. Since the emphasis was on "retention of the principle of grouping," the hypothesis that these two tests and the learning task might load on the same factor is considered tenable.

MMR—Memory for semantic relations. This factor is described as

> the ability to remember meaningful connections between related verbal elements [Brown et al., 1966, p. 9].

The two tests selected were those recommended by the authors of the above mentioned report, namely Remembered Relations and Recalled Analogies.

In Remembered Relations, S first studied a list of sentences all expressing relations between two objects or events. The test page required S to select a relation from four choices (specifically, three relations and the answer "none of these") that completed a given sentence involving the objects previously studied. The test items frequently reversed the order of the objects or events which, in the case of asymmetrical relations, demanded that S remember the "connections between verbal elements" in the context studied and not to merely recall the different relations studied; e.g., studying the relation "is darker than" might demand correct test item completion in the form "is lighter than." It appeared that what S might be recalling was an idea (or fact) inherent in the studied statements, and, in this sense, it was thought that the ability necessary for successful performance on the test might also be associated with similar performance on the learning task. During the early phases of the learning task, S, being forced to make a decision with insufficient information, might revert to recalling not only the exemplar and/or exemplars presented in conjunction with the postulate and/or postulates, but also sentences already sorted in attempting to classify a particular item. For example, in judging "I saw the fox chasing the goose," previous encounter with "I see the fox chasing a goose" and the presented exemplar "I am aware of a red flash" might contribute to the decision-making process. Preceding items might very well function (for some subjects) as the "studied list" in Remembered Relations. However, if this supposition were correct, it would seem logical to suppose that after the first few sorts dependence on remembering meaningful relations among items would lessen for two reasons; firstly, repetition of the same stimulus card over the sorting phases served as stages of practice when viewed as a memory-type task, and, secondly, new information was posited at each phase which facilitated successful categorizing behavior.

Recalled Analogies was selected for the test battery primarily to serve as catalyst in isolating and verifying the factor labeled MMR by Guilford et al. On a study page S was required to supply the fourth component for each analogy in addition to learning the analogy for subsequent recall. Test items presented the third component of studied analogies and required production of the fourth. The demand to produce a term dependent on a remembered relation did not logically appear to parallel any activity engaged in by S in the learning task.

MMT—Memory for semantic transformations. The structure-of-intellect model defines this factor as

> the ability to remember redefinitions or other changes in meaning [Brown et al., 1966, p. 10].

The two recommended tests, Double Meanings and Homonyms, were selected for isolating and verifying the SI factor. Double Meanings first required S to study paired sentences, each pair containing the same underlined word used in different contexts; test items asked S to decide whether a pair of definitions did or did not match a word on the study page. Homonyms likewise presented pairs of sentences for S's study—the paired sentences in this case containing homonyms. Each test item presented the meaning of one element of a studied homonymic pair; S had to select (from four choices) the meaning corresponding to the other element.

In the learning task, discriminating between the different meanings implied by the same word used in different contexts was considered necessary for successful performance. The shift in meaning of the word "feel" is exemplified by the following three stimulus sentences: "I feel sick," "I feel the baby is crying," and "I can feel the rope shredding." MMT was included in the battery because of the hypothesized parallel activity between Double Meanings and the learning task.

I—Induction. The manual accompanying the Kit of Reference Tests for Cognitive Factors, Educational Testing Service, describes this factor as

> Associated abilities involved in the finding of general concepts that will fit sets of data, the forming and trying of hypotheses [French et al., 1963, p. 19].

The two ETS tests elected to confirm this factor were Letter Sets and Locations Test. Both tests required S to search for and apply a pattern or rule. In Letter Sets, S examined five sets of four letters each in order to "discover" the rule which related four of the sets and eliminated the fifth. His task was to mark the set which did not fit. Locations Test required S to discover the pattern or rule inherent in four given rows of "places and gaps" and then mark one of the five lettered places in the fifth row accordingly.

The specific task requirements in Locations Test appeared relevant to the learning task. The presentation of postulates in the latter task was considered analogous to the four given rows of "spaces and gaps" in Locations Test. In both cases S was required to comprehend and apply a given rule.

It is hypothesized that this factor is associated with successful performance on the learning task.

RS–Syllogistic reasoning The Manual for Kit of Reference Tests for Cognitive Factors refers to this factor as the

> ability to reason from stated premises to their necessary conclusions [French et al., 1963, p. 37].

It is further identified as

> the factor originally called "Deduction" by Thurstone.....Guilford has called it "Logical Evaluation," the evaluation of semantic relations [French et al., 1963, p. 37].

The two tests selected from the Kit of Reference Tests to identify this factor were Nonsense Syllogisms and Logical Reasoning. In the former, S was required to decide whether stated conclusions following premises involving nonsensical ideas were logically correct. In Logical Reasoning emphasis was on choosing the correct conclusion that could be drawn from two given statements.

The syllogistic-reasoning factor was included in the battery for several reasons (other than that recommended by previous research and discussed in Chapter I). Firstly, S's success in sorting the stimulus cards at any one phase might depend on his ability to make valid judgments based on given assumptions (the postulates). Furthermore, the first few stages of the learning task might specifically parallel Nonsense Syllogisms in that at this point both postulates and stimulus sentences might appear nonsensical to S, his task requiring him to sort (decide according to stated premises. Secondly, inclusion of the factor might clarify the relation of Logical Reasoning to the EMR factor, evaluation of semantic relations, and verify the test's previously shown factorial complexity (Nihira et al., 1964).

CMU–Cognition of semantic units. The factor usually called "general reasoning" has been assigned to the CMS cell in the SI model. It is described as

> the ability to comprehend relatively complex ideas [Guilford and Hoepfner, 1966, p. 6].

Although this factor appears to be isolated by tests involving arithmetic reasoning, emphasis is on understanding and structuring solutions, not providing solutions. Guilford (1959) stresses this point.

> ...It should be a broad ability to grasp all kinds of systems that are conceived in terms of verbal concepts, not restricted to the understanding of problems of an arithmetical type [Guilford, 1959, p. 472].

Two of the most commonly used referents for this factor were selected: Ship Destination and Necessary Arithmetic Operations. The former required S to compute the distance between a ship and a port according to given rules concerning wind direction, ocean current, etc. Successive groups of test items were graduated in complexity by increasing the number of rules that S was required to apply for correct solution. In Necessary Arithmetic Operations S selected from four choices the numerical operations necessary to solve a given problem. No computation was required.

The learning task was thought to reflect the same type of graduated complexity with respect to rule application operative in Ship Destination. It is hypothesized that the factor marked by these tests is associated with successful performance on the learning task.

EMR–Evaluation of semantic relations. The structure-of-intellect model describes this factor as

> the ability to make choices among semantic relationships on the basis of similarity and consistency of meanings [Guilford and Hoepfner, 1966, p. 12].

The selection of the two referential tests Verbal Analogies III and Best Trend Name was based on the results of the semantic evaluation investigation (Nihira et al., 1964). Verbal Analogies III followed the typical format for analogy-type tests but differed in that the relations between the first pairs of words were obvious and the choices for completion (the fourth component) were made difficult "in order to maximize evaluative variance by requiring S to compare the given alternatives in the light of the standard relations specified in the first pairs." Best Trend Name required S to select the word that best described the order of four given words.

Since, in the learning task, S was continually forced to evaluate whether items of information (the stimulus sentences) did or did not meet "certain standards or goals" and, more specifically during the early sorting phases, "to evaluate relations between words or ideas," it is hypothesized that this factor, if isolated, contributes substantially to the factorial decomposition of the learning task.

CMS—Cognition of semantic systems. The structure-of-intellect model defines this factor as

> the ability to comprehend the meanings of words [Guilford and Hoepfner, 1966, p. 5].

The factor generally has appeared under the label "verbal comprehension" in most factor analytic studies. Two Educational Testing Service tests were selected as referents for the factor: Advanced Vocabulary V–4 and Advanced Vocabulary V–5. It is hypothesized that this factor does not load substantially on any of the six sorting phases of the learning task.

PROCEDURE

In September 1966, eight college students enrolled in an introductory educational psychology course volunteered to serve as subjects and subsequent critics of a trial version of the learning task.[14] These subjects apparently had no trouble with the postulates and confined their censuring comments to the sentences employed as stimuli. Upon their combined recommendations, four sentences were replaced.

The Pilot Study

During the following week in afternoon sessions, a pilot study was conducted to evaluate the effects of variations in feedback and postulate conditions on the learning task. The feedback dimension (F) was defined by two levels, namely:

- F_-: No information provided S with respect to correct or incorrect categorizing of stimulus cards.
- F_+: Immediate informative feedback provided.

In the experiment, Ss receiving informative feedback were directed to turn over the stimulus card after placement on the "Yes" or "No" pile. In the upper right hand corner of the back of the card was printed either a "Yes" or a "No." The postulate dimension, likewise bileveled, was described as:

- P_-: Postulates removed after reading.
- P_+: Postulates available for reference during the entire experiment.

Subjects in a P_- assignment were directed to place the postulate card face down immediately after reading it. The four experimental conditions were:

- P_-F_-, postulates removed, no feedback;
- P_-F_+, postulates removed, immediate feedback;
- P_+F_-, postulates available, no feedback;
- P_+F_+, postulates available, immediate feedback.

A total of 32 subjects (men and women) randomly drawn from an introductory educational psychology course at the University of Wisconsin were randomly assigned to the four experimental conditions. Each subject selected an experimental session[15] most convenient to him; consequently, it was not uncommon to administer directions for all four experimental conditions in the same testing session. After the experimenter read the written instructions aloud as each S read silently, additional instructions were given orally to S corresponding to his randomly assigned experimental condition.

Although no information was given to S concerning a maximum time limit for postulate reading, any S who studied the postulate beyond one minute was asked to begin sorting the cards. Discussions with subjects at the close of the experiment together with the results of the data analysis (Chapter III) indicated a problematic fourth postulate. An alternative interpretation of C. D. Broad's views were condensed in the fourth postulate in order to alleviate this problem (See Appendix B to Jones, 1967).

Additionally, the following changes in the task and improvements in administration were suggested by the pilot study:

1. Increase the maximal postulate reading time to one minute and fifteen seconds for all postulates except the fourth which should be allotted one minute and forty-five seconds.

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[14] The trial version is not reported since only four stimulus cards were changed.

[15] Three testing sessions were available each afternoon for the entire week.

2. Revise the format of the postulate cards and/or simplify the postulates (See Appendices A and B to Jones, 1967).

3. Compose a more inclusive and descriptive set of written instructions.[16]

4. Select the P_F_ experimental condition for use in the factor analytic study.

The Factor Analytic Study

The revised version of the task was administered to 112 subjects during afternoon sessions of the third week of November. Subjects selected and signed up in advance for a 1, 2, 3, or 4 o'clock testing-session for any day, Monday through Friday.

Sufficient decks of stimulus cards were produced to permit the processing of at most 12 subjects in each of two consecutive hours. At the close of each testing session, errors and number correct in the "Yes" pile for each subject were counted and the results recorded on tabs especially provided. Decks were then thoroughly shuffled and arranged in packs of six decks[17] each for the next testing hour.

Each subject was assigned an identification number and assured anonymity throughout the entire study. No name was ever attached to any test booklet or task tabsheet.

All experimental sessions were held in either or both of two large conference rooms. Subjects were seated at least five feet apart, no two subjects at any one table. Distractions were at a minimum.

Statistical results appear in Chapter III.

Since reliability estimates for some of the selected ability tests were not available for a college student population, a small group of subjects (college men) was tested and reliabilities were computed (See Chapter III).

The test battery was administered during three massed three-hour testing sessions: Saturday, December 3, 9:00 a.m. to 12:00 and 1:00 p.m. to 4:00 p.m., and Monday, December 5, 7:00 p.m. to 10:00 p.m. Testing was done in a small auditorium-type lecture hall (100-seat capacity).

All tests except Recalled Analogies and Letter Sets were machine-scored. For all ability tests, total number of correct responses was the measure analyzed.

[16]The nature and number of queries made by Ss in the pilot study warranted this change.

[17]To facilitate scoring procedures, each subject was provided with six identical decks of stimulus cards—one to be used after each postulate reading.

Statistical descriptions of the ability tests are reported in Chapter IV.

THE SUBJECTS

The 32 subjects for the pilot study were both men and women randomly drawn from an introductory educational psychology course at the University of Wisconsin. All were either upper-division or first year graduate students pursuing the teaching profession. Participation in the learning experiment satisfied course requirement. No subject served more than one hour in the study.

The subjects for the factor-analytic study were female upper-division or first-year graduate students enrolled in three education and/or educational psychology courses at the University of Wisconsin. Of the 112 who participated in the learning task, 102 completed the three-hour reference test battery. The maximum total number of hours served by any one subject was four. The mean age of the group completing all four hours of the testing program was 21.1 years. The frequency distribution of ages appears in Table 1. All subjects were given credit in their respective classes for participating.

Table 1

Frequency Table for Ages of Subjects (N = 102)

Age in Years	Frequency
33	1
.	.
.	.
.	.
27	1
26	4
25	1
24	2
23	9
22	7
21	25
20	44
19	7
18	1

THE MODELS FOR DATA ANALYSIS

Univariate Analysis

The structural model appropriate for the analysis of the pilot study data was of the form

$$X_{pfsn} = \mu + \alpha_p + \beta_f + \gamma_s + \alpha\beta_{pf} + \alpha\gamma_{ps} + \beta\gamma_{fs} + \alpha\beta\gamma_{pfs} + \pi_{n(pf)} + \gamma\pi_{sn(pf)} + e_{n(pfs)}$$

where X_{pfsn} represents an arbitrary observation; μ, the grand mean; α_p, β_f, and γ_s, the three main effects at levels p, f, and s respectively; $\alpha\beta_{pf}$, $\alpha\gamma_{ps}$, and $\beta\gamma_{fs}$, the three two-factor interaction effects; $\alpha\beta\gamma_{pfs}$, the three-factor interaction effect; $\pi_{n(pf)}$, the effect of person n nested under the treatment combination represented by the subscripts pf; $\gamma\pi_{sn(pf)}$, the subject x sort interaction effect; and $e_{n(pfs)}$, the error associated with person n under the treatment combination indicated by the subscripts pfs. A 2 x 2 x 6 factorial design with repeated measures across the last factor is appropriate for evaluating the effects given in the model and is schematized in Figure 3. The notation G_{--} denotes the group of subjects assigned to treatment combination P_-F_-. Table 2 indicates the orthogonal partitioning of the total sum of squares used in the analysis.

The model associated with the analysis of the task data collected on 102 people under treatment condition P_-F_- was

$$X_{sn} = \mu + \gamma_s + \pi_n + e_{sn}$$

where X_{sn} is an arbitrary observation and

μ = grand mean

γ_s = effect of factor S at level s

π_n = effect of person n

e_{sn} = error associated with person n at level s.

The appropriate orthogonal partitioning of the total sum of squares appears in Table 3.

Table 2

Summary of Analysis of Variance

Source of Variation	df	
Between subjects	31	
Groups	3	
P		1
F		1
P x F		1
Subjects/Groups	28	
Within subjects	160	
S	5	
S x G	15	
S x P		5
S x F		5
S x P x F		5
S x subjects/groups	140	
Total	191	

Table 3

One-Way Analysis of Variance

Source of Variation	df	
Between subjects	111	
Within subjects	560	
S		5
Residual		555
Total	671	

In both the factorial and the one-way repeated measures designs covariance matrices were assumed arbitrary in form. Since tests on ratios of mean squares were either non-

		S_1	S_2	...	S_6
P_-	F_-	G_{--}	G_{--}	...	G_{--}
	F_+	G_{-+}	G_{-+}	...	G_{-+}
P_+	F_-	G_{+-}	G_{+-}	...	G_{+-}
	F_+	G_{++}	G_{++}	...	G_{++}

Figure 3. Schematic Representation of the Factorial Design for the Pilot Study

significant under a regular F test or significant using the Geisser and Greenhouse (1958) conservative test, employment of Box's (1954) approximate test was unnecessary.

A test of trends is also reported in Chapter III, the components of "within subject" variation being partitioned into five nonoverlapping parts— namely linear, quadratic, cubic, quartic, and quintic trends— each accounting for one degree of freedom.

Multivariate Analysis

Since "A choice between these two [alpha and incomplete image analyses] involves essentially a preference for level of specificity [Harris and Liba, 1965]," both alpha factor analysis and incomplete image analysis were employed to permit a comparison of methods as well as an analysis of the data.

The following symbolization, based on p test variables, was observed throughout the discussion:

R = the p x p observed correlation matrix with units as diagonal elements.

U^2 = a p x p diagonal matrix of unique variances.

S^2 = a p x p diagonal matrix with diagonal elements equal to the reciprocals of corresponding diagonal elements of R^{-1}.

H^2 = a p x p diagonal matrix with communalities as diagonal elements.

D^2 = an arbitrary diagonal matrix of characteristic roots corresponding to an arbitrary characteristic equation. The diagonal elements are individually denoted by d_i^2, i = 1,2,...,m, where m denotes the number of roots retained.

Q = a matrix whose columns are the normalized characteristic vectors corresponding to the solutions of a characteristic equation.

P = an initial (unrotated) factor matrix.

Alpha factor analysis (Kaiser and Caffrey, 1965) emerged as a means for determining common factors such that each has maximum Kuder-Richardson or Cronbach alpha reliability. The restriction is realized by solving the characteristic equation

$$H^{-1}(R - U^2)H^{-1} - d^2 I = 0.$$

Observe that pre- and postmultiplying $R - U^2$ by the diagonal matrix of the reciprocals of the communalities merely rescales the variables in the metric of the common parts of the data yielding a correlation matrix of the common parts. Employing the principal component algorithm, selecting the characteristic roots greater than one, computing the associated normalized characteristic vectors and then rescaling back to the original metric of the variables yields F, the initial factor matrix whose component matric factors are expressed in

$$F = HQD.$$

Retaining only those characteristic vectors associated with characteristic roots greater than one is equivalent to retaining only those alpha factors which have positive generalizability.

Since the communalities are unknown, trial values must first be selected and the operations described above carried out; new communality estimates based on factors corresponding to characteristic roots greater than one are computed each time and the procedure is repeated until fairly stable values are obtained.

A second analysis reported for the total population was achieved by factoring $S^{-1}(R - S^2)S^{-1}$, a rescaling of the correlation matrix with smc's (multiple correlation coefficients) on the diagonal (Harris, 1962). The image covariance matrix G (Guttman, 1953) may be written

$$G = R + S^2 R^{-1} S^2 - 2S^2$$

from which

$$R - S^2 = G - S^2 R^{-1} S^2 + S^2$$

obtains. Pre- and postmultiplying by S^{-1} yields

$$(1)\ S^{-1}(R - S^2)S^{-1} = S^{-1}GS^{-1} - SR^{-1}S + I.$$

Let B represent the diagonal matrix of characteristic roots of $S^{-1}RS^{-1}$ and Q the matrix whose columns are the corresponding normalized characteristic vectors; then

$$S^{-1}(R - S^2)S^{-1} = QBQ' - I$$

and

$$Q'S^{-1}(R - S^2)S^{-1}Q = [(b_i - 1)] = B - I.$$

Let

$$B - I = D^2$$

where only the $b_i > 1$[18] are retained. The factor matrix for this model may then be written

$$F = SQD.$$

Harris (1962) has shown that

$$S^{-1}GS^{-1} = Q\left[\frac{(b_i - 1)^2}{b_i}\right]Q'$$

[18] The number of roots greater than one equals Guttman's (1954) "strong" lower bound to the number of common factors.

and

$$SR^{-1}S = QB^{-1}Q'.$$

Pre- and postmultiplying (1) by Q' and Q respectively gives

$$[(b_i-1)] = [(\frac{(b_i-1)^2}{b_i})] - [(\frac{1}{b_i})] + I.$$

The factor matrix F = SQD when appropriately modified (i.e., post multiplication by $[(\frac{1}{\sqrt{b_i}})]$ for $b_i > 1$) gives an incomplete image analysis.[1] This factoring procedure has been described by Harris (1964) as "a back door to an incomplete image analysis." He has shown that the first m factors (where m represents Guttman's "strong" lower bound for the number of common factors) of $S^{-1}(R-S^2)S^{-1}$ and the corresponding factor measurements (estimated) generate the scores on the image variables.

Both F = HQD and F = SQD represent initial solutions. The derived solutions were obtained by applying Kaiser's (1958) normal varimax method of rotation. The varimax procedure is based on maximizing the variance of the squared factor loadings for each factor. "Normal" varimax applies the above procedure to a rescaled F matrix, i.e., each factor loading is divided by the square root of its communality. The entire process is summarized by:

1. Normalize the rows of F.
2. Carry out the varimax rotation.
3. Rescale the rotated F in the original metric.

SUMMARY

A verbal concept learning task especially developed for use in the factor-analytic investigation was described. Instructions, postulates, and stimulus sentences in their complete form are given in Jones (1967).

The 16 ability tests selected for the test battery were discussed in terms of the factors previously identified by them and a logical analysis of similarities of test and task requirements. Because both tests recommended as referents for each of the factors MMC, induction, EMR, and syllogistic reasoning were thought to involve activities which were common to the task, a positive relationship between task variables and the factors (if isolated) was hypothesized. A secondary purpose for inclusion of Logical Reasoning was to clarify the test's relationship with the EMR factor. The factors MMR, MMT, and CMS were selected on the basis of similarities between only one of the paired referent tests and task demands. CMU, the verbal comprehension factor, was hypothesized to be unrelated to task variables.

A pilot study was conducted prior to the planned factor analytic investigation in order to determine the effects of four experimental conditions (varied along feedback and postulate-availability dimensions) on learning. A 2 x 2 x 6 factorial design with repeated measures across the last (6-leveled) factor was employed in the analysis of the data. An analysis of trends was also performed.

After minor revisions, the learning task was administered to 112 college women. Of these, 102 completed the 3-hour test battery. Task data (N = 102) were analyzed by means of a one-way repeated measures analysis of variance.

The multivariate models employed in analyzing the learning and ability measures were alpha factor analysis and a factor analytic technique which produces factors comparable to an incomplete image analysis. All factor matrices were orthogonally rotated by the normal varimax method.

III
UNIVARIATE STATISTICAL RESULTS

The univariate statistical results reported in the chapter appear according to the order of their occurrence within the total investigation, namely, analysis of the pilot study, analysis of the revised learning task, and reliability estimation.

THE PILOT STUDY

The original version of the task was administered in afternoon sessions within the same week to 32 subjects randomly assigned to the four experimental groups described in Chapter II.

Table 4 shows the means and standard deviations for each experimental group at each sorting phase. Three of the means (underlined in Table 4) were not significantly different from chance. The occurrence of two of these at the first sorting phase (P_+F_- and P_-F_-) was not surprising since S had only one bit of information as basis for judgment. Resort to guessing is plausible under the forced choice situation. The lack of a significant difference from chance under the P_+F_- condition at the fourth phase suggested postulate difficulty.

A 2 x 2 x 6 factorial design with repeated measures (S's total error score at each card sorting) across the last factor partitioned the total sum of squares appropriately to test the following hypotheses:[19]

1. There is no difference among the six sort means. $H_0: \mu_{..1.} = \mu_{..2.} = \cdots = \mu_{..6.}$.
2. There is no difference between the means of the two feedback conditions. $H_0: \mu_{.1..} = \mu_{.2..}$.
3. There is no difference between the two means of the postulate factor. $H_0: \mu_{1...} = \mu_{2...}$.

[19] The ordered subscript notation for an arbitrary observation X_{pfsi} is defined as follows: p, postulate level; f, feedback level; s, sort number; i, individual.

Table 4

Means and Standard Deviations, Criterion: Total Error Score

		Sort 1	Sort 2	Sort 3	Sort 4	Sort 5	Sort 6
P_+F_-	M	<u>23.2</u>[a]	18.4	15.4	<u>22.2</u>	18.2	16.0
	Sd	7.45	3.77	5.15	8.64	5.56	7.18
P_+F_+	M	15.5	14.6	12.0	10.0	9.5	8.5
	Sd	3.67	4.74	6.06	6.44	5.05	6.71
P_-F_-	M	<u>22.2</u>	19.5	17.6	18.8	17.0	14.6
	Sd	8.20	4.61	5.74	9.28	5.22	5.81
P_-F_+	M	16.6	10.1	6.8	4.6	4.5	4.0
	Sd	7.35	5.60	3.15	3.67	3.94	4.72

[a] Underlined means are not significantly different from chance.

4. The shapes of the learning curves defined over the six sorting phases for the two postulate conditions are the same. This information obtains from testing
$H_0: \mu_{p.s.} - \mu_{p...} - \mu_{..s.} + \mu_{....} = 0.$

5. The shapes of the learning curves corresponding to the two feedback levels are the same. The appropriate interaction test is:
$H_0: \mu_{.fs.} - \mu_{.f..} - \mu_{..s..} + \mu_{....} = 0.$

6. There is no difference among the means (computed over the six sorts) for the four experimental conditions. Consider an arbitrary observation represented by X_{gsi} where $g = 1,2,3,4$ indicates the experimental group, $s = 1,2,\ldots,6$, the sorting phase, and $i = 1,2,\ldots,8$, the individual. Then
$H_0: \mu_{1..} = \mu_{2..} = \mu_{3..} = \mu_{4..}$.

7. The shapes of the learning curves associated with the four experimental conditions are identical. In analogous fashion to 4 and 5, but using the notation in 6, we test
$H_0: \mu_{gs.} - \mu_{g..} - \mu_{.s.} + \mu_{...} = 0.$

The results of the analysis of variance performed on the total error scores are summarized in Table 5. Since the population variance-covariance matrix was assumed arbitrary, the Geisser and Greenhouse (1958) conservative test was employed in evaluating the significance of the sort factor main effect. Only Hypotheses 1, 2, and 6 were rejected. A post mortem Scheffe test on the four experimental group means (Table 6) showed three of the six possible pairwise differences significant, namely P_-F_+ and P_-F_-, P_-F_+ and P_+F_-, P_+F_+ and P_+F_-. Failure to reject the fourth, fifth, and seventh hypotheses permitted the conclusion that the shapes of the learning curves associated with each hypothesis were not different. Statistical identity of shape, however, does not imply coincidence. Table 7 summarizes the results of appropriate joint tests (Geisser and Greenhouse, 1958, pp. 890—891) permitting answers to the following queries:

1. Do the vectors of means over the sort factor corresponding to the four experimental groups come from the same population? Testing, jointly,

$H_0: \mu_{gs.} - \mu_{g..} - \mu_{.s.} + \mu_{...} = 0$ for all g,s, and

$H_0: \mu_{g..} = \mu_{...}$ for all g,

an arbitrary observation being denoted by X_{gsi} (see above), yields the desired results (i.e., $\mu_{gs.} = \mu_{.s.}$ for all g,s). See G and G x S in Table 7.

Table 5

ANOVA for Total Error Scores

Source of Variation	df	MS	F
Between subjects	31		
Groups	3	1386.10	15.29**
P	1	247.52	2.73
F	1	3780.75	41.70**
P x F	1	130.02	1.43
Subjects/Gr.	28	90.66	
Within subjects	160		
S	5	295.36	9.36**
S x G	15	32.44	1.03
S x P	5	19.60	<1
S x F	5	55.82	1.77
S x P x F	5	21.90	<1
S x S/Gr.	140	31.55	

$**p < .01$

Table 6

Scheffe Post Mortem Test on the Six Pairwise Differences of the Four Experimental Means

P_-F_+	P_+F_+	P_-F_-	P_+F_-
7.8	11.7	18.3	18.9
--	3.9	10.5**	11.1**
	--	6.6	7.2**
		--	.6

$**p < .01$. Smallest significant difference = 7.198.

Table 7

Joint Tests for Profile Clusters

Source of Variation	df	MS	F
G and G x S	18	258.03	6.23**
P and P x S	6	57.58	1.39
F and F x S	6	676.65	16.34**
Within cell	168	41.40	

$**p < .01$

2. Is there a significant difference between the mean vectors corresponding to the two levels of the postulate factor? The appropriate joint test utilizes both

$$H_0: \mu_{p.s.} - \mu_{p...} - \mu_{..s.} + \mu_{....} = 0$$

for all p, s,

and

$$H_0: \mu_{p...} = \mu_{....} \quad \text{for all p,}$$

an arbitrary observation being symbolized by X_{psfi} (see Note 19). Observe line 2, P and P x S of Table 7.

3. Lastly, are the two vectors of means associated with the two levels of the feedback factor significantly different? In analogous fashion, we consider simultaneously

$$H_0: \mu_{.fs.} - \mu_{.f..} - \mu_{..s.} + \mu_{....} = 0$$

for all f, s,

and

$$H_0: \mu_{.f..} = \mu_{....} \quad \text{for all p.}$$

Results of the appropriate conservative F tests indicated that the two feedback curves were not coincident and that at least one pair of curves associated with the experimental groups among the six possible pairwise comparisons was significantly different positionwise (i.e., although statistical identity in shape existed, coincidence did not).

Examination of the profiles of means in Figures 4,5, and 6 suggests an overall linear trend. A disturbing influence at the fourth sorting phase is evident in all three figures for conditions not involving F_+ and indicates a possible cubic trend. The profile of the sort factor at F_+ in Figure 5 and P_-F_+ in Figure 6 further suggests the rectangular hyperbola as a probable model fitting the data of those experimental conditions.

An analysis of trends is reported in Table 8. Since there are six card sorting phases, any of the learning curves could be described completely by a fifth degree equation. Results showed a significant linear trend at the .01 level in the main effect of the sort factor implying that the slope of the best-fitting line (to the profile of overall sort-means) is significantly different from zero. That none of the interactions associated with linearity were significant indicated that the slopes of the best-fitting lines to the profiles of means corresponding to specific interactions did not differ. Cubic trends were significant at the .05 level indicating that a cubic curve is a better fit to the data than either linear or quadratic functions. The S x F interaction under cubic trends was significant at the .10 level giving statistical support to observable evidence of a more dominant cubic trend in the simple effects of the sort factor at level F_- than F_+. Results of tests associated with quartic and quintic components of variation were all nonsignificant and, therefore, omitted from Table 8.

Analysis of the Revised Version of the Task (N = 102)

The learning task was administered to 112 subjects; only 102 of these completed the 3-hour test battery. All statistics and analyses reported were based on the smaller (N = 102) group. Table 9 shows the means, standard deviations, and standard errors of measurement of each sorting stage. Standard errors are upper-bound estimates computed from the

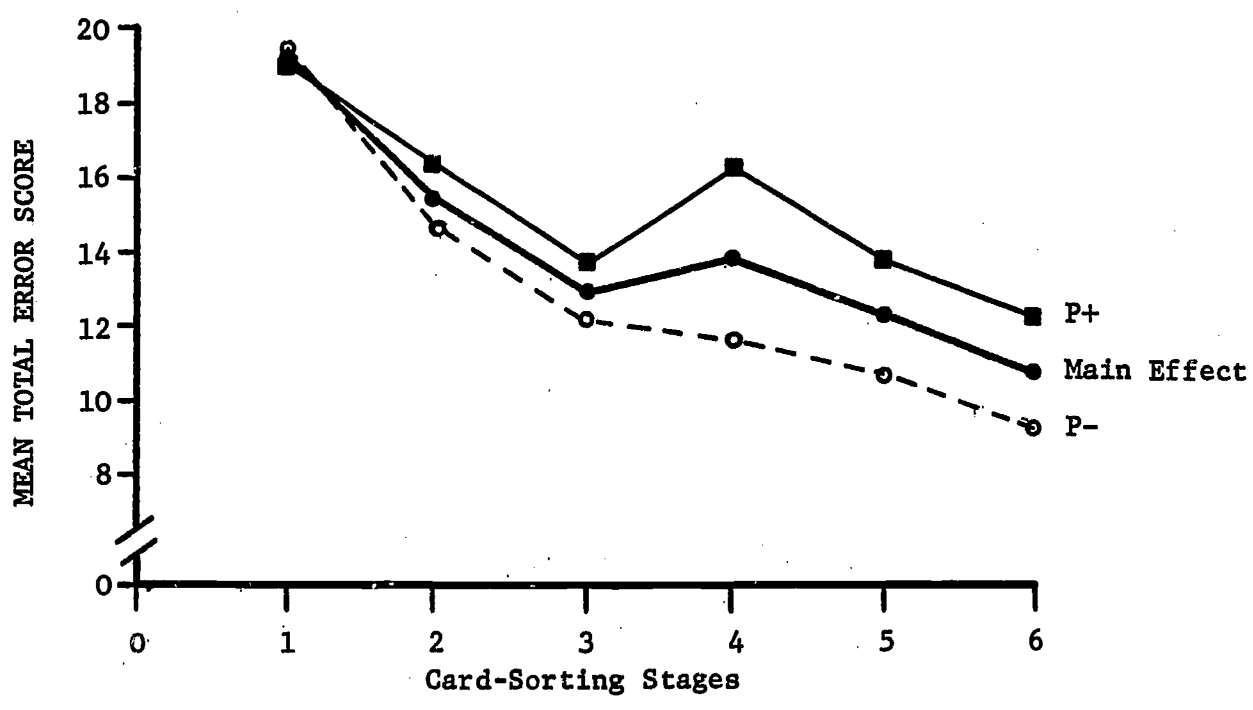

Figure 4. S Profiles at Both Levels of P and S Main Effect

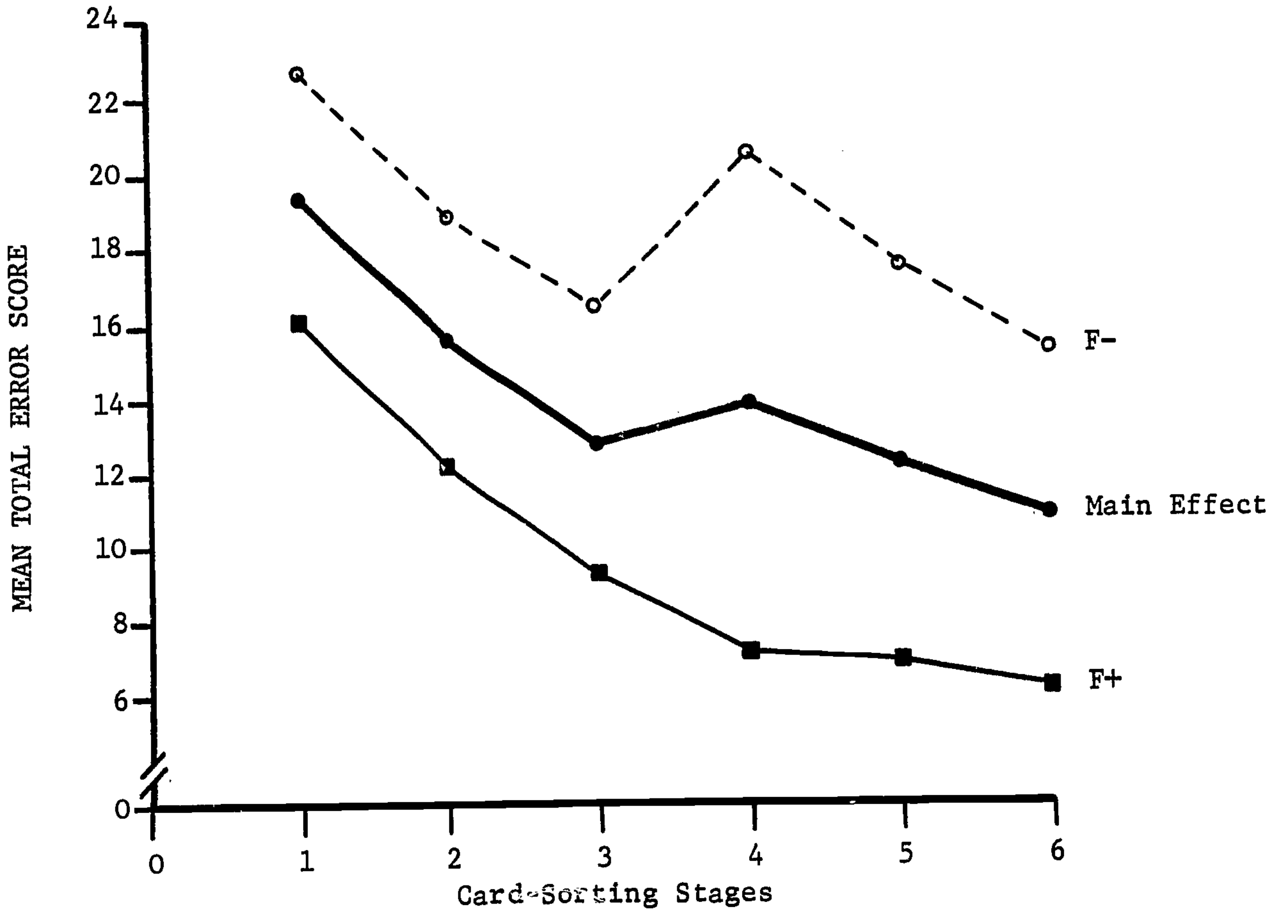

Figure 5. S Profiles at Both Levels of F and S Main Effect

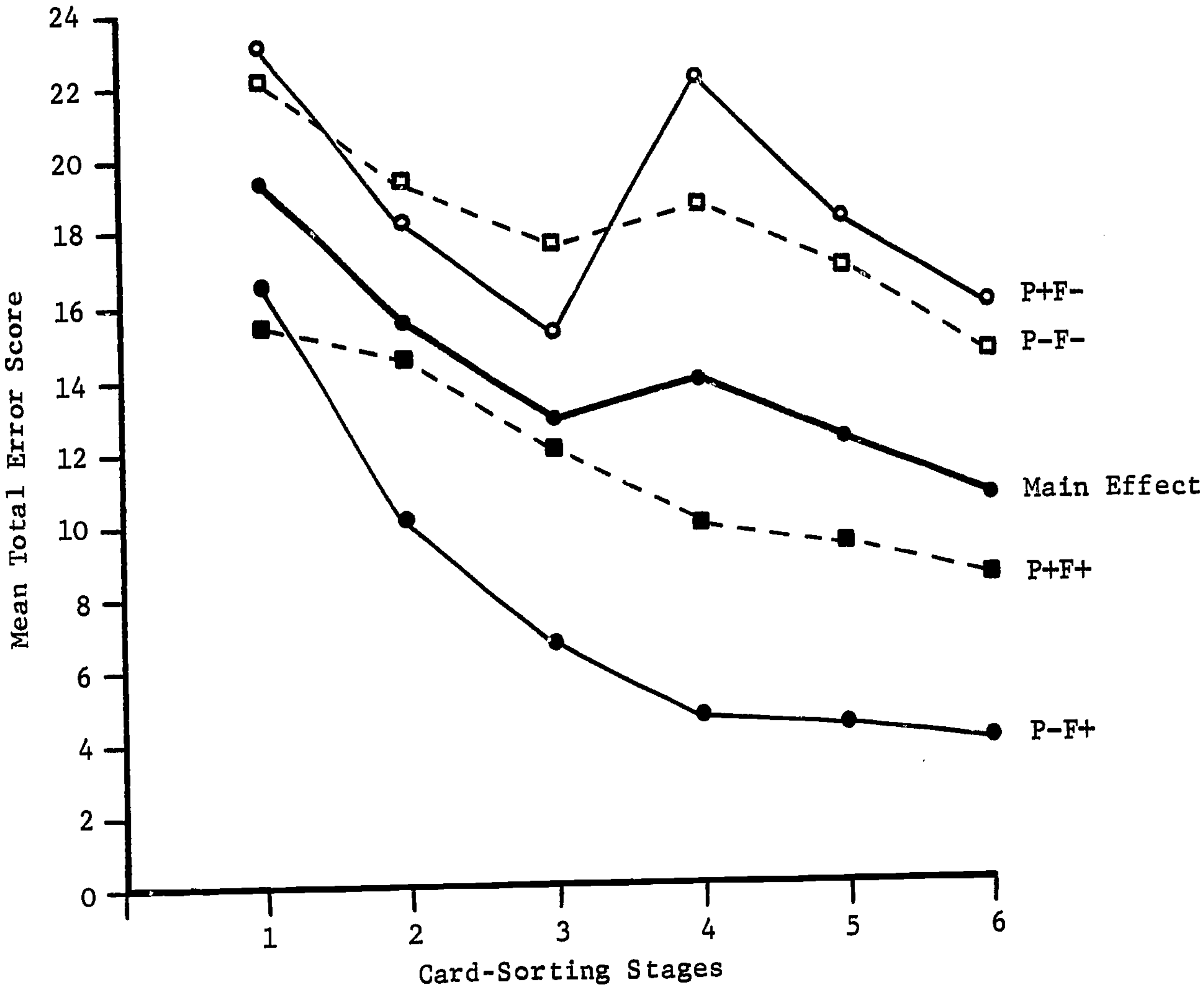

Figure 6. S Profiles for Experimental Treatments and S Main Effect

Table 8

Analysis of Trends

Within Subjects	df	MS	F
Linear Trends			
S	1	1245.04	19.47**
S x G	3	55.56	.87
S x P	1	56.58	.88
S x F	1	103.72	1.62
S x P x F	1	6.43	.10
S x S/Gr.	28	63.96	
Quadratic Trends			
S	1	96.63	3.19+
S x G	3	32.61	1.12
S x P	1	19.17	.66
S x F	1	36.91	1.27
S x P x F	1	41.75	1.44
S x S/Gr.	28	29.02	
Cubic Trends			
S	1	98.96	5.16*
S x G	3	39.54	2.06
S x P	1	2.06	.11
S x F	1	74.03	3.86+
S x P x F	1	42.54	2.22
S x S/Gr.	28	19.16	

+ $p < .10$
* $p < .05$
** $p < .01$

formula S.E. = S.D. $\sqrt{1 - r_{xx'}}$ where $r_{xx'}$ represents the lower-bound estimate of the reliability coefficient.[20] The reliability $r_{xx'}$ is the correlation between two replicate measures of x where x represents one of the six sorting stages.

[20] Lower-bound estimates of reliabilities are communalities of corresponding variables obtained from the incomplete image analysis, Chapter IV.

An important consideration in the analysis of the task measures was the relationship between observed gain (g) and true gain (G).[21] Lower-bound estimates (communalities) for task-variance reliabilities ($r_{xx'}$) were employed in all computations; hence, the degree of insurance against the observed change being a product of chance fluctuation is conservative. Table 10 shows the estimated reliabilities ($r_{gg'}$) of observed change for all possible combinations of task variables. For example, the last element in the first row represents the lower-bound estimate of the reliability of the observed change between Sort 1- and Sort 6-scores. The computation formula (Lord, 1963) is

$$r_{gg'} = \frac{s_y^2 r_{yy'} - 2s_y s_x r_{xy} + s_x^2 r_{xx'}}{s_y^2 - 2s_y s_x r_{xy} + s_x^2}$$

where

s_y^2 = variance of measures at stage y,

s_x^2 = variance of measures at stage x,

r_{xy} = correlation of measures at stages x and y,

$r_{xx'}$, $r_{yy'}$ = reliabilities of stage scores.

The reliability coefficient ($r_{gg'}$) is a ratio of true gain variance (s_G^2) to observed gain variance (s_g^2). Table 11 shows the estimated (conservative) correlations (r_{gG}) between observed change and true change. Computing formula is

$$r_{gG} = \sqrt{r_{gg'}} .$$

[21] Since total error score was the dependent measure, gain (g or G) is expressed by a negative number.

Table 9

Means, Standard Deviations, and Standard Errors of Measurement of the Six Stages of the Concept Learning Task (N = 102)

	Sort 1	Sort 2	Sort 3	Sort 4	Sort 5	Sort 6
Mean	21.5	16.8	12.3	13.8	15.8	12.2
S.D.	6.89	7.07	5.55	7.35	8.54	5.92
S.E.	4.82	4.41	3.42	3.61	3.91	3.37

Table 10

Reliabilities ($r_{gg'}$) of Measured Change

Task Variable	Sort 1	Sort 2	Sort 3	Sort 4	Sort 5	Sort 6
Sort 1		.48	.17	.44	.40	.33
Sort 2			.12	.43	.44	.27
Sort 3				.28	.47	.15
Sort 4					.03	.21
Sort 5						.49

Table 11

Estimated Correlations (r_{gG}) Between Observed Change and True Change

Task Variable	Sort 1	Sort 2	Sort 3	Sort 4	Sort 5	Sort 6
Sort 1		.69	.42	.66	.64	.58
Sort 2			.34	.66	.67	.52
Sort 3				.53	.68	.39
Sort 4					.17	.46
Sort 5						.70

Figure 7 is a scatterplot of total error scores for the first and sixth card-sorting phases. The extimated value (G) of true change (G) is given by

$$\hat{G} = \bar{G} + b_{Gx.y}(x - \bar{x}) + b_{Gy.x}(y - \bar{y})$$

where x, y and $\bar{x}$, $\bar{y}$ are observed stage scores and means respectively, and $\bar{G} = \bar{y} - \bar{x}$ (since for large $\bar{N}$, $\bar{Y} - \bar{X} = \bar{y} - \bar{x}$). Computing formulas for $b_{Gx.y}$ and $b_{Gy.x}$ (Lord, 1963, p. 28) yielded the equation

$$\hat{G} = - 6.69 - .32x + .35y.$$

The lines defined by the above equation for $\hat{G}$ = 0, -5, -10, -15 have been drawn and indicated in Figure 7; the four equations are:

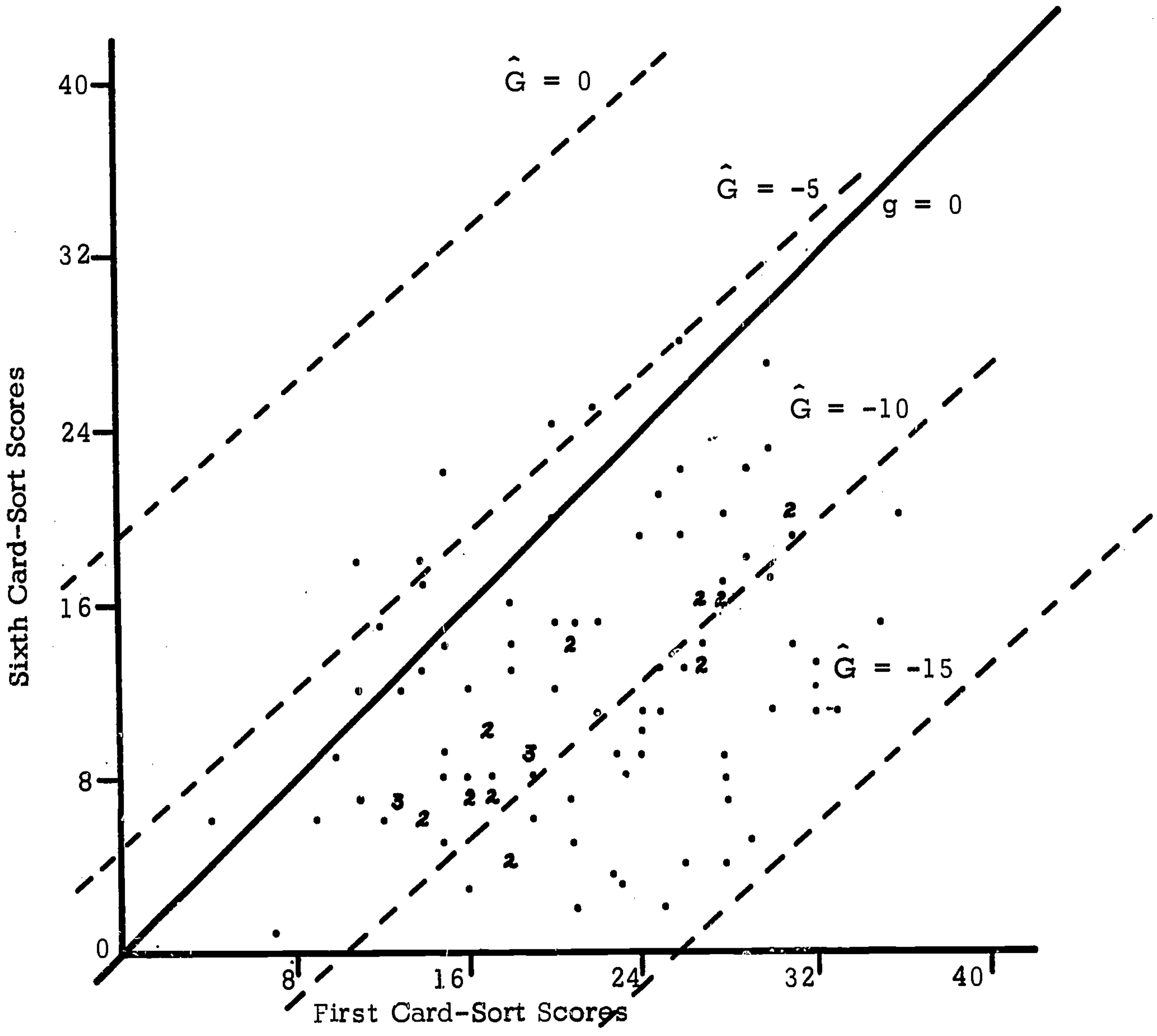

Figure 7. Scatterplot of First and Sixth Card-Sort Scores

$\hat{G} = 0, -.32x + .35y = 6.69$

$\hat{G} = -5, -.32x + 35y = 1.69$

$\hat{G} = -10, -.32x + .35y = -3.31$

$\hat{G} = -15, -.32x + .35y = 8.31$

The line x = y (no observed change) has also been drawn and labeled (g = 0). The ten points above the line g = 0 represent subjects whose observed scores showed a "loss" (i.e., an increase in total errors between the first and sixth card-sort); however, these points fall below $\hat{G} = 0$ (the line representing zero true change) and, therefore, are estimated to have true gain, the discrepancies being attributed to errors of measurement. Only one subject's observed change was zero (the point on the line g = 0); his estimated true gain, however, was better than -5. All but 6 of the 102 subjects showed a true gain beyond -5 (i.e., the total error score decreased by more than five points); of these 96 subjects, four actually exhibited a loss (i.e., increase in total error score). Furthermore, the line (g = 0) representing zero observed gain (or any line of constant observed gain) is not parallel to lines representing estimated true gain which implies that subjects with the same observed gain do not have the same estimated true gain. With respect to this situation, Lord (1963, p. 30) commented, "All this is due to a regression effect acting on the errors of measurement; if there were no errors of measurement, this effect would disappear."

Table 12 shows the distribution of total error scores for each card-sorting stage.

Table 13 summarizes score frequencies for the six sorting stages with respect to non-chance occurrence at three confidence levels. The second column indicates the smallest difference (between an individual score and its group mean) that is not likely to have occurred by chance at the three selected significance levels. The last column presents the number of significant differences which could have occurred by chance alone. Computations for Table 13 employed the conservative (upper-bound) estimate of the standard error of measurement obtained from communalities (see pp. 28 and 30). Smallest significant differences were derived from

Smallest Difference = $(S.E._{(x-\bar{x})})$ (Appropriate normal deviate)

where

$$S.E._{(x - \bar{x})} = S.E._x \sqrt{\frac{101}{102}}$$ (Davis, 1964, p. 190).

Tukey's test for nonadditivity (Winer, 1962, pp. 216–218) was applied to the data to insure

Table 12

Frequency Distribution Table for the Six Card-Sorting Stages (N = 102)

Class Interval[a]	Sort 1	Sort 2	Sort 3	Sort 4	Sort 5	Sort 6
37–39	0	1	0	1	0	0
34–36	2	0	0	0	2	0
31–33	8	0	1	0	5	0
28–30	15	3	0	3	4	1
25–27	14	3	0	3	7	2
22–24	10	9	4	9	14	5
19–21	15	11	10	11	9	9
16–18	15	16	9	17	7	11
13–15	14	10	20	9	6	18
10–12	6	13	20	13	14	15
7– 9	2	19	25	19	22	24
4– 6	1	14	9	14	11	13
1– 3	0	3	4	3	1	4

[a]Total error score

that the additive model described in Chapter II was appropriate for analyzing the data. Table 14 shows the orthogonal breakdown of the residual sum of squares and resulting nonsignificant ratio of mean squares (for nonadditivity).

Table 15 summarizes the results of an analysis of variance. Since the covariance matrix was assumed arbitrary, the Geisser and Greenhouse conservative test was employed in determining the significance (.01 level) of the sort factor. Significance of the main effect and direction of the means indicated nonchance performance (learning). The graph of the six sort means is presented in Figure 8.

Table 16 summarizes the results of a trend analysis. The increase in goodness of fit provided by each of the successively higher order polynomials through the fourth degree fitted to the data was significant.

RELIABILITY ESTIMATION

Eight of the ability tests[22] were not prechecked with respect to reliability estimation since Lemke's (1965) study reported satisfactory

[22]Letter Sets, Locations, Nonsense Syllogisms, Logical Reasoning, Necessary Arithmetic Operations, Ship Destination, Advanced Vocabulary V–4, and Advanced Vocabulary V–5.

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Table 13

Frequency Summary

Task Variable	Significance Level	Smallest Sig. Difference	Non-chance Frequencies Sig.# x < x	Sig.# x > x	Total	Frequencies Possible by Chance Alone
Sort 1	.01	12.4	3	2	5	2
	.05	9.4	8	10	18	6
	.15	6.9	18	17	35	16
Sort 2	.01	11.3	3	5	8	2
	.05	8.6	16	10	26	6
	.15	6.3	19	20	39	16
Sort 3	.01	8.8	4	5	9	2
	.05	6.7	8	15	23	6
	.15	4.9	18	20	38	16
Sort 4	.01	9.3	8	12	20	2
	.05	7.0	17	19	36	6
	.15	5.2	29	27	56	16
Sort 5	.01	10.0	5	13	18	2
	.05	7.6	27	22	49	6
	.15	5.6	38	32	70	16
Sort 6	.01	8.6	4	8	12	2
	.05	6.6	10	17	27	6
	.15	4.8	27	23	50	16

Table 14

Partitioning of Residual Sum of Squares for Tukey's Test for Nonadditivity

Source of Variation	df	MS	F
Residual	505		
Nonadditivity	1	25.83	1.18
Balance	504	21.97	

to good coefficients[23] for all eight tests for a similar population (college females). Previously reported reliabilities for 10 tests drawn from the Guilford laboratory (8 of which were included in the test battery and described in Chapter II) ranged from .46 to .76. Reliability estimates, however, had been computed from scores obtained from eleventh-grade students.

[23]Reliability estimates were derived from correlations of split-halves followed by the Spearman-Brown correction for test length; the coefficients ranged from .64 to .93.

Table 15

Analysis of Variance Summary for Total Error Scores on the Learning Task (N = 102)

Source of Variation	df	MS	F
Between Subjects	101		
Within Subjects	510		
Sort	5	1261.40	57.39**
Residual	505	21.98	

**p <.01.

Because of the disparity in populations, the 10 tests were administered to a small group (N = 14) of college males and reliabilities were computed.

Table 17 compares reliability coefficients based on raw scores and scores corrected for guessing. Best Word Class and Sentence Selection were eliminated as potential elements of the test battery. Sentence Selection had been selected as a Guilford EMI reference

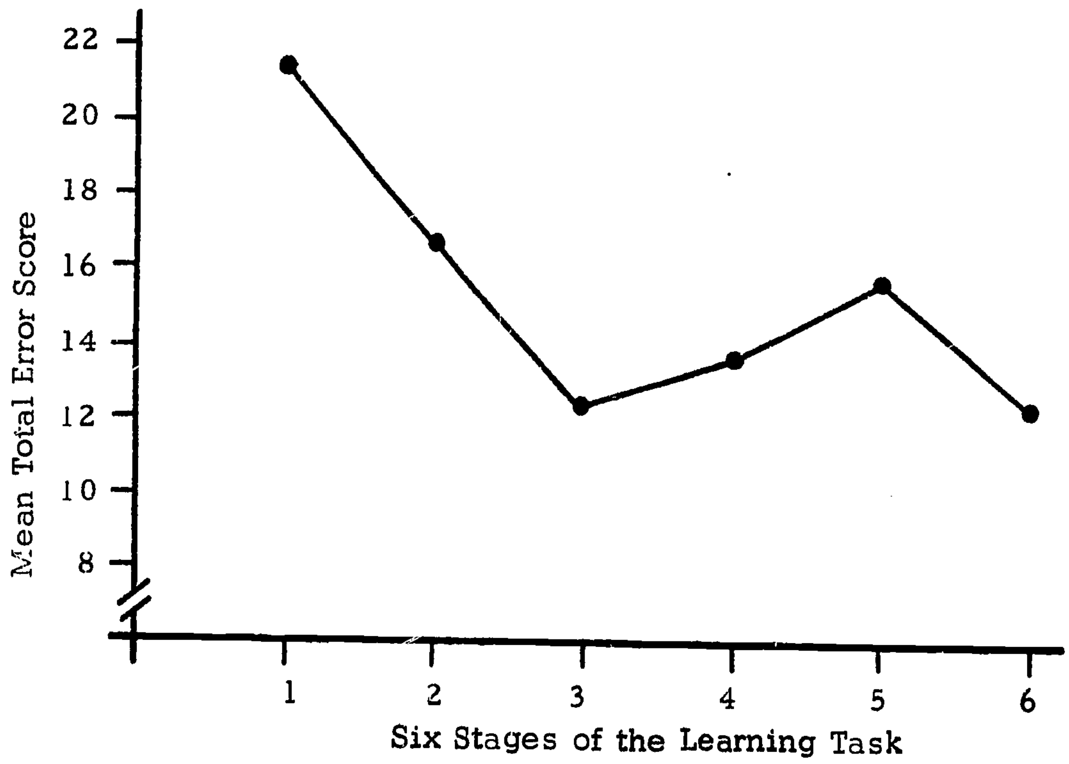

Figure 8. Profile of Means

Table 16

Analysis of Trends

Source of Variation	df	MS	F
Within Subjects			
Sort	5		
Linear	1	3351.77	152.49**
Quadratic	1	1185.45	53.93**
Cubic	1	1201.62	54.67**
Quartic	1	520.29	23.67**
Quintic	1	47.86	2.18
Residual	505	21.98	

**p < .01

Table 17

Reliability Estimates for Ten Ability Tests
(N = 14)

Test Name	r (derived from raw scores)	r (derived from scores corrected for guessing)
Picture Class Memory	--	.81
Classified Information	.72	.55
Remembered Relations	.79	.79
Recalled Analogies	.76	.76
Double Meanings	--	.46
Homonyms	.97	.95
Verbal Analogies	.82	.82
Best Trend Name	.62	.62
Best Word Class	.02	.03
Sentence Selection	.22	.23

test; Logical Reasoning replaced it. Dropping Best Word Class necessitated deleting Class Name Selection, the companion marker-test for Guilford's EMC factor.

IV
MULTIVARIATE ANALYSES

Factor analytic results are presented in this chapter according to the population analyzed, namely the total population, symbolized by G_T, and two subgroups of the total population, $G_{E<12}$ and $G_{E\geq 12}$. $G_{E<12}$ was defined as the set of all subjects achieving a total error score less than twelve at the sixth card-sorting stage; the complement of $G_{E<12}$ in G_T was denoted by $G_{E\geq 12}$. Both alpha and incomplete image analyses are reported for G_T, only alpha factor analyses for the two subgroups.

THE TOTAL POPULATION

Tables 18, 19, and 20 summarize measures descriptive of the total group (N = 102). All correlations are Pearson product-moment coefficients. Frequency distribution tables for task and test variables are presented in the original report (Jones, 1967). Scores on task variables are total number of errors; scores on ability tests represent the number of correct responses. It therefore follows that a positive relationship between a task variable and an ability test is expressed as a negative correlation coefficient. The meaning inherent in the opposition of signs is likewise reflected in the loadings of variables on any one factor; i.e., an arbitrary factor exhibiting substantial positive correlations with a task variable and negative correlations with ability tests does not imply bipolarity.

Tables 21 and 22 present the orthogonally rotated factor matrices of alpha and incomplete image analyses. All coefficients greater than or equal to .30 have been underlined. Six alpha and twelve image factors were extracted. The incomplete image solution is discussed concomitantly with alpha for maximum comparative and explanatory value.

Table 18

Means and Standard Deviations of the Six Stages of the Concept Learning Task and the Sixteen Ability Tests
(N = 102)

Variable Name and Number	Mean	Standard Deviation
1. Task: Sort 1	21.48	6.89
2. Task: Sort 2	16.77	7.07
3. Task: Sort 3	12.27	5.55
4. Task: Sort 4	13.81	7.35
5. Task: Sort 5	15.81	8.54
6. Task: Sort 6	12.16	5.92
7. Picture Class Memory	34.86	6.24
8. Classified Information	54.06	7.60
9. Remembered Relations	22.14	5.98
10. Recalled Analogies	19.39	5.00
11. Double Meanings	24.65	8.17
12. Homonyms	11.59	3.95
13. Letter Sets	22.70	3.14
14. Locations	10.86	3.58
15. Nonsense Syllogisms	18.13	4.30
16. Logical Reasoning	16.70	2.05
17. Necessary Arithmetic Operations	20.33	3.69
18. Ship Destination	13.66	3.33
19. Advanced Vocabulary V–4	22.29	4.55
20. Advanced Vocabulary V–5	20.88	5.77
21. Verbal Analogies III	13.08	2.33
22. Best Trend Name	16.08	1.99

As principles of classification (deduced mathematically), factors were conveniently labeled Alpha I, Alpha II, Image I, etc. Interpretive factor denotation should in no way be construed as scientific factor evidence.

Table 19

Reliabilities and Standard Errors of Measurement for Ability Tests and Stages of the Concept Learning Task (N = 102)

Variable Name and Number	Reliability[a]	Standard error of Measurement
1. Task: Sort 1	.55[b]	4.82
2. Task: Sort 2	.61[b]	4.41
3. Task: Sort 3	.62[b]	3.42
4. Task: Sort 4	.76[b]	3.61
5. Task: Sort 5	.79[b]	3.91
6. Task: Sort 6	.66[b]	3.37
7. Picture Class Memory	.59	3.98
8. Classified Information	.83	3.15
9. Remembered Relations	.70	3.26
10. Recalled Analogies	.51	3.52
11. Double Meanings	.78	3.80
12. Homonyms	.71	2.13
13. Letter Sets	.56	2.07
14. Locations	.60	2.25
15. Nonsense Syllogisms	.64	2.58
16. Logical Reasoning	.40[b]	1.58
17. Nec. Arith. Operations	.64	2.22
18. Ship Destination	.56[c]	2.22
19. Advanced Vocabulary V—4	.70	2.48
20. Advanced Vocabulary V—5	.78	2.69
21. Verbal Analogies III	.33	1.91
22. Best Trend Name	.54	1.35

[a]All reliability coefficients (unless otherwise noted) are parallel halves correlations corrected for length by the Spearman-Brown formula.

[b]Lower bound estimates of reliability obtained from communalities of variable (Incomplete Image Solution).

[c]Kuder-Richardson Formula 21.

Such attached "surplus meaning" is operative in the theoretical domain only, supporting, suggesting, and/or refuting hypotheses.

Superscripts were attached to factor loadings in the following interpretations to indicate the rank of a specified loading within the factorial structure of the corresponding variable.

A. Meaningful-Memory Factors

	Alpha I	Image II
7. Picture Class Memory (MMC)	$.66^{1}$	$.61^{1}$
8. Classified. Information (MMC)	$.54^{1}$	$.57^{1}$
9. Remembered Relations (MMR)	$.64^{1}$	$.62^{1}$
10. Recalled Analogies (MMR)	$.38^{1}$	$.41^{1}$
11. Double Meanings (MMT)	$.64^{1}$	$.63^{1}$
12. Homonyms (MMT)	$.53^{1}$	$.47^{1}$
14. Locations (I)	$.30^{2}$	$.19^{2}$
17. Nec. Arithmetic Operations (CMS)	$.30^{3}$	$.24^{5}$
18. Ship Destination (CMS)	$.37^{1}$	$.27^{4}$

Discussion:

Both analyses clearly isolated a factor which loaded substantially on the six memory tests. Some memory tests showed moderate to small loadings on a second factor in both analyses but no combinatorial alignments occurred (in the total population) suggestive of Guilford's MMC, MMR, and MMT.

Three reasoning tests displayed loadings of .30 or better with Alpha I. Ship Destination showed its largest correlation with this factor. Image II showed the same pattern of loadings for reasoning tests but loadings were of lesser strength. It was concluded that for Ss involved in this study a meaningful-memory ability as measured by tests included in this battery is related to successful performance on certain reasoning tests. The role of memory with respect to performance on reasoning tests appeared more definitive in the subgroup analyses.

B. Within Task Factors

	Alpha II	Image I
1. Task: Sort 1	$.55^{1}$	$.60^{1}$
2. Task: Sort 2	$.54^{2}$	$.62^{1}$
3. Task: Sort 3	$.67^{1}$	$.73^{1}$
4. Task: Sort 4	$.80^{1}$	$.80^{1}$
5. Task: Sort 5	$.89^{1}$	$.83^{1}$
6. Task: Sort 6	$.74^{1}$	$.75^{1}$
14. Locations (I)	$-.25^{3}$	$-.18^{3}$
17. Nec. Arithmetic Operations (CMS)	$-.32^{2}$	$-.31^{3}$
18. Ship Destination (CMS)	$-.30^{3}$	$-.27^{5}$

Discussion:

This factor is one of the expected "practice matrix" reclassifications. (The other is Alpha

Table 20

Correlation Matrix of Task and Ability Variable (N = 102)

Variable Name and Number	1	2	3	4	5	6	7	8	9	10	11
1. Task: Sort 1		56	50	40	50	40	-08	01	-11	-10	-05
2. Task: Sort 2	56		58	46	50	50	-16	-12	-24	-19	-06
3. Task: Sort 3	50	58		62	56	58	-19	-05	-24	-21	-11
4. Task: Sort 4	40	46	62		78	66	-33	-08	-21	-30	-13
5. Task: Sort 5	50	50	56	78		72	-28	-00	-13	-19	-06
6. Task: Sort 6	40	50	58	66	72		-31	-03	-27	-28	-14
7. Picture Class Memory	-08	-16	-19	-33	-28	-31		40	43	44	36
8. Classified Information	01	-12	-05	-08	-00	-03	40		32	22	38
9. Remembered Relations	-11	-24	-24	-21	-13	-27	43	32		29	47
10. Recalled Analogies	-10	-19	-21	-30	-19	-28	44	22	29		40
11. Double Meanings	05	-06	-11	-13	-06	-14	36	38	47	40	
12. Homonyms	-06	-15	-15	-25	-26	-30	45	28	41	19	33
13. Letter Sets	-07	-22	-21	-16	-18	-26	20	15	23	31	16
14. Locations	-12	-18	-20	-29	-29	-25	26	16	13	27	23
15. Nonsense Syllogisms	02	-07	-06	-25	-18	-15	19	08	11	35	20
16. Logical Reasoning	-20	-26	-27	-20	-16	-25	11	05	10	26	02
17. Necessary Arithmetic Operations	-32	-33	-33	-38	-32	-36	29	09	39	34	33
18. Ship Destination	-23	-33	-26	-35	-35	-34	39	18	39	29	15
19. Advanced Vocabulary V–4	-04	-08	-04	-13	-13	-14	12	13	11	21	10
20. Advanced Vocabulary V–5	-10	-04	-10	-13	-09	-15	12	05	02	27	09
21. Verbal Analogies III	-25	-25	-19	-25	-26	-21	17	16	13	24	07
22. Best Trend Name	-17	-35	-19	-23	-16	-19	19	15	15	24	16

Variable Name and Number	12	13	14	15	16	17	18	19	20	21	22
1. Task: Sort 1	-06	-07	-12	02	-20	-32	-23	-04	-10	-25	-17
2. Task: Sort 2	-15	-22	-18	-07	-26	-33	-33	-08	-04	-25	-35
3. Task: Sort 3	-15	-21	-20	-06	-27	-33	-26	-04	-10	-19	-19
4. Task: Sort 4	-25	-16	-29	-25	-20	-38	-35	-13	-13	-25	-23
5. Task: Sort 5	-26	-18	-29	-18	-16	-32	-35	-13	-09	-26	-16
6. Task: Sort 6	-30	-26	-25	-15	-25	-36	-34	-14	-15	-21	-19
7. Picture Class Memory	45	20	26	19	11	29	39	12	12	17	19
8. Classified Information	28	15	16	08	05	09	18	13	05	16	15
9. Remembered Relations	41	23	13	11	10	39	39	11	02	13	15
10. Recalled Analogies	19	31	27	35	26	34	29	21	27	24	24
11. Double Meanings	33	16	23	20	02	33	15	10	09	07	16
12. Homonyms		36	37	18	14	24	35	19	14	19	18
13. Letter Sets	36		44	21	42	37	38	-10	03	13	13
14. Locations	37	44		25	11	38	38	-08	04	00	13
15. Nonsense Syllogisms	18	21	25		28	38	21	22	32	30	27
16. Logical Reasoning	14	42	11	28		19	20	05	15	12	14
17. Necessary Arithmetic Operations	24	37	38	38	19		38	02	11	31	25
18. Ship Destination	35	38	38	21	20	38		13	14	19	32
19. Advanced Vocabulary V–4	19	-10	-08	22	05	02	13		71	23	17
20. Advanced Vocabulary V–5	14	03	04	32	15	11	14	71		22	23
21. Verbal Analogies III	19	13	00	30	12	31	19	23	22		28
22. Best Trend Name	18	13	13	27	14	25	32	17	23	28	

NOTE.—Decimal points omitted

Table 21

Alpha Factor Analysis, Rotated Factor Matrix
Total Population (N = 102)

Variable Name and Number	I	II	III	IV	V	VI	h^2
1. Task: Sort 1	05	55	01	-07	-43	00	49
2. Task: Sort 2	-11	54	03	-19	-59	02	69
3. Task: Sort 3	-09	67	01	-15	-28	-01	56
4. Task: Sort 4	-17	80	-08	-04	-04	-23	73
5. Task: Sort 5	-08	89	-08	-06	00	-11	82
6. Task: Sort 6	-17	74	-11	-18	-07	-07	64
7. Picture Class Memory	66	-21	10	10	-01	11	50
8. Classified Information	54	07	07	03	12	00	32
9. Remembered Relations	64	-14	-03	09	15	02	46
10. Recalled Analogies	38	-13	17	21	09	36	37
11. Double Meanings	64	01	-01	-03	-03	22	47
12. Homonyms	53	-18	13	26	06	04	41
13. Letter Sets	22	-08	-09	86	04	12	82
14. Locations	30	-25	-12	37	-18	24	40
15. Nonsense Syllogisms	09	-03	24	21	02	70	61
16. Logical Reasoning	01	-15	10	42	18	14	26
17. Necessary Arithmetic Operations	30	-32	-10	19	20	47	50
18. Ship Destination	[illegible]7	-30	06	32	14	15	37
19. Advanced Vocabulary V—4	14	-06	89	-09	06	02	82
20. Advanced Vocabulary V—5	03	-06	74	08	06	22	61
21. Verbal Analogies III	14	-16	21	00	35	28	29
22. Best Trend Name	19	-13	16	10	32	25	26

NOTE: Decimal points omitted

	I	II	III	IV	V	VI
Variance	2.5	3.5	1.6	1.5	1.0	1.3
Percent of Total Variance	11.4	15.8	7.2	6.8	4.7	5.8
Percent of Common Variance	22.1	30.5	14.0	13.1	9.0	11.3
Common Variance =	11.38					

V [and its correspondent Image VII]). The construct associated with the factor was defined in terms of the categorizing behavior demanded of S in the learning task, i.e., the ability to respond to stimulus items as representatives of a class rather than as individual entities. A likely interpretation of the pattern exhibited by task-variable loadings is Gagné's "concept learning":

> The learner becomes able to respond in a single way to a collection as a class... [Gagné, 1965, p. 114].

The correlations of two reasoning tests (Locations and Ship Destination) with Alpha II (and to a lesser degree with Image I) supported logical arguments offered in Chapter II with respect to relatedness of task and test requirements.

C. Verbal Comprehension (CMU) Factors

	Alpha III	Image III
19. Advanced Vocabulary V—4 (CMU)	.89[1]	.80[1]
20. Advanced Vocabulary V—5 (CMU)	.74[1]	.79[1]

Discussion:

Both analyses clearly identified the verbal-comprehension factor. There was no relationship between task variables and CMU for the total population.

D. Reasoning Factors

	Alpha IV (Inductive)	Image IV (Deductive)	Image V (Inductive)
12. Homonyms (MMT)	.26[2]		.36[2]

Table 22

Incomplete Image Analysis, Rotated Factor Matrix
Total Population (N = 102)

Variable Name and Number	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	h^2
1. Task: Sort 1	60	07	-03	-07	-04	13	-20	-17	-14	04	-24	-08	55
2. Task: Sort 2	62	-09	00	-20	-04	11	-37	-12	-05	06	-11	-03	61
3. Task: Sort 3	73	-10	-01	-19	-02	01	-11	-11	-06	08	05	-06	62
4. Task: Sort 4	80	-14	-06	-01	-13	-26	-03	08	03	-09	01	00	76
5. Task: Sort 5	83	-04	-06	02	-19	-13	01	08	09	-11	-08	05	79
6. Task: Sort 6	75	-15	-10	-15	-13	-09	02	-04	08	-08	01	10	66
7. Picture Class Memory	-20	61	07	04	17	11	02	-07	04	24	05	-01	53
8. Classified Information	03	57	04	04	06	-04	15	-14	02	-04	09	07	40
9. Remembered Relations	-15	62	01	09	04	-00	08	34	-11	09	00	-02	56
10. Recalled Analogies	-15	41	19	25	12	33	07	02	27	05	-02	-06	50
11. Double Meanings	-02	63	04	-02	10	20	00	15	05	-16	-09	-04	51
12. Homonyms	-14	47	14	11	36	01	00	01	-29	08	09	-05	51
13. Letter Sets	-10	19	-09	53	44	09	05	09	-05	03	04	-05	55
14. Locations	-18	19	-06	11	63	15	04	00	04	-02	-05	02	51
15. Nonsense Syllogisms	-04	10	23	17	18	57	13	02	-01	01	08	-00	47
16. Logical Reasoning	-18	02	08	58	06	11	08	00	02	01	03	02	40
17. Nec. Arith. Operations	-31	24	-02	13	29	34	15	38	07	-01	14	02	56
18. Ship Destination	-27	27	09	16	37	04	26	14	-05	28	04	-01	49
19. Advanced Vocabulary V-4	-07	12	80	-04	-08	05	07	-02	-06	03	05	-02	68
20. Advanced Vocabulary V-5	-05	03	79	09	04	15	08	02	06	-01	03	01	67
21. Verbal Analogies III	-21	12	18	08	-04	25	24	04	-04	03	39	-01	37
22. Best Trend Name	-16	15	16	08	08	17	48	02	01	02	08	-00	35

NOTE: Decimal points omitted

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Variance	3.6	2.2	1.5	.9	1.1	.9	.6	.4	.2	.2	.3	.04
Percent of Total Variance	16.3	10.1	6.7	4.2	5.1	4.0	2.9	1.8	1.1	1.0	1.4	.2
Percent of Common Variance	29.8	18.4	12.3	7.7	9.3	7.4	5.2	3.3	2.0	1.8	2.5	.3
Common Variance =	12.06											

	Alpha IV (Inductive)	Image IV (Deductive)	Image V (Inductive)
13. Letter Sets (I)	.86[1]	.53[1]	.44[2]
14. Locations (I)	.37[1]		.63[1]
16. Logical Reasoning (RS)	.42[1]	.58[1]	
17. Ship Destination (CMS)	.32[2]		.37[1]

Discussion:

Alpha IV was heavily loaded with reasoning tests; its leading identifier (Letter Sets) suggested the inductive-reasoning interpretation. Two image factors (IV and V) which appeared to have been fused in Alpha IV each loaded substantially on Letter Sets. Identification of each image factor was based on the remaining prime contributors to factor variance. Image IV was interpreted as a deductive-reasoning factor, Image V, an inductive-reasoning factor.

Letter Sets was a relatively pure measure of Alpha IV; its communality was .82 and its second highest loading was .22 (Alpha I). Logical Reasoning did not display its usual factorial complexity; however, only 26% of the test's variance was accounted for in the alpha analysis, 40% by image factors.

E. Early Task Factors (Also Guilford's EMR)

	Alpha V (EMR)	Image VII (EMR)?	Image XI (EMR)?
1. Task: Sort 1	-.43[2]	-.20[3]	-.24[2]

	Alpha V (EMR)	Image VII (EMR)?	Image XI (EMR)?
2. Task: Sort 2	-.59[1]	-.37[2]	
3. Task: Sort 3	-.28[2]		
21. Verbal Analogies III (EMR)	.35[1]	.24[3]	.39[1]
22. Best Trend Name (EMR)	.32[1]	.48[1]	

Discussion:

Alpha V was isolated by early task variables and the two EMR tests. The factor appeared to be a coalition of Image VII and Image XI.

The interpretation of Alpha V clearly resided in the communality of EMR test—and early task—requirements (see Chapter II for a discussion of the paralleled activity). The Guilford SI interpretation, i.e., the ability to evaluate relations between words or ideas, was not considered incompatible with an "ability to make multiple discriminations." The pattern of loadings exhibited by task variables on Alpha V was attributed to multiple discrimination learning. Gagne's (1965) definition of the latter term is:

> ...the individual becomes capable of making different responses to the different members of a particular collection [p. 114].

The isolation of two image factors related to task variables and EMR tests made interpretation difficult. Image VII loaded on the same variables as Alpha V. Image XI carried Verbal Analogies highest loading and suggested that some aspect of activity required of S at the first card-sorting phase was related to Verbal Analogies but not to Best Trend Name. The latter test exhibited factorial complexity (a CMS loading) in the Nihira (1964) study. It is possible that Image VII which showed a .26 loading for Ship Destination involved a cognitive as well as an evaluative ability. Image VII accounted for 5.21% of the common variance whereas Image XI only accounted for 2.48%; Alpha V represented 9.04% of the common variance. (See Tables 21 and 22.)

The Nihira study also showed larger loadings for the two referent tests on the EMR factor than the above results. Reliability estimates (based on a high school population in that study) were .73 for Best Trend Name and .60 for Verbal Analogies III whereas in the present investigation estimates were .54 and .33 respectively.[24]

The absence of a significant correlation between Logical Reasoning and the EMR factor supported previous findings (Nihira et al., 1964) which suggested that the logical-evaluation factor and EMR were not the same.

F. Reasoning Factors

	Alpha VI (Syllogistic)	Image VI (Syllogistic)	Image VIII ?
9. Remembered Relations (MMR)			.34[2]
10. Recalled Analogies (MMR)	.36[2]	.33[2]	
15. Nonsense Syllogisms (RS)	.70[1]	.57[1]	
17. Nec. Arith. Oper. (CMS)	.47[1]	.34[2]	.38[1]
21. Verbal Analogies III (EMR)	.28[2]	.25[2]	
22. Best Trend Name (EMR)	.25[2]	.17[2]	

Discussion:

Alpha VI, Image VI, and Image VIII were classified as reasoning factors. Alpha VI and Image VI were interpreted as syllogistic-reasoning factors primarily because Nonsense Syllogisms exhibited substantial loadings on these factors and, in both analyses, appeared as a relatively pure measure of said factors. Necessary Arithmetic Operations displayed its largest correlation (.47) with Alpha VI but a communality of .50 and factorial complexity (Alpha I and II) detracted from its role as a construct identifier.

The two image factors (VI and VIII) appeared to isolate components of variance coalesced on Alpha VI. Alpha VI with a variance of 1.28 accounted for 11.26% of the common variance and 5.82% of the total variance whereas the corresponding figures for Image VI and Image VIII were .89, 7.37%, 4.04%, and .40, 3.34%, 1.83%, respectively.

24 It has been shown that a factor loading is a function of the square root of the variable's reliability; i.e., as reliability decreases, loadings also decrease proportionately (Guilford and Michael, 1950).

The appearance of secondary loadings for two MMR tests suggested a relatedness of performance on MMR tests and certain reasoning tests. In Recalled Analogies S was required to supply fourth components to verbal analogies provided on a study page; test items presented third components to which S responded by writing his recalled "fourth." Number correct scores on this test appeared dependent on correct analogy completion as well as recall. Remembered Relations, on the other hand, merely required S to select the relation joining two entities according to what had been given previously on a study page. Since "entities" were reused in differing relations in study items and since test items sometimes demanded that S reverse the studied relation, it is plausible to suppose that S may have viewed the totality of sentences studied as a semantic system. This supposition would permit a CMS linking to Image VIII which correlated .34 with Remembered Relations and .38 with Necessary Arithmetic Operations.

Verbal Analogies III and Best Trend Name were included in the enumeration of variables contributing to factor variance not because of size of loading but mainly to emphasize the secondary ranking of Alpha VI and Image VI within the factorial structure of these two tests.

THE TWO SUBGROUPS

The dichotomization of the total population described at the beginning of the chapter is very much akin to Manley's (1965) solver-nonsolver bifurcation in that classification in both studies was based on level of performance.[25] Since only a portion of the total learning process was represented by the six stages of the task, the labels "achievers" and "nonachievers" were employed to indicate $G_{E<12}$ and $G_{E\geq12}$ rather than "solvers" and "nonsolvers."

The descriptive statistics reported in Table 23 give a clearer picture of the two subgroups than the definitions given early in the chapter. Comparison of standard deviations of task variables for the subgroups with those given in Table 18 for the total population displays the increased homogeneity of the two subgroups. At all six task stages standard deviations for subgroups were less than those for the total population; also standard deviations for $G_{E<12}$ were always less than those for $G_{E\geq12}$. The disparity was most evident at the sixth card-sorting stage. Variation in ability tests did not reflect the patterns observed in task variables. Except for Locations (whose total group standard deviation was 3.58), each total group standard deviation fell within the interval defined by the corresponding subgroup measures. Only Picture Class Memory showed a difference in standard deviations greater than one (difference = 1.01). Variation in six of the ability tests was greater for $G_{E<12}$ than $G_{E\geq12}$; the tests were Recalled Analogies, Double Meanings, Nonsense Syllogisms, Logical Reasoning, Advanced Vocabulary V-4 and V-5. The means of ability tests were all larger for $G_{E<12}$ than $G_{E\geq12}$ except Classified Information (difference = .1). The size of differences, however, in no way compared with task mean differences. Since subgroup size is relatively large (N = 50 and N = 52), a mean difference as small as 1 could be significant if corresponding standard deviations were likewise small.

Tables 24 and 25 are the intercorrelation matrices for $G_{E<12}$ and $G_{E\geq12}$. Tables 26 and 27 present the orthogonally rotated alpha factors for the two subgroups.

Factors from the two subgroup analyses were discussed concurrently whenever a common interpretation was applicable.

A. Meaningful-Memory Factors

	$G_{E<12}$: Alpha I (Meaningful Memory)	$G_{E\geq12}$: Alpha II (Meaningful Memory I)	$G_{E\geq12}$: Alpha VII (Meaningful Memory II)
1. Task: Sort 1	.32[2]		
7. Picture Class Memory (MMC)	.67[1]	.61[1]	.29[3]
8. Classified Information (MMC)	.58[1]	.37[1]	.31[2]
9. Remembered Relations (MMR)	.61[1]	.41[2]	.42[1]

[25] Numerous methods for classifying learners have been reported in the literature in the area of cognitive style. Baggaley's (1955) analytic versus nonanalytic thinkers, Osler and Fivel's (1961) gradual and sudden learners, and Woodworth's (1938) hypothesis testing and composite photography are examples.

Table 23

Comparison of the Means and Standard Deviations of Task and Test Variables for the Two Subgroups

Variable Name and Number	Mean		Standard Deviation	
	$G_{E<12}$	$G_{E\geq 12}$	$G_{E<12}$	$G_{E\geq 12}$
1. Task: Sort 1	19.2	23.6	6.54	6.59
2. Task: Sort 2	13.6	19.8	5.96	6.75
3. Task: Sort 3	9.78	14.7	4.40	5.53
4. Task: Sort 4	9.84	17.6	5.95	6.53
5. Task: Sort 5	10.6	20.8	6.24	7.44
6. Task: Sort 6	7.2	16.9	2.50	4.11
7. Picture Class Memory	36.1	33.6	4.79	6.80
8. Classified Information	54.0	54.1	7.34	7.91
9. Remembered Relations	22.8	21.5	6.23	5.63
10. Recalled Analogies	20.1	18.6	4.83	5.13
11. Double Meanings	25.5	24.1	8.56	7.99
12. Homonyms	12.3	11.0	3.55	4.19
13. Letter Sets	23.4	22.1	2.86	3.29
14. Locations	11.6	10.1	3.51	3.53
15. Nonsense Syllogisms	18.8	17.5	4.43	4.10
16. Logical Reasoning	17.0	16.4	2.16	1.91
17. Necessary Arithmetic Operations	21.3	19.4	3.14	3.97
18. Ship Destination	14.7	12.7	2.99	3.38
19. Advanced Vocabulary V-4	23.5	21.4	4.89	4.20
20. Advanced Vocabulary V-5	22.0	19.8	6.07	5.30
21. Verbal Analogies III	13.6	12.6	2.13	2.43
22. Best Trend Name	16.5	15.6	1.94	2.08

	$G_{E<12}$: Alpha I (Meaningful Memory)	$G_{E\geq 12}$: Alpha II (Meaningful Memory I)	$G_{E\geq 12}$: Alpha VII (Meaningful Memory II)
10. Recalled Analogies (MMR)		$.31^{4}$	$.39^{2}$
11. Double Meanings (MMT)	$.72^{1}$		$.81^{1}$
12. Homonyms (MMT)	$.50^{1}$	$.74^{1}$	$.26^{2}$
13. Letter Sets (I)	$.31^{3}$	$.45^{2}$	
14. Locations (I)		$.57^{1}$	
17. Nec. Arith. Oper. (CMS)		$.35^{1}$	
18. Ship Destination (CMS)	$.41^{1}$	$.69^{1}$	
22. Best Trend Name (EMR)		$.30^{2}$	

Discussion:

The above three factors isolated in the two subgroup analyses were interpreted as meaningful-memory factors. The labels "meaningful-memory I" and "meaningful-memory II" were employed to differentiate between the two factors extracted in the $G_{E\geq 12}$ analysis.

Alpha I ($G_{E<12}$) loaded on all memory tests except Recalled Analogies. For the achievers, successful performance on this test appeared related to abilities other than memory (see Alpha V for $G_{E<12}$). Two reasoning tests also correlated substantially with the factor. That a small portion of the variance of Letter Sets was accounted for by a meaningful-memory ability does not seem unreasonable; in order to choose from five given sets of four letters each that set which does not belong, S must remember the characteristics shared by four of the letter sets. Had S been required instead to study these items first and then on a test page mark similar sets of letters according to whether the "concept" had or had not occurred on the study page, the test in this form, whose requirements now parallel those of Picture Class Memory, would probably be a prime identifier

Table 24

Correlation Matrix of Task and Ability Variables for $G_{E<12}$ (N = 50)

Variable Name and Number	1	2	3	4	5	6	7	8	9	10	11
1. Task: Sort 1		47	45	21	43	31	20	19	14	-05	27
2. Task: Sort 2	47		64	36	37	34	07	02	-06	-26	14
3. Task: Sort 3	45	64		50	56	26	04	06	-10	-10	14
4. Task: Sort 4	21	36	50		76	46	-07	08	-13	-15	-01
5. Task: Sort 5	43	37	56	76		45	08	14	04	03	09
6. Task: Sort 6	31	34	26	46	45		-09	03	-09	-18	13
7. Picture Class Memory	20	07	04	-07	08	-09		48	35	29	48
8. Classified Information	19	02	06	08	14	03	48		28	23	43
9. Remembered Relations	14	-06	-10	-13	04	-09	35	28		31	51
10. Recalled Analogies	-05	-26	-10	-15	03	-18	29	23	31		27
11. Double Meanings	27	14	14	-01	09	13	48	43	51	27	
12. Homonyms	16	-13	-20	-29	-18	-13	28	24	36	03	39
13. Letter Sets	-11	-33	-32	-04	-05	-23	14	28	39	22	15
14. Locations	-11	-18	-34	-35	-37	-22	21	10	09	17	13
15. Nonsense Syllogisms	10	-05	-09	-17	-02	-12	08	12	23	34	26
16. Logical Reasoning	-14	-34	-29	-14	-16	-28	04	16	07	09	06
17. Nec. Arith. Operations	-20	-21	-31	-35	-26	-21	22	-02	45	28	25
18. Ship Destination	-17	-35	-35	-35	-26	-14	32	19	44	22	27
19. Advanced Vocabulary V—4	29	30	12	-01	11	25	-07	13	-03	16	09
20. Advanced Vocabulary V—5	11	20	-03	-04	15	20	02	01	01	29	14
21. Verbal Analogies III	-05	04	05	-06	01	01	-02	04	03	11	-04
22. Best Trend Name	04	-37	-08	01	11	06	-03	15	03	26	11

Variable Name and Number	12	13	14	15	16	17	18	19	20	21	22
1. Task: Sort 1	16	-11	-11	10	-14	-20	-17	29	11	-05	04
2. Task: Sort 2	-13	-33	-18	-05	-34	-21	-35	30	20	04	-37
3. Task: Sort 3	-20	-32	-34	-09	-29	-31	-35	12	-03	05	-08
4. Task: Sort 4	-29	-04	-35	-17	-14	-35	-35	-01	-04	-06	01
5. Task: Sort 5	-18	-05	-37	-02	-16	-26	-26	11	15	01	11
6. Task: Sort 6	-13	-23	-22	-12	-28	-21	-14	25	20	01	06
7. Picture Class Memory	28	14	21	08	04	22	32	-07	02	-02	-03
8. Classified Information	24	28	10	12	16	-02	19	13	01	04	15
9. Remembered Relations	36	39	09	23	07	45	44	-03	01	03	03
10. Recalled Analogies	03	22	17	34	09	28	22	16	29	11	26
11. Double Meanings	39	15	13	26	06	25	27	09	14	-04	11
12. Homonyms		33	27	23	26	11	29	25	22	03	11
13. Letter Sets	33		37	23	44	32	33	-04	-01	04	20
14. Locations	27	37		23	-02	26	28	-05	-02	-27	-01
15. Nonsense Syllogisms	23	23	23		35	42	24	31	39	13	27
16. Logical Reasoning	26	44	-02	35		08	17	10	19	00	18
17. Nec. Arith. Operations	11	32	26	42	08		35	-23	01	10	11
18. Ship Destination	29	33	28	24	17	35		-01	01	09	17
19. Advanced Vocabulary V—4	25	-04	-05	31	10	-23	-01		75	28	10
20. Advanced Vocabulary V—5	22	-01	-02	39	19	01	01	75		21	14
21. Verbal Analogies III	03	04	-27	13	00	10	09	28	21		24
22. Best Trend Name	11	20	-01	27	18	11	17	10	14	24	

NOTE.— Decimal points omitted

Table 25

Correlation Matrix of Task and Ability Variables for $G_{E\geq12}$ (N = 52)

Variable Name and Number	1	2	3	4	5	6	7	8	9	10	11
1. Task: Sort 1		51	41	36	40	25	-13	-16	-32	-08	-09
2. Task: Sort 2	51		38	25	29	24	-12	-26	-38	-09	-16
3. Task: Sort 3	41	38		52	32	52	-17	-13	-31	-27	-26
4. Task: Sort 4	36	25	52		63	49	-39	-24	-22	-38	-18
5. Task: Sort 5	40	29	32	63		52	-31	-11	-19	-25	-11
6. Task: Sort 6	25	24	52	49	52		-29	-11	-50	-39	-25
7. Picture Class Memory	-13	-12	-17	-39	-31	-29		47	52	56	29
8. Classified Information	-16	-26	-13	-24	-11	-11	47		36	24	32
9. Remembered Relations	-32	-38	-31	-22	-19	-50	52	36		28	43
10. Recalled Analogies	-08	-09	-27	-38	-25	-39	56	24	28		43
11. Double Meanings	-09	-16	-26	-18	-11	-25	29	32	43	43	
12. Homonyms	-14	-08	-04	-13	-23	-33	56	33	46	40	34
13. Letter Sets	08	-02	-01	-08	-09	-13	26	07	06	36	07
14. Locations	-00	-03	05	-09	-08	-10	30	23	14	33	27
15. Nonsense Syllogisms	04	04	08	-24	-19	-00	27	04	-05	31	17
16. Logical Reasoning	-19	-10	-17	-15	-04	-21	17	-05	10	41	-09
17. Nec. Arith. Operations	-32	-27	-22	-27	-18	-30	30	17	32	37	39
18. Ship Destination	-14	-14	-01	-14	-19	-20	40	19	32	28	-04
19. Advanced Vocabulary V–4	-22	-21	01	-03	-15	-12	15	17	27	21	17
20. Advanced Vocabulary V–5	-20	-10	-00	-02	-08	-11	11	09	01	22	10
21. Verbal Analogies III	-32	-36	-21	-26	-30	-13	24	26	18	32	12
22. Best Trend Name	-29	-30	-27	-31	-17	-15	31	20	29	18	16

Variable Name and Number	12	13	14	15	16	17	18	19	20	21	22
1. Task: Sort 1	-14	08	-00	04	-19	-32	-14	-22	-20	-32	-29
2. Task: Sort 2	-08	-02	-03	04	-10	-27	-14	-21	-10	-36	-30
3. Task: Sort 3	-04	-01	05	08	-17	-22	-01	01	-00	-21	-27
4. Task: Sort 4	-13	-08	-09	-24	-15	-27	-14	-03	-02	-26	-31
5. Task: Sort 5	-23	-09	-08	-19	-04	-18	-19	-15	-08	-30	-17
6. Task: Sort 6	-33	-13	-10	-00	-21	-30	-20	-12	-11	-13	-15
7. Picture Class Memory	56	26	30	27	17	30	40	15	11	24	31
8. Classified Information	33	07	23	04	-05	17	19	17	09	26	20
9. Remembered Relations	46	06	14	-05	10	32	32	27	01	18	29
10. Recalled Analogies	40	36	33	31	41	37	28	21	22	32	18
11. Double Meanings	34	07	27	17	-09	39	-04	17	10	12	16
12. Homonyms		43	51	13	03	40	43	11	01	28	27
13. Letter Sets	43		45	14	37	34	35	-22	-02	14	04
14. Locations	51	45		23	20	41	40	-16	02	15	19
15. Nonsense Syllogisms	13	14	23		16	31	11	07	19	42	14
16. Logical Reasoning	03	37	20	16		23	15	-02	05	18	06
17. Nec. Arith. Operations	40	34	41	31	23		32	09	12	39	34
18. Ship Destination	43	35	40	11	15	32		14	15	17	37
19. Advanced Vocabulary V–4	11	-22	-16	07	-02	09	14		70	15	22
20. Advanced Vocabulary V–5	01	-02	02	19	05	12	15	70		17	28
21. Verbal Analogies III	28	14	15	42	18	39	17	15	17		28
22. Best Trend Name	27	04	19	14	06	34	37	22	28	28	

NOTE.— Decimal points omitted

Table 26

Alpha Factor Analysis, Rotated Factor Matrix
Subgroup $G_{E<12}$ (N = 50)

Variable Name and Number	I	II	III	IV	V	VI	VII	h^2
1. Task: Sort 1	32	41	25	27	-12	02	-09	42
2. Task: Sort 2	07	40	25	78	-07	-07	-23	90
3. Task: Sort 3	06	60	03	41	-07	-20	-16	60
4. Task: Sort 4	-09	85	-11	-01	-15	-01	00	76
5. Task: Sort 5	09	89	06	00	02	-09	-05	82
6. Task: Sort 6	00	45	22	-02	-20	-01	-32	40
7. Picture Class Memory	67	-01	-07	07	13	05	-02	48
8. Classified Information	58	16	04	-13	-04	-01	14	41
9. Remembered Relations	61	-07	-06	-02	35	-02	06	51
10. Recalled Analogies	25	-03	15	-25	43	-04	04	34
11. Double Meanings	72	11	14	04	18	07	-05	59
12. Homonyms	50	-27	28	-04	-10	11	24	48
13. Letter Sets	31	-09	-04	-32	20	15	45	48
14. Locations	19	-33	06	-13	18	65	02	62
15. Nonsense Syllogisms	14	-03	42	-08	53	04	26	56
16. Logical Reasoning	06	-13	13	-16	03	-03	82	73
17. Nec. Arith. Operations	19	-29	-11	-08	69	01	01	62
18. Ship Destination	41	-34	-00	-30	21	01	04	43
19. Adv. Vocabulary V-4	07	06	92	04	-11	-14	01	88
20. Adv. Vocabulary V-5	-00	05	79	-03	18	-07	04	66
21. Verbal Analogies III	01	-05	21	-14	11	-53	-02	36
22. Best Trend Name	08	11	19	-51	14	-17	09	37

NOTE.— Decimal points omitted

	I	II	III	IV	V	VI	VII
Variances	2.50	2.89	2.07	1.46	1.41	.86	1.24
Percent of Total Variance	11.34	13.12	9.42	6.63	6.41	3.91	5.63
Percent of Common Variance	20.08	23.24	16.68	11.74	11.36	6.93	9.97
Common Variance =	12.42						

for Alpha I. Ship Destination showed its highest loading on Alpha I; the factor accounted for 17% of the test's variance. The positive relationship between meaningful-memory ability and successful performance on the test was exhibited for the first time in the present investigation. The remaining significant contributor to Alpha I variance was the first card-sorting stage whose .32 loading expressed a negative correlation with the factor.

For nonachievers, memory tests correlated substantially with two factors. Alpha VII, labeled "meaningful-memory II," was identified by Double Meanings (.81) and Remembered Relations (.42). No attempt was made to assign either of the two SI model interpretations to the factor since the recommended correlative tests for MMR and MMT appeared on Alpha II (labeled "meaningful-memory I"). The combination of variables contributing to Alpha II's variance was considered one of the most important findings of the investigation. The factor exhibited highest loadings for three memory tests and three reasoning tests. That the factor was not interpreted as a reasoning ability stemmed from the relationships observed on Alpha I for achievers; i.e., a relatively small portion of the variance of two reasoning tests was accounted for by a meaningful-memory ability for a group of Ss whose mean scores on the ability tests (see Table 23) indicated better performance. In light of this interpretation, Ship Destination which had almost 50% of its variance accounted for by the factor appeared to measure a memory rather than a reasoning ability for nonachievers.

B. Within Task Factors

	$G_{E<12}$: Alpha II	$G_{E\geq 12}$: Alpha I
1. Task: Sort 1	.41[1]	

Table 27

Alpha Factor Analysis, Rotated Factor Matrix

Subgroup$_{E \geq 12}$ (N = 52)

Variable Name and Number	I	II	III	IV	V	VI	VII	h^2
1. Task: Sort 1	26	-02	-14	-06	67	01	02	54
2. Task: Sort 2	15	-07	-06	00	69	02	-10	52
3. Task: Sort 3	50	11	06	-17	45	12	-24	56
4. Task: Sort 4	77	-10	04	-02	24	-23	-07	73
5. Task: Sort 5	68	-14	-04	02	21	-16	06	55
6. Task: Sort 6	64	-15	-08	-27	15	20	-22	62
7. Picture Class Memory	-35	61	13	02	-02	12	29	62
8. Classified Information	-11	37	07	-18	-20	06	31	32
9. Remembered Relations	-25	41	12	00	-34	-28	42	61
10. Recalled Analogies	-34	31	22	48	06	23	39	70
11. Double Meanings	-07	15	05	00	-10	11	81	7.
12. Homonyms	-11	74	-01	08	-06	05	26	64
13. Letter Sets	01	45	-18	52	07	11	-01	53
14. Locations	08	57	-14	27	-02	21	14	49
15. Nonsense Syllogisms	-10	12	11	13	06	73	06	60
16. Logical Reasoning	-11	06	02	63	-11	07	-06	44
17. Nec. Arith. Operations	-06	35	02	32	-37	27	24	50
18. Ship Destination	-08	69	16	16	-15	-01	-21	59
19. Adv. Vocabulary V–4	-05	03	92	-11	-14	-03	12	90
20. Adv. Vocabulary V–5	01	04	74	07	-11	16	-00	59
21. Verbal Analogies III	-14	18	09	08	-42	47	08	46
22. Best Trend Name	-12	30	21	00	-39	12	04	32

NOTE.— Decimal points omitted

	I	II	III	IV	V	VI	VII
Variances	2.21	2.68	1.65	1.30	1.97	1.23	1.51
Percent of Total Variance	10.03	12.19	7.52	5.89	8.94	5.58	6.84
Percent of Common Variance	17.60	21.39	13.19	10.33	15.69	9.79	12.01

Common Variance = 12.54

	$G_{E < 12}$: Alpha II	$G_{E \geq 12}$: Alpha I
2. Task: Sort 2	.40[2]	
3. Task: Sort 3	.60[1]	.50[1]
4. Task: Sort 4	.85[1]	.77[1]
5. Task: Sort 5	.89[1]	.68[1]
6. Task: Sort 6	.45[1]	.64[1]
7. Picture Class Memory (MMC)		-.35[2]
10. Recalled Analogies (MMR)		-.34[3]
14. Locations (I)	-.33[2]	
17. Nec. Arith. Oper. (CMS)	-.29[2]	
18. Ship Destination (CMS)	-.34[2]	

Discussion:

This factor (in both groups) was identified as one of the task factors. It was described earlier as an ability to respond to a collection of items as a whole or class. A discriminating element between the two groups was the point in the learning process where the construct first appeared important. Achievers apparently used the ability when sorting cards as early as the first stage. Nonachievers did not begin to respond to sets of items as classes or wholes until the third stage.

The significant loadings of reasoning tests on the factor for achievers as compared with memory tests for nonachievers was considered one of the major findings of the investigation. In the $G_{E < 12}$ analysis, the factor accounted for 11% of the variance for Locations, 8% for Necessary Arithmetic Operations, and 12% for Ship Destination; in the $G_{E \geq 12}$ analysis, 12% of the variance of both Picture Class Memory and Recalled Analogies was explained by the factor.

C. Verbal Comprehension (CMU) Factors

	$G_{E<12}$: Alpha III	$G_{E\geq 12}$: Alpha III
15. Nonsense Syllogisms (RS)	.42[2]	
19. Adv. Vocabulary V-4 (CMU)	.92[1]	.92[1]
20. Adv. Vocabulary V-5 (CMU)	.79[1]	.74[1]

Discussion:

The verbal comprehension factor was identified in both analyses by Advanced Vocabulary V-4 and Advanced Vocabulary V-5. The .42 loading of Nonsense Syllogisms for achievers paralleled the .49 loading for Manley's (1965) solvers for the same test on the verbal factor identified in that study; the nonsolver loading was .05 as compared to .13 for $G_{E\geq 12}$.

D. Early Task Factors (EMR)

	$G_{E<12}$: Alpha IV	$G_{E\geq 12}$: Alpha V
1. Task: Sort 1	.27[3]	.67[1]
2. Task: Sort 2	.78[1]	.69[1]
3. Task: Sort 3	.41[2]	.45[2]
9. Remembered Relations (MMR)		-.34[3]
13. Letter Sets (I)	-.32[2]	
17. Nec. Arith. Oper. (CMS)		-.37[1]
18. Ship Destination (CMS)	-.30[3]	
21. Verbal Analogies III (EMR)		-.42[2]
22. Best Trend Name (EMR)	-.51[1]	-.39[1]

Discussion:

Both analyses isolated a factor which loaded substantially on early task variables. The factor was interpreted as an ability to make multiple discriminations. The interpretation was considered in harmony with Guilford's EMR.

Achievers showed only a tertiary loading on the factor for the first card-sort as compared to the primary loading for nonachievers. In accord with the multiple-discrimination interpretation, achievers apparently viewed stimulus sentences as belonging or not belonging to the whole defined by the first postulate; probably little attention was given to sentences at this point as specifics. The greatly increased loading at the second phase suggested that achievers began responding to stimulus sentences as separate entities which had to be discriminated from each other. Examination of task-variable loadings on Alpha II, the categorizing or classifying ability, suggested that achievers were primarily concerned with wholes or classes throughout all six stages and apparently discriminated among and categorized sentences simultaneously at the second and third stages. Nonachievers, on the other hand, appeared to employ the abilities disjointedly. Alpha V ($G_{E\geq 12}$) correlated highly with early task variables whereas the within task factor (Alpha I) showed only small loadings on the first two card-sorting stages. Thereafter Alpha I was the prime contributor to task variable variances.

The two EMR tests, Verbal Analogies III and Best Trend Name, loaded -.42 and -.39 respectively on Alpha V ($G_{E\geq 12}$). Only Best Trend Name showed a significant loading on the corresponding factor for achievers.

Several reasoning tests and one memory test exhibited loadings greater than or equal to .30 (in absolute value). In the $G_{E<12}$ analysis, Letter Sets and Ship Destination correlated -.32 and -.30 respectively with the factor; in the $G_{E\geq 12}$ analysis, Remembered Relations and Necessary Arithmetic Operations correlated -.34 and -.37 respectively. Negative correlations represented positive relationships.

E. Reasoning Factors (CMS and CMR)

	$G_{E<12}$: Alpha V (CMS)	$G_{E\geq 12}$: Alpha VI (CMR)
9. Remembered Relations (MMR)	.35[2]	
10. Recalled Analogies (MMR)	.43[1]	
15. Nonsense Syllogisms (RS)	.53[1]	.73[1]
17. Nec. Arith. Oper. (CMS)	.69[1]	.27[4]

	$G_{E<12}$: Alpha V (CMS)	$G_{E\geq 12}$: Alpha VI (CMR)
21. Verbal Analogies III (EMR)		.47[1]

Discussion:

The only observable link between Alpha V ($G_{E<12}$) and Alpha VI ($G_{E\geq 12}$) was the contribution of Nonsense Syllogisms to factor variances. A similar factor extracted in the alpha analysis of the total population was labeled "syllogistic-reasoning" primarily because of Nonsense Syllogisms' loading.

Alpha V ($G_{E<12}$) was interpreted as Guilford's CMS. Necessary Arithmetic Operations exhibited its highest loading on the factor. Forty-nine percent of the test's variance was explained by Alpha V whereas only 13% was accounted for by the remaining six factors. Under the CMS interpretation, the loadings of Remembered Relations and Recalled Analogies suggested that achievers might first employ a cognizing ability in order to place (or recognize the position of) the test item within the "system" or complex structure studied on a previous page and then attempt to correctly recall specific information.

Alpha VI ($G_{E\geq 12}$) was isolated by Nonsense Syllogisms (.73) and Verbal Analogies III (.47). The hypothetical construct associated with the factor was Guilford's CMR. The SI model defines CMR as

> the ability to see relations between ideas or meanings of words [Guilford and Hoepfner, 1966, p. 6].

Verbal-analogy tests have typically been employed to measure CMR. Verbal Analogies III, however, was constructed such that cognition of the relation between first and second components was relatively easy, the difficulty being embedded in selecting the "best" fourth component. It was thought that nonachievers experienced difficulty in seeing some of the relations as well as in properly evaluating given fourth components. CMR (Alpha VI) explained this portion of the test's variance.

Nonsense Syllogisms apparently measured different constructs in the two subgroups. A possible explanation is that achievers recognized test items as either logically valid or logically invalid systems whereas for nonachievers comprehension of the relations involved in any one item was necessary for successful performance.

F. Reasoning Factors (Deductive)

	$G_{E<12}$: Alpha VII	$G_{E\geq 12}$: Alpha IV
6. Task: Sort 6	-.32[2]	-.27[2]
10. Recalled Analogies (MMR)		.48[1]
13. Letter Sets (I)	.45[1]	.52[1]
16. Logical Reasoning (RS)	.82[1]	.63[1]
17. Nec. Arith. Oper. (CMS)		.32[3]

Discussion:

Letter Sets and Logical Reasoning identified a factor in each analysis which was interpreted as a deductive-reasoning factor. Logical Reasoning emerged as a relatively pure measure of the factor in each analysis. In the $G_{E<12}$ analysis, the factor loading was .82 as compared with a .73 communality; in the $G_{E\geq 12}$ analysis, factor correlation was .63, communality, .44.

A similar alignment of Letter Sets and Logical Reasoning occurred in the Manley (1965) study. Primary loadings of .40 for Letter Sets and .50 for Logical Reasoning on a factor labeled "general reasoning" were reported for the solver-analysis. Two concept attainment tasks also exhibited highest loadings on that factor.

Alpha IV ($G_{E\geq 12}$) accounted for 23% of the variance of Recalled Analogies which suggested that nonachievers probably had more difficulty completing the analogy correctly than recalling the fourth component. Recall that the test correlated .31 and .39 with two factors (Alpha II and VII) interpreted as meaningful-memory factors.

The secondary loadings for the sixth card-sorting stage permitted the conclusion that the ability represented by Letter Sets and Logical Reasoning is related to successful performance on the learning task employed in this investigation.

G. Uninterpreted Factor

	$G_{E<12}$: Alpha VI
14. Locations (I)	.65[1]
21. Verbal Analogies III (EMR)	-.53[1]

Discussion:

Bipolarity was displayed on Alpha VI ($G_{E<12}$) by loadings of two ability tests. The factor accounted for only 6.93% of the common variance and 3.91% of the total variance. Although classified as "uninterpretable," the factor merits discussion.

If the factor be associated with an inductive-reasoning ability, it can be concluded that for the achievers performance on Verbal Analogies III is inversely related to the ability. Upon examining the relationships of Verbal Analogies III and Locations with the other variables (see Tables 24 and 25) marked differences were observed between the two subgroups. For achievers Verbal Analogies III correlated near zero with all variables except Locations (-.27), Advanced Vocabulary V-4 (.28), Advanced Vocabulary V-5 (.21), and Best Trend Name (.24). For nonachievers all correlations expressed positive relationships; only seven of the coefficients were less than .20 in absolute value. For Locations the most obvious disparity between subgroups lay in correlations with task variables. For achievers a positive relationship existed between the test and six phases of the task; three coefficients fell in the .30 to .40 range (in absolute value). The same six coefficients were near zero for nonachievers.

GENERAL DISCUSSION

One of the major goals of the study was to isolate and describe theoretical constructs that were being measured by the learning task. Reclassification of the common variation of 22 variables by alpha factor analysis for the total population and two subgroups yielded two task-related factors in each case.

The within task factor was thought to be a classifying or categorizing ability. Employment of the ability meant that S was aware of and made his response to the whole or class to which the stimulus belonged. The factor was considered analogous to Reasoning III, a hypothesized (but not isolated) classifying ability of the Green et al. (1953) study. Results of that study indicated that classification tests had little of their variance explained by reasoning factors except for the general-reasoning factor to which the authors commented, ". . . and this is probably true only when the classifying task becomes difficult [p. 157]."

The early task factor was identified as an ability to make multiple discriminations; the latter interpretation was considered in harmony with Guilford's EMR whose referent tests loaded on the factor.

The pattern of loadings on each task factor were thought indicative of occurrences of multiple discrimination learning and concept learning as defined by Gagné (1965). The six postulates of the learning task were viewed as instructions which "are part of the conditions of learning but not part of what is learning [Gagné, 1965, p. 90]." For both types of learning Gagné listed reinforcement as a necessary condition of learning; in the learning task the postulates were thought to function in two ways: 1) to provide information for subsequent card-sorts and 2) to serve as feedback agents following an arbitrary card-sort. It is also possible that the postulates served as discriminative stimuli and/or positive reinforcers in s → r links mediated between the stimulus sentence and overt response (yes or no). But even in this role postulates become verbal instructions, self-administered; in the Gagnéian sense, they are part of the conditions of learning.

The factors identified as reasoning abilities appeared the least clearly defined. Reference tests for the factors tended to be factorially complex. In the alpha analysis of the total population, the factorial structures of Letter Sets, Nonsense Syllogisms, and Logical Reasoning were simple; only 26% of the variance of Logical Reasoning, however, was explained. In the $G_{E<12}$ analysis, Logical Reasoning and Necessary Arithmetic Operations were relatively pure measures of the factors they identified. In the $G_{E\geq 12}$ analysis, simple structures were exhibited by Locations, Nonsense Syllogisms, Logical Reasoning, and Ship Destination.

Examination of the factorial structures of Necessary Arithmetic Operations and Ship Destination offered insight to psychological constructs measured by the tests. In the total population (Table 21) both tests showed similar portions of variance accounted for by the meaningful-memory and within-task factors. Neither test loaded substantially on the verbal comprehension and early task factors. The principal difference was observed in the reasoning factor loadings, Necessary Arithmetic Operations relating with an induction factor, Ship Destination with syllogistic reasoning. Only 37% of the variance of the latter test was accounted for by alpha factors. In the $G_{E\geq 12}$ analysis, the two tests showed their only alignment on a meaningful-memory factor; in $G_{E<12}$ analysis, on the within task factor.

One of the major differences in the two subgroup analyses was the factor components contributing to memory-test variances. Tables 26 and 27 clearly display the contrasting (simple versus complex) structures. The average communalities of memory tests in the $G_{E<12}$ and $G_{E\geq 12}$ analyses were .47 and .60 respectively.

Although several memory tests loaded on the within task factor for nonachievers, the factorial structure of task variables did not exhibit strong correlations with memory factors in any of the factor analyses. A probable explanation is that in the memory tests S was asked to recall meaningful but unrelated bits (or items) of information; the successful S probably employed associative techniques (within the "system" or totality of studied items) to facilitate recall. Stimulus sentences in the learning task are not unrelated bits of information. The nature of the task demands that S comprehend and recall relevant information given in the postulates. The forced relatedness of "bits of information" in the task stands somewhat in contrast to the independence of memory-test items.

V
SUMMARY AND CONCLUSIONS

The purpose of the investigation was to examine in the laboratory the type of learning commonly found in the school situation— the formalized acquisition of concepts. A verbal concept-learning task suitable for college students was devised which permitted the externalizing and quantifying of behavior at six points in the learning process.

A preliminary study investigated the effects of feedback and postulate-availability conditions over six stages of learning. Four experimental conditions were symbolized and defined as follows:

P_+F_-, postulates available, no feedback;

P_+F_+, postulates available, feedback;

P_-F_-, postulates removed, no feedback;

P_-F_+, postulates removed, feedback.

Results indicated that the two learning curves associated with the two levels of feedback could be considered identical in shape but not coincident, that learning curves corresponding to the two levels of the postulate factor were coincident, and that although the four learning curves corresponding to the four experimental conditions were identical in shape, at least one pair was not coincident. A trend analysis provided statistical support for suspected linear and cubic trends.

After only minor revisions, the learning task was administered to the population selected for the factor-analytic study. The experimental condition described as "postulates removed, no feedback" exhibited results sufficiently indicative of the learning phenomenon to permit its use in the planned factor-analytic investigation. Exploring learning behavior stripped of externally applied feedback[26] was a prime goal of the study.

[26] By "externally applied feedback" is meant feedback which is administered to S; informing S when he is right or wrong or both is an example. The postulates (and the stimulus sentences) were thought to function as internal-type feedback; i.e., the corrective-power of any postulate was dependent on S's use of it.

Utilizing communalities obtained from the subsequent factor analysis as lower-bound estimates of task-variable reliabilities permitted examination of the relationship between observed gain and true gain. Results, however, must be regarded as conservative (i.e., they are at least this good if not better) because of the reliability estimates employed. Reliabilities for observed change were all less than .50; the smallest (.03) occurred for differences between the fourth and fifth card-sorts, the largest (.49) between the fifth and sixth. The average reliability was .31. Estimated correlations between observed and true change ranged from .17 to .70; the coefficient corresponding to first and sixth card-sort differences was .58, to fifth and sixth, .70. It was also shown that, although some Ss exhibited an observed "loss" (increased total error score) between the first and sixth card-sorts, true differences were all "gains."

Sixteen ability tests purporting to measure reasoning, memory, and verbal factors comprised the test battery. Selection was based on a logical analysis of test and task requirements and the results and recommendations of previous research. The names of tests and associated factors are as follows:

Picture Class Memory Classified Information	MMC:	Memory for semantic classes
Remembered Relations Recalled Analogies	MMR:	Memory for semantic relations
Double Meanings Homonyms	MMT:	Memory for semantic transformations

Letter Sets Locations	I:	Induction
Nonsense Syllogisms Logical Reasoning	RS:	Syllogistic reasoning
Necessary Arithmetic Operations Ship Destination	CMS:	Cognition of semantic classes
Verbal Analogies III Best Trend Name	EMR:	Evaluation of semantic relations
Advanced Vocabulary V–4 Advanced Vocabulary V–5	CMU:	Cognition of semantic units

The 22 measures obtained on the 102 college females who completed the entire testing program were of two types: (1) total error scores for learning task variables and (2) total number correct scores for ability tests. Hence, a positive relationship between a task and test variable was indicated by a negative correlation coefficient. Likewise, when loadings of task and test variables on an arbitrary factor exhibited opposing signs, a positive relationship between factor and variables was implied.

Four factor analyses were reported. Data for the total group (N = 102) were analyzed by both alpha factor analysis and factor analytic techniques which yield results comparable to an incomplete image analysis (i.e., for the first m factors where m is Guttman's "strong" lower bound for the number of common factors). Only alpha factor analyses were reported for two subgroups symbolized and defined as:

$G_{E<12}$: (Achievers) the set of all subjects achieving a total error score less than 12 at the sixth card-sorting stage. (N = 50)

$G_{E\geq 12}$: (Nonachievers) the set of all subjects whose total error score at the sixth card-sort was greater than or equal to 12. (N = 52)

The derived orthogonal solutions were all obtained by Kaiser's (1958) normal varimax rotation procedure. Six alpha and 12 image factors were extracted and rotated in the total population analyses, 7 alpha factors in each subgroup analysis.

In the analyses of the total population six areas of cognitive ability were associated with mathematically deduced factors in an attempt to explain sources of common variance. These abilities were identified as meaningful memory, multiple discrimination (also, Guilford's EMR), a classifying or categorizing ability, verbal comprehension (also, Guilford's CMU), induction, and syllogistic reasoning.

Within the subgroup analyses factors were isolated which appeared to correspond sufficiently to permit univocal interpretation. Such cognitive areas were verbal comprehension, multiple discrimination, classification (ability to categorize), and meaningful memory. Two factors in the $G_{E\geq 12}$ analysis were assigned meaningful-memory status as compared to one factor in the $G_{E<12}$ analysis. Reasoning factors were less clearly defined and test alignments on isolated factors in all three alpha analyses (total group, $G_{E<12}$, and $G_{E\geq 12}$) differed. For nonachievers reasoning tests identified two factors, Guilford's CMR and deduction for achievers the corresponding factors were interpreted as Guilford's CMS and deduction. In the $G_{E<12}$ analysis one factor was not interpreted because of bipolarity.

Results are discussed in terms of the three objectives (reformulated as questions) of the factor analytic study cited in Chapter I.

I. What intellectual abilities are associated with or dissociated from successful performance on the concept learning task?

In all analyses task variables clearly isolated two factors. Signifcant loadings of EMR tests on the early task factor together with a logical analysis of test and early task requirements suggested that an ability to make multiple discriminations was associated with successful task performance. The within task factor was defined as an ability to respond to items as a whole or class. In the analysis of the total population, the two CMS tests, Necessary Arithmetic Operations and Ship Destination, helped identify the factor.

Overall results and interpretations of the factor analyses suggested that the occurrence of learning might be expressed concretely in terms of patterns of factor loadings. Gagne's hierarchically structured "conditions of learning" appear readily adaptable to such phenomena (patterns of loadings) observed on factors identified by sequentially sampled learning task measures. For the task employed in the present research, the two extracted task-related factors together with the increasing-decreasing pattern of loadings were interpreted as objective evidence of multiple discrimination learning and concept learning.

Except for the verbal comprehension factor which was not associated with successful task performance as predicted, the remaining conjectures offered in Chapter II with respect to relatedness of task performance and factors isolated by ability tests were not supported. Separate subgroup analyses, however, revealed important differences in ability test contributions to task-factor variances.

2. What are the similarities and/or differences in the factorial structure of the learning task at successive stages of proficiency?

In the total population (alpha analysis) all task variables loaded significantly on the within task factor; only the first two phases correlated substantially with EMR. Loadings on the remaining factors appeared trivial.

For achievers the first task phase exhibited a negative relation with the meaningful-memory factor. The .41 loading on the within task factor as compared to a .27 loading on EMR suggested that achievers viewed stimulus sentences in terms of class membership (as defined by postulate 1) and did not discriminate between them (sentences). The nonachiever analysis showed only EMR as major contributor to the variance of the first phase. At the second card-sort significant loadings were observed on the two task factors for achievers but only on EMR for nonachievers. The third phase in both analyses showed major loadings on both task factors. Nonachievers also exhibited a positive correlation (.24 in absolute value) with a meaningful-memory factor. The fourth and fifth card-sorts in both analyses correlated substantially with only one factor, namely, the within task or classification factor. The factorial structure of the sixth card-sort for achievers was marked by two significant loadings, one on the within task factor and the other on deductive reasoning. The same stage for nonachievers also exhibited a major loading on the within task factor and a -.27 loading (a positive correlation) with a deductive-reasoning factor.

3. What are the major findings in comparing the two subgroup analyses?

A comparison of the two task factors for achievers and nonachievers uncovered a differentiating element which suggests important implications for learning. Achievers were simultaneously involved in stimulus discrimination and stimulus generalization during early task stages. Postulates were considered to be sources of feedback as well as providers of information for card sorting. Succeeding stimulus sentences (in particular, during the first card-sort) were thought to function as reinforcers for categorizing responses to earlier appearing sentences. Nonachievers appeared to employ the abilities discretely. These Ss responded to stimulus sentences as individual entities during early task stages. Grouping or classifying did not appear until the third sorting stage.

Ability tests also related differentially to task factors. For achievers reasoning tests loaded on both task factors. For nonachievers task factors showed correlations with memory tests.

Another major difference between the two subgroup analyses was the factorial structure of memory tests. Two factors were isolated by memory tests in the $G_{E \geq 12}$ analysis as compared to one in the $G_{E<12}$ analysis. For nonachievers performance on certain reasoning tests was associated with a meaningful-memory ability.

Finally, factors isolated by reasoning tests showed the least correspondence in the two analyses. Apparently reasoning tests measure different constructs for achievers and nonachievers.

Before stating the major conclusions of the investigation, several points are worthy of comment:

1. Of the 16 ability tests, scores on only 2 (Advanced Vocabulary V-4 and Advanced Vocabulary V-5) were dependent almost completely on previous learning. Scores on all other tests were determined by S's actual performance on a task; e.g., a typical memory test required S to study given items of information, recall of which was measured by subsequent testing.

2. Ship Destination for the first time in the literature and in both subgroup analyses exhibited its primary loading on a meaningful-memory factor.

3. The CMS tests, Necessary Arithmetic Operations and Ship Destination, did not emerge as pure measures of any one factor. Test alignment was observed on meaningful-memory and classification factors.

4. Nonsense Syllogisms displayed a significant loading on the verbal comprehension factor in the $G_{E<12}$ analysis; a similar relationship was reported by Manley (1965) for the solver subgroup.

The conclusions which follow are specific to this study. The phrases "the subjects in this investigation" and "the task and tests employed in this study" are understood to apply in each case. It was concluded that:

1. The psychological constructs underlying the learning task are an ability to make multiple discriminations and an ability to respond to stimulus items as representatives of a class rather than as individual entities.

2. The pattern of loadings on each task factor is evidence of an occurrence of learning; the type of learning is specific to the learning task and the abilities isolated by it.

Interpretation of task factors as abilities and not specific "learning" factors makes comparison with other research (Duncanson, 1966; Stake, 1961; Allison, 1960) difficult.

3. Achievers are able to utilize task-related abilities simultaneously; nonachievers employ abilities disjointedly.

4. Performance on meaningful-memory tests is positively related to a classifying ability for nonachievers, reasoning tests for achievers.

Dunham et al. (1966) reported significant loadings for learning measures on memory factors (MMC and MSC). For Manley's (1965) nonsolvers, a concept learning task exhibited high loadings on a memory factor while another factor (identified by card sorting tasks) displayed a substantial loading on an inductive reasoning test (Letter Sets). Lemke (1965) reported positive relationships between obliquely rotated reasoning and task factors.

5. For nonachievers successful performance on reasoning tests is associated with a meaningful-memory ability.

6. A verbal ability is not related to successful performance on the learning task.

After an oblique rotation, Lemke (1965) found positive correlations greater than .30 between the verbal comprehension factor and two learning task factors. Manley's (1965) nonsolvers showed a significant loading for one of the concept learning tasks on a verbal factor. Concept formation task measures in Duncanson's (1966) study were not related to a verbal ability (or to any other abilities isolated in that study).

The reported research revealed potential sources of invariance in human learning. It is recommended that future factor analytic research

1. give more attention to relevant subgroup analyses; and

2. employ a sufficiently large N such that each subgroup N is at least in the 80—100 range.

It is also recommended that the learning task devised for the present research be subjected to further experimentation. Some suggestions are:

1. vary the type and/or number of instances (i.e., positive and negative) associated with the postulates;

2. examine the effect of a "postulate-no postulate" dimension holding constant the given exemplars and nonexemplars.

3. subject the responses to the 50 stimulus sentences to an item analysis;

4. impose time controls on the task; in particular investigate the effect of a "post informative feedback interval" dimension.

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ABSTRACT

The investigation examined in the laboratory the type of learning commonly found in the school situation--the formalized acquisition of concepts. A verbal concept-learning task suitable for college students was devised which permitted the externalizing and quantifying of behavior at six points in the learning process.

A pilot study evaluated the effects of four experimental conditions on learning; one of these conditions described as "postulates removed, no feedback" was employed in the factor-analytic study. The learning task and sixteen nonarbitrarily selected ability tests purporting to measure reasoning, memory, and verbal factors were administered to 102 college females.

Two major conclusions were: (1) that the psychological constructs underlying the learning task are an ability to make multiple discriminations and an ability to respond to stimulus items as representatives of a class rather than as individual entities; and (2) that the pattern of loadings on each task factor is evidence of an occurrence of learning; the type of learning is specific to the learning task and the abilities isolated by it.