PIAGETIAN CONSERVATION AND CLASSIFICATION TESTS

IN FACTORIAL PERSPECTIVE

A Thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfilment of the Requirements
for the Degree of Master of Arts

Department of Education
McGill University

by

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Montreal, Canada

December, 1973

Short Title:

Piagetian Tests in Factorial Perspective

by

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Acknowledgements

To Professor R. Edwards, director of the research, the writer extends sincere appreciation for his valuable advice, for his efforts in obtaining the sample, and for his assistance in the preparation of this manuscript.

My sincere thanks are due to the following school principals who, in various ways, supported this research: J. Killingbeck at Sunnydale Elementary, B. Jones at Thorndale Elementary, D. McOuat at Seigniory Elementary, and A. Craig at Allancroft Elementary. And, of course, I express my gratitude to those youngsters who so willingly participated in this study.

I am indebted to Charlene for assistance given in testing the sample and to Jeannette for typing the manuscript.

My thanks also go to the Research Committee, Faculty of Education, for substantial financial assistance needed to purchase testing materials and computer time.

Abstract

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Title: Piagetian Conservation and Classification Tests in Factorial Perspective

Department: Education, McGill University

Degree: Master of Arts

Summary

Previous studies have demonstrated that many different factor patterns are involved in Piaget's tests.

An attempt was made to determine the factor content of several Piagetian conservation and classification tests. Fifty-two children, with an average age of 94 months, were given the Piagetian tests along with certain conventional intelligence, verbal, perceptual, and memory tests.

The results were correlated and factor analyzed. Varimax and quartimax rotations with both non-normalized and normalized data tended to indicate that the factor composition of the Piagetian tests differed from that of the conventional tests:

Extrait

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Sommaire

Des études antérieurs ont démontré que plusieurs échantillons factoriels sont inclus dans les tests de Piaget.

Un essai a été tenté afin de déterminer le contenu factoriel de plusieurs tests de conservation et de classification. On a fait subir à cinquante-deux enfants ayant un âge moyen de 94 mois les tests Piagétiens ainsi que certains tests conventionnels d'intelligence, verbal, perceptuel et de memorisation.

Les résultats ont été échantillonés et analysés. Les rotations varimax et quartimax mises en rapport avec les données à la fois non-normatives et normatives tendent à indiquer que le facteur composition des tests Piagétiens est différent de celui des tests conventionnels.

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CHAPTER 1

Introduction

Intelligence and human abilities have been persistent topics of extensive discussion. Over the years, philosophers and researchers have congregated around schools of thought and in due course have formulated theories of intelligence. Early researchers, first in France and Germany and later primarily in Britain and the United States, have perfected ability testing and have analyzed the results of their testing with statistical techniques of varying sophistication in order to arrive at bodies of knowledge organized into what is known today as "classical" theories of intelligence. A counterpart to those theories is Piaget's developmentalism, a theory also about intelligence. Piaget's expertise does not rest in his careful use of accurate tests nor in his use of statistical procedures but in his clinical observation of routine problems presented to and somehow solved by children.

For years there were inconsequential exchanges between classical theorists and Piagetian developmentalists. Classical theorists defined and organized such constructs as verbal ability, reasoning ability, memory, and so on;

developmentalists examined and ordered constructs such as object permanence, conservation, logical thought, and so forth. Not until someone noted the difference between the two schools and argued for the superiority of one school over the other did a fruitful interaction between the two schools take place. Today a considerable body of related research exists. Some studies suggest that Piagetian measures are essentially reasoning measures or verbal measures; others maintain that perception is most important; still others conclude that they are unlike anything utilized by classical theorists.

From that point of view, it becomes important to examine the dependent or independent relationships between the constructs of Piaget and those of classical psychometric theorists. A modest investigation will be designed to define and explore the relationships between the following theoretical constructs: general intelligence, verbal ability, memory, perception, conservation, and classification. Selected tests for each of those constructs will be given to a sample, and the results will be factor analyzed. A deliberate attempt will be made to isolate factors that could be designated as general intelligence, verbal ability, memory, and perception. Subsequently, attention will be paid to the dependence of conservation and classification tests on, and conversoly, to the independence of them from, those classical factors.

CHAPTER 2

Literature Review

Piaget's Theory of Intelligence

Piaget's observations have led him to the conclusion that an organism's behavior is not random but structured; the movements are patterned, organized, coordinated, ruled, or principled (Furth, 1969). Behavior that is structured accomplishes its goals intentionally and purposefully. The coordinations or principles are referred to as schemes (Furth, 1969; Inhelder, 1962) and are those aspects of behavior which are transferred to other but similar circumstances. For instance, what is common to throwing a baseball, on the one hand, and throwing a softball, on the other, is the scheme. At the simplest level, the coordinations are between the different fine- and gross-motor skills, between the senses, and between the senses and the motor skills. At another level, the coordinations are between the simplest level, the sense and motor coordinations, and a few aspects of the environment. For instance, two quite different aspects of the environment are coordinated with one another and with the behavioral schemes of the organism. At the highest level, the simplest coordinations and the many different variables present in the environment are coordinated (Baldwin, 1967).

A four-point criterion(Inhelder, 1962) has been used to group the schemes. The groupings are levels or stages of development. The criteria require that each stage involve the formation of a unique structure, that each structure constitute the end of one stage and the beginning of the next, that the sequences of the stages, regardless of the age variable, be constant for all individuals, and, finally, that preceding stages are part of and are implicated in succeeding stages. That criterion has led Piaget and Inhelder to conclude that there are essentially four stages: sensori-motor, preoperational, concrete operational, and formal operations.

The sensori-motor stage consists of the coordinations of senses and/or motor activities. The schemes which imply a mental event or an interiorized action (Boyle, 1969), say, knowing that an object exists even though it is not being perceived, and those schemes which can take into account only one aspect of the environment, those schemes make up the preoperational stage. The schemes which involve similar mental events and which can simultaneously take into account more than one aspect of the environment but which can operate only in the presence of concrete objects make up the concrete-operational stage. Finally, the schemes which show interiorization even in the absence of concrete objects and which can work with propositions, the probable but not necessarily the real, make up the formal-operational stage. Evidence is adduced to show that the sensori-motor stage is followed by the preoperational stage which is followed by the concrete-operational stage which, in turn, is followed by the formal operational; that sequence, it is postulated, is invariable.

Tests have been devised to help define the different schemes of the four stages. For instance, the test that measures object permanence is a test that taps a sensori-motor scheme. The conservation and classification tests are utilized to help clarify the behavior patterns of the concrete-operational stage. The tests which require the formulation of propositions or which require a grasp of propositional statements expressed in terms of formal logic, those tests clarify the schemes of the formal-operational stage (Phillips, 1969).

A host of such tests have been created; Piaget's prolific writings indicate that on the spur of the moment available materials were manipulated to create a problem or a test. To this day, many of the materials have retained that haphazard character, that unstructured and non-standardized element. The difference between such tests and those contained in most intelligence and achievement tests is obvious.

Piaget (Laurendeau and Pinard, 1962; Piaget, 1950) has written about a test battery consisting of his tests. He has stated that such a battery would certainly be as valuable as the intelligence tests of Binet and Wechsler. According to him, the value would derive from the application of his developmental theory which would permit a comprehensive analysis of someone's score or someone's abilities implied by that score. The intelligence quotient of conventional testing does not suggest anything about the nature of a person's abilities; it merely ranks the individuals in terms of their abilities. A score from his battery, Piaget believes, would rank a person, show the stage of mental processing, and by drawing support from his theoretical writings, give a definition of the most powerful mental operations that the individual is capable of performing. While Piaget himself has not collated his tests into a battery, Almy et al.(1970), Lunzer(1970), Pinard and Laurendeau (1964), Tuddenham (1970), Ward (1970), and Warburton (1970) have taken up the task. Some of those have tried to retain the clinical, somewhat subjective judgment in their structured and standardized approach; but most have tried to standardize the materials, problems, and questions, to specify the possible correct responses, and to give differential values for the possible responses.

To date, reliabilities and validities have been inconsistent. Lunzer (1970) has suggested that once the instructions and procedures have been standardized, the observations placed in an objective perspective, and the criteria for evaluation stabilized,once that has been accomplished, the reliability of the tests will no longer be a problem. The tests, then, will measure well whatever they measure.

Unfortunately, even Piaget's writings do not give us a clear picture of what his tests are measuring. For example, regarding the development of sensori-motor structures, Piaget (1950) believes that those structures are correlated with, but not totally dependent upon, perception. Elsewhere he states that perceptual structures play a necessary though not a sufficient role in the development of concrete-operational structures. Those structures contain both an active element and a perceptual element; for him, abstracting is an active process consisting of taking relationships out of and adding relationships to perceptual givens (Inhelder and Piaget, 1964). In addition, language plays an auxiliary role in the development of structures which are cognitive in nature (Inhelder and Piaget, 1964). Memory (Piaget, 1952) is also a factor. Then there are a cluster of possible intervening factors such as the length of the instructions, their more or less concrete character, the relationship between the instructions and the individual experiences of the child, the number of elements involved, and the number system (Piaget, 1952). Therefore, while Piaget would like to be measuring a subject's operative thought, one's ability to structure, or one's understanding of, say, conservation in its pure state, ~~he~~ readily admits that the intervention of other factors precludes this. He is well aware that one's concept or structure of conservation is always with respect to a given problem and given material (Piaget, 1952).

Putting all of Piaget's descriptive, theoretical writings aside, we can ask whether his test items, individually or in battery form, give us information different from that given by the usual intelligence and achievement test. Are we measuring some phenomenon that has been largely overlooked by such men as Binet and Wechsler? Undoubtedly Binet and Wechsler, just like Piaget, would be working under the influence of those intervening factors--length of instructions, the more or less concrete character of the tasks, words, numbers, and so forth. Moreover, those would be factors influencing the results of any kind of testing. One difference, and it may be crucial, between a Piagetian test and most others is that the former require that the environment be manipulated. That is best exemplified by the pouring of water from one glass to another of a different shape or by the changing of a ball of clay to a sausage of clay. Structuring that kind of environmental change may require something other than what is required for success in conventional intelligence tests. That missing element may be one of several that would indicate that we are getting different information from a Piagetian test than from most other tests.

However, that, just as most comments on Piaget's work, is speculative. The questions still remain: do Piagetian tests measure the same phenomena as conventional tests or have they defined areas untouched by other tests? If they measure different phenomena, then what is the nature, what are the attributes of those abilities?

Theories of Intelligence and Factor Analysis

The problem of what a test measures along with the larger issue on the nature of human abilities dates back to approximately 1870. Working with the problem of individual differences and using either regression analysis or Pearson's product-moment correlation, Galton found evidence for the age-old philosophical distinction between general ability and special aptitudes. Spearman (1927) gave more credence to that distinction by arguing, largely on the basis of the tetrad difference ($r_{ap} \times r_{bq} - r_{aq} \times r_{bp} = 0$), for a single general factor theory, g, more often represented as a two-factor theory, g and s, where g denotes the general factor, s the specific factors.

Henceforth, factor analysis, implicit in Spearman's work, inherent in the partial correlation of Yule (Cronbach, 1957), and developed by Pearson and by Burt (1940), often paralleled the organization of theories of intelligence and human abilities. Particularly in England, the mode of operating theoretically was by means of hierarchical models. Burt's attempts to organize abilities resulted in the first of such hierarchies; having developed a formula for simple summation and a technique for assessing group factors (Burt, 1940), he went on to give evidence for not only the general factor but also for such group factors as verbal, numerical, and kinesthetic (Burt, 1949). Spearman, albeit reluctantly, accepted group factors, particularly verbal and kinesthetic, and later certain others. A theoretical framework similar to Burt's but accounting for g, group factors, and specific factors was conceived by Vernon (1950). Thomson (1939) also worked with methods of factor analysis and developed the sampling theory; although he himself denied any hierarchy or any g, others (Vernon, 1950) believed the g to be a measure of the total number of bonds, the basic elements of Thomson's sampling theory.

As opposed to hierarchies, multiple-factor theoretical frameworks became the means for organizing abilities particularly in America. Thurstone drew support for his multiple-factor theory when he had demonstrated that Spearman's tetrad difference was a special case which was bound to yield a single factor. He noted that when more tests were used, the proportionality among the correlations would not exist, a general factor would not emerge, and more factors would be required (Thurstone, 1952). Concomitant to that theoretical work, his laboratory concentrated on two other psychometric issues: test construction and statistical techniques. He utilized large numbers of short tests in his batteries, developed complex diagrams to facilitate the calculation of correlation, and developed the centroid method of analysis for resolving the communality problem in a single, though approximate, way. Moreover, he solved the problem of making his factors meaningful, notably, by the simple-structure and positive-manifold criteria. The final contribution to statistics was in the realm of orthogonal and oblique axis solutions. His work resulted in the postulate that there were seven primary mental abilities: verbal comprehension, word fluency, number, space, associative memory, perceptual speed, and induction (Thurstone, 1938).

Multiple-factor theories became viable frameworks readily accepted by Guilford. For years, first with the army and later at the university, he worked with concepts such as attention, judgment, foresight, reasoning, creativity, mechanical aptitude, and a host of personality variables. Factor-analytic studies by Guilford and many others had generated large quantities of factors; in the intellectual realm alone, by 1946, there were twenty five; unfortunately, factor analysis itself showed no promising, conclusive framework to organize the factors. In 1955, having been invited to a symposium on factor analysis, Guilford prepared a paper in which he attempted to organize logically the then recognized intellectual abilities. He accepted the orthodox distinction between verbal and non-verbal, but even for non-verbal material, for instance, a further distinction had to be made between that containing figures and that containing letters. He proposed a further distinction between memory, discovery, evaluation, and others. At a later date, social intelligence became a recognized factor in the realm of abilities. The multitudinous factors were finally integrated into a tentative, structure of intellect model (Guilford, 1967). The model is a cube-like, rectangular parallelopiped, the three dimensions of which are operations, contents, and products. Any operation can work on any content to create any product, making a total of a hundred and twenty postulated abilities. Of the total, about eighty now are supported by empirical evidence.

Fundamental to any theory about the results of testing must be the structure and operations of the tests themselves. Sometimes that fact is lost or overlaid by the emphasis upon correlation analysis. Many tests in the early days were named upon scanty evidence as to what they measured. When so named, it was sometimes supposed that they measured what had been named. It was a long time before a theory emerged, including the application of factor analysis, which results today in our present knowledge of psychometric procedures (Guilford, 1954; Guilliksen, 1950).

For this and other reasons, common to most classical theories of intelligence is the reliance upon factor analysis. It, more than any other technique, has been used to clarify the contents of tests. It consists of obtaining a small number of constructs or factors by which to represent a large number of tests. Each test in the battery is explainable in terms of the various factors. The factors are thought of as being the crucial variables in the test battery (Adcock, 1954); they are means used to describe the contents of the tests (Burt, 1940); and they suggest psychological constructs under which the tests can be subsumed (Anastasi, 1965). The constructs may in turn imply human abilities; it must, however, be noted that those constructs remain hypothetical entities which may never have any real existence. Much more research is needed on those constructs.

Returning to Piaget, we find that he has given extensive clinical judgments on what the problems he poses to children are measuring. He has used concepts such as logical structuring, closure, reversibility, assimilation, accommodation, and equilibrium to describe what the child's mind does in attempting to solve his problems. Asking whether those concepts are inherent in the solution to his problems is posing a question also answerable in terms of classical theories of human abilities. Putting the question within the framework of those theories and of factor analysis, one can detect factors and, by inference, abilities that are required to complete, for instance, the conservation and classification problems.

An Integration of Piagetian Analysis and Correlational Analysis

Attempting to place part of Piaget's developmental theory into factor-analytic research is really posing another query: is it logical to synthesize aspects from a developmental theory and aspects from the classical theories of intelligence? Considerable debate between Michener, Wohlwill, Birch and others (Garrison, 1966) has centered on resolving the apparent disparity between the two approaches. It has been argued that developmental approaches order sequential abilities, showing how, for instance, formal operational abilities are natural sequels to concrete operational abilities; the more usual psychometric approach, correlating, analyzes parallel abilities, showing how one ability is related to another, not sequentially, but concurrently. Hence, they argue, correlating tests for sequential abilities would result in a zero correlation. In practise that argument is refuted by noting that Piaget's tests, particularly the standardized ones, do have an order of difficulty, do produce a range of scores, and can produce a normal distribution of scores. Moreover, two tests, both designated to measure operational abilities, may not be done equally well by the same individual. Occasionally, an individual will experience partial failure in a test measuring one level of ability while achieving partial success in a test designated for a higher level ability. Since the tests do not fall into neat packages which can be sequenced and since the tests probably overlap in terms of the abilities they measure, they lend themselves readily to the usual psychometric analysis. In general, these apparently polar theories of intelligence can help clarify each other.

That congruence between the two schools is accepted by Piaget (1950) who states that both schools are getting at the same phenomenon, intelligence. There is no difference between Spearman's eduction of relations, Binet's judgment, Wechsler's purposeful behavior, and Piaget's logical structuring (Elkind, 1969). More boldly stated, Kohlberg (1968) hypothesizes that Piagetian tests will load on a general factor that will be greater than, but of the same nature as the general factor found in certain factor-analytic studies. Guilford (1967) believes that Piaget's tests require the cognition of figures, occasionally the cognition of semantics, in each of the product categories. Further hypotheses relating the two schools of intelligence have been made by Ball (Garrison, 1966), Braine (1959) and Meyers and Dingman (1966). Others have not indulged in theoretical discussions as to whether or not tests unique to developmental theories can be psychometricized; they simply put tests, no matter the source, into a battery and calculated correlations or factor analyzed the results.

A large number of such correlational studies have been conducted. Some researchers have correlated several Piagetian tests with each other while others have correlated those tests with intelligence tests, language tests, and perceptual tests. These correlational studies are valuable in that they show the degree of relationship or the lack of relationship between the Piagetian tests themselves or between those tests and other better-known tests.

Taking a wide view of what constitutes intelligence tests, significant correlations have been found between some Piagetian tests and the Stanford Binet (Fiegenbaum, 1963; Gruen and Vore, 1972; Kohlberg, 1968). Goldschmid (1967), Marchi (1971), and Miller (1970) found significant relationships between conservation and the Wechsler Intelligence Scale for Children (WISC), although, Elkind (1961) found low but significant relationships between conservation and only certain of the WISC scores. Similarly, Swize (1972) found a non-significant relationship between conservation and the WISC comprehension subtest. The correlation between the Peabody Picture Vocabulary Test (PPVT) and conservation was significant (Gaudi, 1971; Ham, 1971) but was non-significant for Swize (1972). Between the PPVT and classification the correlation was low (Carlson, 1971; de Lacy, 1971). Raven's Progressive Matrices correlated positively with classification (Carlson, 1971).

Changing now to language abilities, Larsen and Flavell (1970) concluded that the level of abstractness of the terms used was a factor in testing conservation abilities. Further, Hamel and Witt (1971) found that language played a role in conservation. Reading readiness tests correlated significantly with conservation (Brekke, 1972; Crutchfield, 1970; Rauscher, 1971), and the Metropolitan Reading

Achievement test related highly with class inclusion (Garrettson, 1971). Aldrich (1970), Berko and Brown (1960), Braine (1959), Braine and Shanks (1965a, 1965b), Bruner (1964), George (1970), and Reitz (1970) reported that verbal material was a mediating factor in conservation. However, several (Inhelder, et al, 1966; Jennings, 1970; Maskovitz, 1971; Ross, 1971) would disagree with that statement.

Similar disparate results were found in the correlations between perceptual or spatial tests and the Piagetian tests. These correlated significantly with tests measuring geography concepts (Satanek, 1972), with tests involving things such as ambiguous figures (Santamaria, 1972), or such as embedded figures (Fleck, 1971), and with the ability to draw geometric figures (Camp, 1971; Champagne, 1971). Overton and Brodzinsky (1972), however, obtained results yielding no support to the hypothesis that there were perceptual factors in tests such as classification.

Turning now to factor-analytic studies that used different Piagetian tests, one finds results that are by no means sufficiently definitive but on the whole encouraging. These studies seem to fall into two categories: those that seek to determine, firstly, whether Piaget's postulated constructs do in fact occur as factors and, secondly, whether the usual verbal factor, perceptual factor, and others occur as factors in Piaget's tests.

Among the first category of studies are those that have attempted to determine whether reversibility is part and parcel of the tests thought to measure concrete-operational schemes. Inhelder and Piaget (1964) maintained that systems of schemes have a stability that depended on the possession of five properties, the main one of which was reversibility. They suggested that reversibility was the basis for understanding logical relationships and was the most general characteristic of operational thought. Being so general, it had an autonomy that transcended such factors as perception, language, and maturation.

O'Bryan and MacArthur (1967) argued that if reversibility was the most general attribute of logical thought, then it ought to be a crucial factor when tests of operational thought are factor analyzed. They defined reversibility as flexibility of foresight and hindsight. Flexibility of foresight occurs when there is a mental prediction of a classification or connection before the class has been worked out, particularly if trial and error are not utilized. Flexibility of hindsight occurs when an individual goes back over an operation in order to take into account properties earlier overlooked or items that are new and have been added to his problem. Hence, having operationally defined foresight by the test which requires a statement of the classification before objects are classified and hindsight by the test which requires a repetition of an earlier operation in order to account for additional objects, these researchers believed that they could quantify reversibility in operational or logical thought.

Their factor analysis of a test battery which included several conservation tests, an inclusion test, and tests of foresight and hindsight produced six factors. The first two factors, the ones that accounted for the largest portion of the total variance, were interpreted as reversibility factors. The first was reversibility to do with the inversion of classes; the second was reversibility to do with the reciprocation of relations. Neither of these factors was general or pervaded all tests. Factor three was a conservation of liquid and area factor, factor four a number factor, factor five decentration, and six logical inclusion.

In a second study (O'Bryan and MacArthur, 1969), the tests of flexibility of foresight and hindsight were paralleled with tests of creativity and intelligence. They attempted to show that what is usually thought of as creativity may possibly be a psychological correlate of their conception of flexibility. Their interpretation of the factors, from the first to the sixth, were reversibility of the reciprocity type, reversibility of the inversion type, numerical combinations, socio-economic status, conservation, and non-verbal creativity. The primary conclusion was that the inversion reversibility was related to creativity but the reciprocity reversibility was related to intelligence. In summary, they maintained that reversibility is a crucial factor in operational or logical thought.

In much the same way as O'Bryan and MacArthur tried to identify reversibility in operational thought, Berzonsky (1971) tried to identify causality. From statements made by Piaget (1953), it was thought that precausality and preoperational were almost if not synonymous concepts. Further, it was thought that the shift from the preoperational stage to the concrete-operational stage also required a concomitant shift in causal reasoning. Thus, Berzonsky isolated the problem of identifying causal and operational thought and of determining the relationship between them.

He defined causal thought by tests which required causal explanations to things such as clouds and sinking ships; operational thought was defined by class-inclusion, conservation, and seriation tests. The five factors were causal reasoning, operational thought, problem solving, causal explanations of concrete situations, and understanding the concept of force. He concluded that since causal and operational thought each defined factors, there was little relation between them.

As opposed to studies which tried to isolate Piagetian constructs in his tests, many studies have been devoted to considering whether the traditional factors, for instance, those of Thurstone and Guilford, appear in Piaget's tests. These latter studies were provoked by some of Piaget's statements that implied a relationship between his framework and that of someone else. For instance, Piaget suggested that seriation was far less closely related to language than classification, or, that seriation, although somewhat related to perception, was more an operation in which some form of order was anticipated (Nelson, 1969). Immediately, the relationship between Piaget's work and Thurstone's Primary Mental Abilities became a problem. Nelson attempted to determine that kind of relationship by including not only seriation tests and Thurstone's

Primary Mental Abilities but also six subtests from the California Achievement Test. The three factors that emerged were achievement or taught abilities, reasoning abilities, and maturation. He went on to conclude that seriation was a reasoning ability since it related well with the Primary Mental Abilities.

In a similar study, Stephens <u>et al</u> (1972) examined the relationship between the WISC, some achievement tests, and about twenty Piagetian tests. All of the WISC and the achievement tests loaded heavily on the first factor; the second factor was labelled operational thought. The others were thought-in-action, maturation, and perceptual factors. Opposed to Nelson but agreeing with Stephens <u>et al</u>, Heron (1971) found no relationship between conservation and either what was called Spearman's g or what was called performance.

Working with adolescents and using Piagetian items dealing with combinations, propositions, reversibility, and seriation, Evans (1970) found that Piaget's tests correlate with reasoning, verbal, and mathematical-educational factors.

P.E. Vernon, although not primarily interested in the Piaget tests <u>per se</u>, took a battery containing some thirty subtests to six different cultural areas. The test battery contained Kohs' Blocks, matrices, vocabulary, arithmetic, creativity, and Piagetian tests; the latter contained conservation, classification, and perspective tasks. The subjects were eleven-year-old boys, and the results were factor analyzed. First, only the Piagetian tests were factor analyzed. The English-sample analysis showed three factors: arithmetic, conservation, and visualization; while most conservation tests loaded on the conservation factor, conservation of amount and length loaded on the arithmetic factor. The main factors of the Jamaican results were arithmetic, verbal, and practical with the conservation tests loading mostly on the practical factor (Vernon, 1965a). Second and for all cultures, the entire test battery was factor analyzed. Again for the English-sample analysis, the Piagetian tests loaded mostly on g, sometimes on the perceptual and practical factors, but not on the education and verbal factors (Vernon, 1965b). The Jamaican results produced a g, a verbal-educational, and a spatial factor, the first of which received the largest loadings from the Piagetian tests (Vernon, 1965b). The Piagetian tests loaded very highly on the general-verbal factor but not at all on the spatial and fluency factor; that was in the Hebridean analysis (Vernon, 1969). The data collected in Uganda yielded a verbal, induction, practical and drawing factor; the tests of Piaget loaded mostly on the verbal factor, some on the induction and practical factor (Vernon, 1967). In Canada, Eskimos near Inuvik were tested; Piaget's tests identified with both g and the conservation factor but not with verbal-education, fluency, nor space. Although the same factors were extracted from the results of the Canadian Indians, the conservation and classification tests identified with the spatial factor (Vernon, 1969).

In California, Orpet and Meyers used Guilford's structure of intellect model as a framework for their work. From data that were not factor analyzed, they concluded that convergent production of semantic material in either the relations, systems, or classes categories were most crucial in the Piagetian tests (Orpet and Meyers, 1970). Five-year-old youngsters were the subjects of their second study. Factor analysis showed that the different tests of Piaget identified with a memory factor and with a factor named convergent production of semantic and symbolic contents but not with a visual factor nor with a spatial-figural-memory factor. In their third study, seven-year-old subjects were used. The conservation tests identified with factors named convergent production of picture-semantic content, and cognitive and memory of figural and semantic content (Meyers and Orpet, 1971).

Lunzer (1970), who has been attempting to standardize Piaget's materials and administration procedures, administered a battery of tasks to seventy-five British children. Factor analysis showed a clear general factor on which all conservation tests and some classification tests loaded. The conservation of area test also loaded on a spatial-visualization factor, the all and some test on a verbal factor. In a second study (Lunzer et al, 1971), conventional tests, used as reference tests, were included with Piagetian tests. Again the conservation tests loaded highly on the general factor, but they also defined their own factor. The variance of the classification tests was explained by factors designated as general, auditory memory, visualization, and conceptual learning.

In general, the above factor-analytic studies appear to lead to the following conclusions. It is somewhat doubtful whether the general factor is inherent in Piagetian tests; there was a close relationship between a general factor and the Piagetian tests in the studies of Lunzer and

Vernon but no relationship in the studies of Orpet and Meyers. The verbal factor was crucial in Vernon's African study and in those of Orpet and Meyers; only the conservation tests identified with a verbal factor in Lunzer's study. Vernon has shown evidence for an arithmetic factor. Orpet and Meyers noted that Piaget's tests correlated with a memory factor. A spatial-perceptual factor was found frequently by Vernon, sometimes by Lunzer. And finally, the conservation tests themselves have been known to define a factor.

CHAPTER 3

Problem, Rationale, and Experiment

Problem

As demonstrated above, several investigations have presumed to show that in Piagetian tests one or more of the following four "classical" factors exist: g, verbal, memory, and spatial-perceptual. It would seem reasonable to design an experiment which would attempt to isolate those generally-found factors, by means of conventional reference tests, and thus examine the nature of Piaget's conservation and classification tests in terms of those factors. The objective would be to test whether those four "classical" factors also define the characteristics of either or both of the conservation and classification tests.

If it were possible to have a quasi-null hypothesis, then that would be to the effect that Piaget's conservation and classification tests and the conventional tests would load on some or all of the same four factorsand to about the same degree. Alternatively, should the selected Piagetian tests load on different factors from the conventional tests, that would be taken as evidence that the factors needed to express the nature of the Piagetian tests are different from those needed to explain conventional cognitive tests.

Rationale for the Selection of the Tests and of the Sample

In a factor-analytic study to test those kinds of hypotheses, it is conventional practice to utilize, along side Piagetian tests, relatively factor-pure reference tests to define the desired factors. Two, preferably three, reference tests are usually included so as to give the effect of over-defining each factor (Guilford, 1954). Moreover, each reference test must work together with its counterpart, both having the highest loadings on a certain factor. In this study, two reference tests are to be selected for each of the g, verbal, memory, and spatial-perceptual factors;those eight reference tests together with a selected number of Piaget's conservation and classification tests will make up the test battery.

Besides the reference tests being relatively factor pure, other considerations must be met in selecting tests. Since the Piagetian tests are individual tests, as opposed to group tests, and since individual tests tend to give more reliable and valid results with younger children, the reference tests also ought to be individual tests or ought to be presented individually. By the same rationale, the reference tests should be unspeeded. In addition, they should be useful for a reasonably wide age range, should be easily given, challenging, and appealing.

Two reference tests which are usually associated with general intelligence are needed to isolate the g factor. On logical grounds, Raven (1960), Wechsler (Buros, 1949), and Bortner (Buros, 1965) give reason to believe that Raven's Colored Progressive Matrices is a measure of general intelligence. In factor-analytic studies, O'Bryan and MacArthur (1969), Tuddenham (1970), Vernon (1969), and Westby (Buros, 1956) use Raven's Matrices as the purest available measure of g. In terms of validity, it correlates at between .50 and .65 with the Terman-Merrill scale; its test-retest reliability ranges from .65 to .90 (Raven, 1960). As its counterpart, Kohs' Block-Design test, was chosen; Kohs states that the test measures intelligence, and that it measures intelligence with a high degree of reliability. Three studies by Vernon (1965b, 1965c, 1969) give evidence showing that Kohs' Blocks load highly on the same factor as does Raven's Matrices. For those reasons, Kohs Block-Design and Raven's Progressive Matrices tests were chosen to hopefully isolate a g factor.

The next factor for which two tests are required is a verbal factor. Meyers and Orpet (1971) have had considerable success with WISC-vocabulary. Wechsler (1949) reports a reliability coefficient of .77 but no validity coefficient for this subtest. Many (Cohen, 1959; Davis, 1956; Glasser and Zimmerman, 1967) conclude that it measures verbal comprehension. The Peabody Picture Vocabulary Test (PPVT) was chosen as the second verbal test. Evidence is wanting as to how well it measures verbal ability (Childers, 1966; Dunn, 1965); Lyman (Buros, 1965) gives some evidence to show that it correlates higher with reading and language tests than with others. The PPVT and the WISC-vocabulary tests were chosen as reference tests for the verbal factor.

Two reference tests are required to isolate a memory factor. The studies by Meyers and Orpet (1971) show that WISC-Digit Span Forwards and Illinois Test of Psycholinguistic Ability (ITPA)- Auditory Sequential Memory seem to work together most effectively to define a factor. WISC-Digit Span Forwards measures the ability to remember (Wechsler, 1949; Friedes in Buros, 1972), memory (Meyers and Orpet, 1971), freedom from distractibility (Cohen, 1959), and fluency or numerical facility (Davis, 1956). It has a reliability coefficient of .60. The ITPA-Auditory Sequential

Memory test measures short-term memory (Carroll in Buros, 1972) or memory for symbolic systems (Meyers, 1969). It has a test-retest reliability ranging from .12 to .86. The WISC and ITPA memory tests have the same procedures and contents and hence may be presumed to define a memory factor.

The spatial-perceptual factor is usually defined by such tests as Formboard, Gottschaldt Embedded Figures, Reproducing Designs (Bender Gestalt and Terman-Merrill), Porteus Mazes and Draw-a-Man. Vernon's research indicates that Gottschaldt Embedded Figures and Reproducing Designs come out most frequently and most strongly ~~on~~ a spatial-perceptual factor. The Gottschaldt Embedded Figures were made public knowledge in Psychologische Forschung (1929) by Kurt Gottschaldt and were used in factor-analytic research by Thurstone (1944). Thurstone tentatively concluded that the test measures perceptual-configuration strength; Tyler (Buros, 1965) concurs saying the test requires the subject to hold a configuration in mind despite distractions. The test has a split-half reliability coefficient of .78. Reproducing Designs consists of, for Vernon, items A, 4, 5, and 6 from Bender Gestalt and item 1, Memory for Design, Terman-Merrill, Form M, Year IX.

Woltmann (Buros, 1959) discusses how different scoring keys can make the Bender Gestalt measure different phenomenon. As a result, the scoring key designed by Koppitz (1968) was used; Koppitz argues that with her key, the Bender Gestalt measures perceptual functioning. The Bender Gestalt has a reliability of .70 (Buros, 1972). Following Vernon's precedent, the item from the Terman-Merrill Intelligence test was included; no comments on or figures for validity and reliability are available. It was hoped that the Gottschaldt Embedded Figures and Reproducing Designs would work together to isolate a spatial-perceptual factor.

Finally, a standardized form of Piaget's conservation and classification tests needs to be chosen. It was thought that what was required was a test that had proven itself in research, that required no clinical evaluation as opposed to the mechanical evaluation with scoring keys, that produced a spread of scores, and that was readily available. Several standardized forms could have been used, but Lunzer's version was selected. Each test in Lunzer's Piaget battery follows a simple-to-difficult sequence, beginning with establishing the required vocabulary and ending with a problem necessitating the simultaneous manipulation of two or more variables; each test presents the key problems either twice or in altered form so as to get more reliable results; each test also ensures that the subject has learned the general procedure when many variations of the same type of task are presented. Lunzer (1970, 1971) reports a reliability coefficient ranging from .40 to .89. Of the entire battery, only two conservation and five classification tests were used (Appendix A).

Considerable care must be taken in selecting subjects for the sample; the Piagetian tests, for instance, cannot be used for subjects of a wide age range. Subjects too old will get too many perfect scores; subjects too young will get too many zero-order scores. A general guideline given by Piaget and most others is that subjects can conserve and classify at the age of seven. However, Braine and Shanks (1965b) found several kinds of conservation at five; their tests, unlike those of Lunzer, used non-verbal assessment which never required the subject to justify a response. Pinard and Laurendeau (1964) concluded that a Montreal sample on the average was a year later in conserving than a European sample. Tuddenham (1969) found that girls experienced success on conservation somewhat later than boys. Besides controlling the sex variable, choosing girls would allow one to work with an older child who had more schooling, test-taking sophistication and so forth. Thus, it was decided to test about fifty grade two girls whose first language was English, who attended a normal classroom in an English-speaking school, who lived in the West Island region of Montreal, a middle-class district, and who were Caucasian.

In summary, sixteen tests will be given to about fifty grade two girls. The following is a list of the tests and where applicable the hypothesized factor content:

Test	Hypothesized Factor
1. Raven's Colored Progressive Matrices A, Ab, B	g
2. Kohs' Block Design Test	g
3. WISC-Vocabulary	verbal
4. PPVT	verbal
5. WISC-Digit Span	memory
6. ITPA-Auditory Sequential Memory	memory
7. Reproducing Designs	spatial-perceptual
8. Gottschaldt Embedded Figures	spatial-perceptual
9. Conservation of Length	
10. Conservation of Number	
11. All and Some	
12. Class Inclusion (Unequal Partitions)	
13. Intersection (Overlapping Enclosures)	
14. Cross Classification	
15. Transformations	
16. Age	

From the outset, several weaknesses in the design of the experiment are fairly obvious. In the first place, the reference tests, though the best available, are limited in number. The time available for testing precluded the use of more reference tests even if they had been suitable for the age of the children to be tested. Further, whilst there is some consensus about the factor structure of the reference tests, there is not complete agreement; they are not pure tests of the factors hypothesized. Besides, many of the reference tests have been designed for use in either England or the United States; the results using a Canadian sample may be quite unlike the results of a non-Canadian sample. There is the added problem that some tests may have a ceiling that is too low or a basal line that is too high. Finally, a sample size of fifty is generally thought to be too small for a factor analysis; but they were the only children available. With a small sample, the error of measurement may make the correlations insignificant and the resulting factor matrix non-interpretable.

Experiment

Subjects were obtained from four elementary schools in the Lakeshore Regional School Board. With the approval of the District Education Officer, each of the four respective principals solicited the cooperation of about a dozen grade two pupils. The subjects, then, were chosen for their willingness and not by random selection techniques.

Inadvertently, six boys were included in the sample; with forty-six girls, the total number of subjects was fifty-two. All subjects were English of Caucasian extraction; all were students in normal classrooms as opposed to special education classrooms; each showed no signs of retardation, emotional maladjustment, or physical impairment. Except for a few, all were just finishing grade two and being promoted to grade three. Their ages ranged from 80 to 103 months.

The tests were administered by three individuals (R. Edwards, C. Haltiner, E. Haltiner). Precautions were taken by pretesting other children to ensure uniformity of test administration. The testing was generally done in a school in a room normally set aside for such purposes. The subjects were tested during the latter part of the 1971-72 school year. Each subject was tested in three sessions of approximately 45 minutes each. The children were reassured that the results of the tests in no way would impede school progress. Throughout, the subjects were complimented in an oblique manner, and, except for a verbal expression of gratitude for participation, no reward was given.

It was thought that, should the tests be administered in an *ad hoc* order, learning experiences from one test could have differential effects on the responses of a second similar test. In order to exert some form of control on learning effects, the tests were administered in the following sequence:

Session 1

Conservation of Length
Conservation of Number
All and Some
Class Inclusion (Unequal Partitions)
Intersection (Overlapping Enclosures)
Cross Classification
Transformations

Session 2

Raven's Colored Progressive Matrices A, Ab, B
WISC-Vocabulary
WISC-Digit Span
Reproducing Designs (Bender Gestalt and Memory for Designs)

Session 3

Peabody Picture Vocabulary Test
Kohs' Block Design
ITPA-Auditory Sequential Memory
Gottschaldt Embedded Figures

Standard procedures were followed in all but three tests. Instructions for the Piagetian tests and for the Gottschaldt Embedded Figures test are given in Appendix A. Reproducing Designs consisted of the Bender Gestalt and Memory for Designs. All Bender-Gestalt designs, rather than only the four used by Vernon, were given; the subject merely had to copy the designs, as opposed to drawing them from memory. The designs and directions in the Terman-Merrill manual were used for the Memory for Designs.

The evaluation of the subject's responses was done according to conventional practice. For Kohs' Block Design, a record blank produced by Casselberry was used to score the responses. The scoring of the Bender-Gestalt designs followed the guidelines outlined by Koppitz (1960). No scoring standards were available for the Gottschaldt Embedded Figures but the following responses were considered erroneous: the simple design correctly drawn in the complex figure but in a rotated or compressed version; the simple drawn in the complex but with extra lines or figures.

In general, fifty-two normal grade two subjects were tested by three people. The testing was done in four elementary schools during the latter part of the 1971-72 school year. The tests were given in three sittings and in a predetermined order. Standard procedures for administration and evaluation were usually used; those tests which deviated from convention have been included in Appendix A.

CHAPTER 4

Results, Discussion and Implications

Results

Forty-six girls and six boys, in all 52 children with an average age of 94 months made up the sample. Sixteen tests were administered to each subject. Frequency distributions for the sixteen variables, means, standard deviations, and correlations were calculated.

Very few of the distributions were normally distributed; most were either U-shaped, skewed, or rectangular. The means were significantly different from zero; however, the mean for the conservation of number test was near the ceiling of the test. The standard deviations tend to show a reasonable spread of scores. There were many zero-order correlations; only 25 of the 120 correlation coefficients were above .27.

A principal-component analysis was attempted. Factors whose eigenvalues were greater than unity were initially selected as indicating the required number of factors. Thus six factors seemed most promising; those were rotated to a varimax solution. To gain clarity, solutions were obtained and rotated for four, five, and six factors. Each solution resulted in a different distribution of eigenvalues, with the last factor extracted having the lowest eigenvalue often being less than unity.

TABLE 1

Varimax Rotated Factor Matrix (4 Factors)

Test No. and Name	Factor 1	Factor 2	Factor 3	Factor 4
1. Raven's Prog. Matrices	775*	108	068	043
2. Kohs Block Design	715	117	043	049
3. WISC-Vocabulary	484	373	231	051
4. PPVT	322	493	-127	133
5. WISC-Digit Span	-004	828	042	006
6. ITPA Aud. Seq. Mem.	-058	673	371	207
7. Reproducing Designs	604	187	200	-208
8. Gottschaldt	611	030	200	-040
9. Conservation-length	281	001	521	567
10. Conservation-number	-077	214	-068	800
11. All and some	105	288	309	276
12. Class inclusion	110	116	344	-075
13. Intersection	-031	-106	528	138
14. Cross classification	418	-127	335	-016
15. Transformations	421	-081	104	126
16. Age	168	085	283	-030
Eigenvalues	3.23	1.69	1.24	.74
Percent of total variance explained	47%	25%	18%	11%
rms	.69	.50	.42	.33

*Decimal points have been omitted

Table 1 shows the results when only four factors are extracted from the correlation matrix. Under these conditions, the fourth factor has an eigenvalue of .74 and explains

11% of the total variance. Kaiser's (1956) root-mean-squares (rms) were calculated; loadings above the rms will be considered large. In addition, for this study, loadings below the rms but above the conventional, arbitrarily chosen value of .30 will be considered significant and will also be used in interpreting factors.

Factor 1, has large loadings on Raven's Progressive Matrices and Kohs Blocks. (Those two tests reflect the ability to abstract, cognize, and make inductions, and usually define g (Lunzer, 1971; Vernon, 1965b).) It has significant loadings on eight of the sixteen variables, and explains 47% of the total variance. For those and other reasons, factor 1 is assumed to be a measure of g.

Factor 2 has large loadings on WISC Digit Span and ITPA Auditory Sequential Memory and is designated the memory factor. The significant loadings from WISC-Vocabulary and PPVT may make this a verbal-memory factor.

Factor 3 has large loadings on conservation of length and intersection (overlapping enclosures). It has significant loadings from all and some, class inclusion (unequal partitions), and cross classification, as well as from ITPA - Memory. With the one large loading and three significant loadings from tests involving grouping tasks, it seems reasonable to label this factor a classification factor.

Factor 4 has large loadings from conservation of number and conservation of length. No other loadings were above .30. As a result this factor was labelled the conservation factor.

TABLE 2

Varimax Rotated Factor Matrix (5 Factors)

Test No.	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1	804	033	074	055	076
2	715	070	097	032	073
3	468	061	373	-232	060
4	297	090	510	-127	121
5	036	-076	778	011	031
6	-059	007	708	376	158
7	578	121	203	164	-227
8	650	-022	-000	186	-021
9	251	097	034	556	469
10	-092	024	207	-006	861
11	155	-134	269	336	274
12	104	032	136	333	-119
13	-050	064	-079	546	078
14	399	089	-115	327	-044
15	267	1.494	-000	134	034
16	232	-151	048	281	-010
Eigenvalues	3.47	2.16	1.60	1.18	.76
% of total variance explained	38%	24%	18%	13%	8%
rms	.62	.49	.42	.36	.29

Table 2 shows the factor loadings when five factors are extracted. The fifth factor has an eigenvalue of .76 and explains 8% of the variance. The rationale for naming the factors and the factor names are essentially the same as when four factors were extracted.

Factor 1 is g. Factor 2 has an unusual loading of 1.49 from the transformation test, making this a transformation factor. (A discussion of this anomalous result is reserved for a later occasion.) Factor 3 is memory. Factor 4 is a classification factor, and factor 5 is labelled conservation.

TABLE 3

Varimax Rotated Factor Matrix (6 Factors)

Test No.	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
1	721	047	189	036	068	147
2	859	066	038	114	102	-094
3	218	036	1.247	120	056	091
4	207	084	326	393	111	-011
5	068	-069	090	869	015	-034
6	000	024	-038	719	247	242
7	534	133	159	153	-181	258
8	697	-012	-016	017	010	160
9	224	119	-048	018	596	482
10	-092	017	049	198	787	-138
11	110	-120	056	234	348	344
12	017	051	068	103	-080	488
13	013	087	-264	-003	170	385
14	349	109	018	-122	-002	387
15	246	1.502	054	-017	059	077
16	192	-137	038	030	036	328
Eigenvalues	3.60	2.23	1.65	1.53	.94	.74
% of total variance explained	34%	21%	15%	14%	9%	7%
rms	.58	.46	.39	.38	.30	.26

Table 3 shows the factor loadings when six factors are extracted. Factor 4 has an eigenvalue of .74 and explains 7% of the variance.

Factor 1 is g; however, it explains only 34% of the total variance and has loadings from only five tests; three of those loadings are large, two others are significant (above .30).

Factor 2 is a transformation factor, loading an unusual 1.50 from the transformation test.

Factor 3 is a verbal factor, loading another unusual 1.24 on WISC-vocabulary and .32 on PPVT.

Factor 4 is the memory factor; it identifies less with the verbal tests as compared to the memory factors found in Tables 1 and 2.

Factor 5 is the conservation factor but here has a large loading from the all and some test.

Factor 6 is the classification factor and here has a large loading from the age variable.

Discussion of Results and Implications

This experiment was designed to determine the factor content of several Piagetian tests. As noted in the results above the Piagetian tests tended to cluster on their own factors which were different from the ones revealed by conventional tests.

Prior to an analysis of each Piagetian test, some preliminary observations need to be made. Firstly, since subjects were chosen for their willingness and not because they represented a population, the generalizability of the results is severely limited. Secondly, age was included in the analysis; it was a non-significant variable but tended to identify with classification and to a lesser degree with g. Thirdly, many of the reference tests proved to be more complex factorially for this age level than was originally predicted.

The reference tests selected as likely to have g-factor content did in practice load most highly on one factor, and that factor was named g. However, that factor also explained much of the variance of the tests thought to be verbal tests and almost all of the variance of the tests which were initially designated as spatial-perceptual. As Tables 1 to 3 show, when more and more factors were extracted, g explained less and less of the variance. Moreover, only about half of the tests loaded significantly on that factor, and of those, only one was a Piagetian test. On the other hand, with children of this age, g is more likely to be found than at a later age. Designating this factor as g, then, was done in the face of several uncertainties.

The tests chosen for their verbal character only isolated a factor when six factors were extracted. When less than six factors were extracted, the presumed verbal tests loaded on g and memory.

The memory tests defined a memory factor fairly clearly and consistently. As noted, the memory factor was also somewhat verbal in character. The ITPA-Sequential Memory tests showed some affinity also with the classification tests.

The tests hypothesized to be spatial-perceptual tests identified with g whether four, five, or six factors were extracted. Some support is given to the earlier suspicion that Raven's Matrices and Kohs' Blocks have figural, spatial, or perceptual attributes (Vernon, 1969).

The Piagetian tests clustered around two factors, conservation and classification. Conservation of length, a complex Piagetian test, loaded highly on both the conservation and the classification and about .25 on g. The reason for its relationship with the classification factor is unclear. However, the frequency distribution for this test showed a u-shaped distribution, suggesting that two distinct levels of abilities were operative or measured. Furthermore, it may well be that, for some children, keeping length variables (long, short, narrow, wide) separate from spatial variables (ahead, behind, horizontal, vertical) is a crucial task and indicative of a classification task. That, together with the two levels of abilities, may make the conservation of length test a measure of both conservation and classification at this age. By the same token, the number variables (more, less) mixed with length (long, short) would also make the conservation of number test both a classification and conservation test. That, however, does not appear to be the case since conservation of number consistently loaded on only the conservation factor. "All and some" loaded primarily on the classification factor but had loadings of .29 and .28 on conservation and memory, respectively. Class inclusion loaded only on classification, as did intersection. Cross-classification divided its variance between g and classification, probably showing the cognitive, inductive nature of the test. Transformations, a test which requires the youngster to change, for instance, color and shape holding size constant, was an unusual test in the battery. When only four factors were extracted, transformations had a loading of .42 on g; when more factors were extracted, it had a spuriously high loading on its own factor.

Does a four, five, or six-factor matrix best explain the total variance? The six-factor matrix recommends itself because it is only when that many factors are extracted that a verbal factor begins to emerge. Similarly, it is only with the five and six-factor matrix that we can see that the transformation test is unique to the battery. The verbal and transformation factors are suspect, though; each factor is defined by only one test and at the expense of a varimax loading greater than unity. Two questions arise. When only one test reveals a factor, what can be said about either the test or the factor? No economy, no clustering, no relationship between tests has resulted. Secondly, are factor loadings greater than unity spurious? Those loadings tend to be since they are thought to be correlations between tests and factors, and correlations should not exceed unity. Besides, rotations are undertaken to ensure the probability of a satisfactory psychological as well as numerical interpretation. The varimax rotation helps the psychological explanation by separating the tests into high-loading and low-loading tests. If the price of achieving that separation is producing varimax loadings in excess of unity, then those loadings are best rejected.

A somewhat extended comment from Comrey (1973) highlights the dilemma.

> With the Varimax method it is important to rotate the proper number of factors. Rotation of too few factors with the Varimax criterion, as with any method of rotation, crowds the variance for n + k factors into a space of only n dimensions, thereby losing some factors and distorting the others. Rotating too many factors, however, can also bring about distortions with the Varimax criterion. The Varimax method will tend to build up the variance on extra small factors to increase the overall variance function , thereby splitting up major factors and "robbing" larger factors of their variance for certain data variables. The best indication that this has happened is the appearance of a Varimax factor with only one large loading and all the rest of the loadings at much lower levels. The solution should be rerotated, dropping out any factor that is artificially overinflated in this way. (p. 178)

The abnormally high loading given by test 15 on factor 2 is an example of Comrey's assertion. That, in fact, predisposes us to take the four factors where no abnormally inflated loadings are obtained.

There exists an earlier and alternate way of rotation, the quartimax. It "attempts to maximize the variance of squared factor loadings by rows, since if all the variance for a given variable is concentrated on one factor, leaving the other loadings essentially equal to zero, this result will be achieved" (Comrey, 1973, p. 173). As Comrey has pointed out "experience with the quartimax approach has shown that it tends to give a general factor, that is, a factor with which all or most of the variables are substantially correlated" (Comrey, 1973, p. 173). Use of the quartimax should serve a dual purpose: firstly, if a general factor is to appear, the quartimax is most likely to give such evidence; in the second place, it may enable us to determine on which factor, if any, the Piagetian tests load.

TABLE 4

Quartimax Rotated Factor Matrix (6 Factors)

Test No.	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
1	027	736	147	033	128	048
2	043	858	-019	104	-097	117
3	026	295	1.266	159	027	047
4	075	234	291	404	-011	105
5	-066	082	051	874	-029	001
6	022	014	-047	716	288	191
7	111	555	132	143	208	-218
8	-030	699	-049	004	144	-010
9	103	236	-032	017	567	516
10	021	-090	041	219	-014	794
11	-119	122	058	236	387	286
12	043	037	087	097	466	-155
13	078	010	-237	-015	421	108
14	090	361	022	-131	371	-056
15	1.586	289	044	-022	089	045
16	-137	199	042	026	320	-013
Eigenvalues	3.68	2.41	1.67	1.58	.95	.73
% of total variance explained	33%	22%	15%	14%	9%	7%
rms	.57	.47	.39	.37	.30	.26

Table 4 shows the factor loadings when six factors are extracted and then rotated to a quartimax criterion. The same difficulty is encountered, a high spurious factor loading (factor 3) appears on test 3 and another loading (factor 1) appears on test 15. The other factors are as might be expected:

Factor No.	Test Nos.	Factor Name
2	1, 2, 7, 8, 14	g
4	5, 6	memory
5	9, 11, 12, 13, 14, 16	classification
6	9, 10	conservation

In an attempt to remove some of the source of our anomalous results, the procedure was repeated with test 15 removed from the battery. Table 5 shows the spuriously high loading on factor 2 from test 13.

TABLE 5

Varimax Rotated Factor Matrix (6 Factors)

Test No.	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
1	679	-007	-042	105	312	156
2	884	056	099	070	145	-191
3	204	-169	033	058	765	183
4	145	064	290	082	618	-024
5	046	-026	709	035	279	-019
6	024	040	865	280	-004	181
7	538	-007	118	-119	197	300
8	712	-047	039	059	-037	165
9	256	062	030	736	-098	359
10	-119	026	164	718	146	-271
11	094	075	207	384	141	237
12	031	014	092	022	039	530
13	013	1.394	017	131	-137	189
14	355	122	-147	065	043	337
15	189	120	024	070	068	247
Eigen values	3.22	2.22	1.70	.94	.71	.67
% of total variance explained	34%	23%	18%	10%	8%	7%
rms	.58	.48	.42	.32	.28	.26

Whilst rotation is responsible for some of the abnormally high loadings, it is also necessary to examine the original communalities prior to rotation. Table 6 presents that data:

TABLE 6

Communalities

Test No.	4 Factors Varimax	5 Factors Varimax	6 Factors Varimax	6 Factors Quartimax	6 Factors Varimax
1	619	622	585	585	596
2	529	532	774	774	857
3	430	420	1.721	1.721	695
4	381	387	320	320	499
5	671	614	780	780	586
6	637	672	635	635	863
7	483	469	450	450	447
8	416	459	513	513	544
9	672	604	655	655	752
10	697	794	689	689	654
11	266	303	321	321	282
12	149	156	262	262	293
13	310	317	252	252	2.016
14	304	290	298	298	283
15	210	2.324	2.611	2.611	---
16	117	158	164	164	121
No. of iterations to reach convergence	40	+200*	+300	+300	+300

* more than 200 iterations

Communalities are produced by an iterative process which removes unique and error variance and makes possible the explanation of a large number of tests in a few factor spaces. In the case of our data, over 300 iterations failed to produce a convergence with a communality less than unity. It is inferred that it has not been possible to remove all the error and unique variance from the test battery, and for some reason this has usually been squeezed onto tests 3 and 15. If error variance can be removed prior to test correlation, which in part is implied by the normalization of test scores, a better solution may be obtained.

At this point evidence may be introduced to the effect of normalizing the test scores. Data were normalized (Ferguson, 1959) using a T-scale ($\bar{x} = 50$, $\sigma = 10$), and the correlation matrix was analyzed as before.

Convergence was reached in 248 iterations. Five factors will be indicated by eigenvalues greater than unity; the sixth factor would have an eigenvalue of .98 when the 16 tests were being represented by 16 factors. As before, rotations were performed on 4, 5, and 6 factors. Tables 7, 8, 9, 10, below are based upon data normalized prior to inter-correlation.

TABLE 7

Varimax Rotated Factor Matrix (4 Factors)

Test No.	Factor 1	Factor 2	Factor 3	Factor 4
1	763	126	084	077
2	722	-058	011	-006
3	432	470	-161	058
4	295	625	-098	092
5	036	685	061	-093
6	-065	623	449	-011
7	555	198	051	153
8	633	039	199	-026
9	103	143	631	111
10	-149	476	274	103
11	075	310	448	-112
12	131	049	253	050
13	-091	-031	693	110
14	453	-147	331	112
15	284	014	157	1.220
16	216	-048	417	-195
Eigen-values	3.24	1.85	1.50	1.25
% of total variance explained	41%	24%	19%	16%
rms	.64	.49	.44	.40

With respect to Table 7, factor 1 is taken to be the g factor, factor 2 is a memory-verbal factor, factor 3 is a Piagetian factor, and factor 4 is the spurious transformations factor. Although convergence was reached after 248 iterations, test 15 still has a communality of 1.595.

TABLE 8

Varimax Rotated Factor Matrix (5 Factors)

Test No.	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1	363	084	189	-055	384
2	756	018	014	-078	097
3	199	020	-004	109	803
4	148	067	-010	353	587
5	078	-083	-030	685	235
6	039	016	308	829	-008
7	480	155	097	079	300
8	772	-000	145	117	-029
9	093	125	607	203	-019
10	-151	091	230	453	139
11	-020	-108	517	235	210
12	104	058	260	052	042
13	-069	131	645	114	-207
14	362	123	413	-202	101
15	223	1.329	131	-007	114
16	177	-161	448	-030	-001
Eigen-values	3.33	1.96	1.64	1.34	.60
% of total variance explained	38%	22%	18%	15%	7%
rms	.62	.47	.42	.39	.26

Table 8 indicates that factor 1 is g, factor 2 is the spurious transformations, 3 is Piagetian, 4 is memory, 5 is verbal. Convergence was not reached at 300 iterations; test 15 has a communality of 1.84 and the inflated factor loading of 1.329.

TABLE 9

Varimax Rotated Factor Matrix (6 Factors)

Test No.	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
1	626	094	185	402	-075	045
2	716	041	061	138	-045	-100
3	170	020	011	810	069	039
4	130	066	-022	595	295	135
5	026	-064	002	280	744	066
6	000	034	296	026	783	279
7	433	187	160	332	124	-089
8	852	-000	102	-040	111	114
9	142	105	482	-043	043	500
10	-086	044	-016	131	233	807
11	-007	-118	444	195	145	307
12	077	077	291	046	081	-005
13	-083	148	621	-219	098	193
14	318	155	467	115	-154	-075
15	194	1.284	101	125	-045	097
16	137	-146	520	008	020	-046
Eigenvalues	3.34	2.00	1.60	1.36	.63	.59
% of total variance explained	35%	21%	17%	14%	7%	6%
rms	.59	.46	.41	.37	.26	.24

Regarding Table 9, factor 1 represents g, factor 2 is again the spurious transformation factor, factor 3 is classification, 4 is verbal, 5 is memory, 6 is conservation. Again convergence was not reached at 300 iterations; test 15 has an abnormal communality of 1.72 and a factor loading of 1.284.

TABLE 10

Quartimax Rotated Factor Matrix (5 Factors)

Test No.	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1	674	055	187	-042	322
2	763	-007	009	-067	025
3	276	012	-000	147	774
4	202	062	009	381	553
5	088	-082	005	697	195
6	027	008	354	810	-047
7	511	135	105	092	247
8	763	-030	150	115	-109
9	093	103	621	168	-033
10	-139	090	258	443	134
11	-006	-124	524	215	203
12	109	046	264	040	031
13	-085	113	655	066	-201
14	378	096	405	-217	076
15	278	1.316	174	-015	092
16	171	-182	440	-053	-015
Eigen-values	3.33	1.96	1.64	1.34	.60
% of total variance explained	38%	22%	18%	15%	7%
rms	.62	.47	.42	.39	.26

With Table 10 we can also determine which factors define the tests:

Tests	Factor	Factor name
1, 2	1	g
3, 4	5	verbal
5, 6	4	memory
7, 8	1	g
9, 11, 13, 14, 16	3	Piagetian
10	4	memory
15	2	transformations

Three hundred iterations failed to reach convergence; test 15 has a communality of 1.840.

In general, as expected the reference tests seem to be fairly well defined. Tests 1, 2, 7, and 8 consistently loaded on a factor which was labelled g; tests 5, 6, thought to be memory tests, consistently loaded on one factor; occasionally tests 3 and 4 defined a verbal factor. Piagetian tests commonly defined their own factor(s); throughout test 15 had a spuriously high loading on a factor of its own.

These results must be compared with those of others. Vernon (1965a, 1965b, 1967, 1969) and Meyers and Orpet (1971) tended to find a close affinity between Piagetian tests and conventional tests; however, in one study by Vernon (1969), the Piagetian tests defined their own factor. Similarly, Lunzer (1971) showed that Piagetian tests cluster on their own factor. There is evidence in our results to indicate that the reference tests are adequately defined by factors and that the Piagetian tests do not load on those factors. Varimax and quartimax rotations with both non-normalized and normalized data indicate some tendency for the Piagetian tests to load on a factor different from those of the reference tests.

Only a few firm implications can be drawn from these results. The most obvious implication is that classical theorists and Piaget are studying different phenomena. In the same vein one may ask, do the results imply that Piaget is measuring more effective components of intelligence than those measured by classical methods? The correlation matrix in Appendix B shows that Piagetian tests correlate with each other and with other tests at a low level. About 15 of the 120 correlations are significant; the highest single correlation does not exceed .42. They correlate little more with themselves than they do with the reference tests. Whilst many of the same correlations could well be significant had a larger sample been used, the mere use of more subjects, desirable though this is, would not be sufficient without internal improvements in the tests themselves. It is concluded, on the basis of these results, that the Piagetian tests in their present form do not meet the criteria required of tests which are included in a factor analysis.

CHAPTER 5

Conclusion

This study was designed to examine how well factors as derived from classical theories of intelligence could define the characteristics of Piagetian tests. Tests thought to be of the general-intelligence, verbal, memory, and spatial-perceptual type, along with two conservation and five classification tests were administered to fifty-two subjects.

The test results were correlated and factor analyzed. Principal factors were obtained and rotated by varimax procedures. A tentative approach was made in terms of eigenvalues greater than unity. With non-normalized data, the eigenvalues suggested six factors. But because of high loadings on a single test, rotations were also carried out on four and five factors. Interpretations were offered for four, five, and six factors so obtained. A quartimax rotation was undertaken to look at the same data from the viewpoint of the separate tests and what the major factor content of each test might be. The data were normalized and reanalyzed. Eigenvalues would indicate that five factors were sufficient, but again, and for the same reasons, four, five and six factors were rotated by the varimax method. A quartimax solution was undertaken for the indicated five factors to attempt to ascertain the significant loadings for each test in turn.

Difficulties were encountered by the failure to secure convergence to less than unit communalities when more than 300 iterations were made from the principal component analysis. A spuriously high factor loading on test 15, the transformation test, continued to occur when more than four factors were rotated and on one occasion when four factors were rotated. The solution using four factors seemed the most amenable to interpretation. The factors were interpreted as follows: factor 1 was g, factor 2 was memory, 3 was classification, and 4 conservation. Though some doubts exist because of the abnormally high communalities and factor loadings, there is no evidence to suggest that the Piagetian tests load on the factors of the reference tests. There is evidence to suggest from the quartimax solution that they load on a common Piagetian factor. If Piagetian tests are capable of being interpreted in factorial terms, the most probable tests from this analysis are conservation of length and number, all and some, class inclusion, and intersection.

It is suggested that the Piagetian tests in their present form are not amenable for use in factor-analytic studies. It is agreed that the sample size was small. Finally, it will be desirable to seek to extend the number of reference tests, but above all more consideration needs to be given to the reliability of tests which are devised in conformity with Piaget's ideas.

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APPENDIX A

Test Protocols

CONSERVATION OF LENGTH

Scoring instructions

All questions score 1 or 0.

Additional information (ring as appropriate)

Q. 13. Score 1 if one of the following categories of answer is given and ring whichever is appropriate. Otherwise score 0.

C = compensation (longer to walk there but shorter here)

I = identity (its the same string, you only moved it)

R = reversibility (if you put the string back it would still fit the square)

Materials

(a) 3 lengths of ¼" dowling (4", 6", 6")

(b) 3 line drawings

(c) 3 rods, 1 cm. sq. X-section (12 cm., 12 cm., 12.2 cm.)

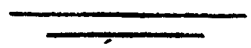
(d) 1 closed length of string, softboard, pins

Method

Part 1 (use material (a))

Present C with the two equal lengths of dowling in parallel and exact alignment.

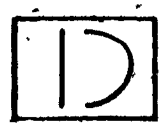
Q. 1. Are these two just as long as each other? Is one longer than the other? (Which one?)

Replace one length of dowling with the 4" piece presented thus. 

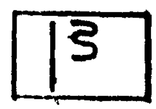
Q. 2. Are these two the same length? Is one longer than the other? (Which one?)

Q. 3. Is one shorter than the other? (Which one?)

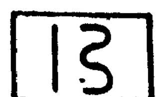
<u>Part 2</u> (use material (b))

Present C with first picture. 

Q. 4. Are these lines just as long as each other? Is one longer than the other? (Which one?)

Present C with second picture. 

Q. 5. Repeat above questions.

Present C with third picture. 

Q. 6. If one snail set out from here and walks along this path like this to the other end here, and, another snail sets out from here and walks to the other end here, would one of them have a longer way to walk? (Which one?)

<u>Part 3</u> (use material (c))

Present equal rods in parallel alignment. "Are they just as long as each other? Is one longer than the other?" (Which one?)

Q. 7. Move one rod forward approx. 1 cm. Repeat question.

Q. 8. Move other element forward approx. 4 cm. in front of first. Repeat question.

<u>DISCONTINUE</u> if C failed to obtain a <u>perfect</u> score on <u>Part 1</u> (3 out of 3), <u>and</u> C fails Q. 7, <u>or</u> Q. 8.

Q. 9. Some children say "This one is longer, do you think they are right?"

Q. 10. Select longest rod and one of the equals. Show alignment and ask usual question. Push shorter rod forward 3 cm. and repeat question.

Q. 11. Revert to equal pair. Show equality, then arrange as T; repeat question.

<u>DISCONTINUE</u> if C has made <u>any</u> error.

<u>Part 4</u>

Present softboard with string arranged on square. Explain that this is a field. A man walks all round it (tracing perimeter). Displace the string and stretch round rectangle approximately twice as long as it is wide.

Q. 12. Tell me. Which way do you think the man would have longer to walk, this way (square) or this (rectangle), or do you think it's the same?

Q. 13. If reply was correct "Why do you think it's the same?"

CONSERVATION OF NUMBER : 1-1 CORRESPONDENCE

Scoring instructions

Q's. 1-6, 9, 10 Score 1 if C gives correct response.

Q. 7. 2 spontaneously correct

1 correct when repeated

Q. 8 and C.S. 2 if adequate reply is given i.e. one of the following, whether spontaneously or in reply to C.S. and ring as appropriate.

I = initial identity - you have only moved them, etc.

C = compensation - these are closer together, etc.

R = reversibility - you can move them back as they were before.

E = enumeration - child has to count to establish equality.

1 if C resists C.S. but is unable to justify.

Materials

(a) 4 blue plastic discs

4 yellow plastic discs

(b) 24 cubes, in two equal sets, of different colour

Method

Part 1 (discs)

Hand C 4 blue discs and ask him to place one on the table. When he does this, place a yellow disc alongside. Repeat until all 4 blue discs are partnered by 4 yellow discs.

Q. 1. Do we have just as many as each other?

Remove a yellow disc.

Q. 2. Now do we have just as many as each other?

Q. 3. Do you have more than I do?

Q. 4. Do you have less than I do?

Part 2 (cubes)

Construct a row of 10 cubes of one colour, with a space of approximately 1-2 cube widths between cubes. Remove the 2 remaining cubes and give C the 12 cubes of the other colour. Say:

Q. 5. I want you to put out some of these cubes so that you have just as many as I have. (construction)

Do you have just as many as I have?

Score as appropriate. If C fails then E should establish 1-1 correspondence and repeat question.

Do not score.

Q. 6. Move the cubes in one of the rows closer together, ask: "Have we still got just as many cubes as each other? Has one of us got more cubes than the other?" If C's reply is "yes," then ask "Who has got the most cubes?"

DISCONTINUE if failure has been recorded for both Q. 5, and Q. 6.

Q. 7. Move the cubes in the other row to make them further spaced. "And now, have we still got just as many cubes as each other? Has one of us got more cubes than the other?"

Q. 8. If reply to Q. 7 is correct, ask: "How do you know?"

<u>Counter suggestion</u>

If C's reply to the HDYK question is difficult to evaluate, e.g. "They're the same," then ask, "Several children told me that there are more cubes in this row because it is longer. Do you think that they could be right?" If C replies "No," then ask: "Why not?"

Q. 9. Re-align so that the two rows are facing. Establish equality. "Watch what I'm doing." First carefully, and in full sight of C, remove a cube from one of the rows and put it away from the cubes before the child. Space the row of 9 cubes so that it extends well beyond the row of 10 cubes. "Have we just as many cubes as each other? Has one of us got more cubes than the other?" If reply is "yes," ask: "Who has the most cubes?"

Q. 10. Re-align as before bringing back the odd cube. Add a cube to one of the rows then space the other row so that it extends beyond the 11 cube row. Describe actions. Question as for Q. 9.

Q. 7. repeat If reply to Q. 7 was false while both Q. 9 and Q. 10 were answered correctly, then re-align, equalize and space, and repeat Q. 7. Omit this question unless all three conditions are satisfied.

ALL AND SOME

Scoring instructions

Set (A)

0 one or more errors on both blocks of questions.

1 if second block (of 3 questions) answered without error, but block of 4 is failed on both occasions.

2 if first block correctly answered second time (second block will also be correct).

3 if first block correctly answered first time.

The scoring for Set (B) is identical.

Range of possible score is 0 - 6.

<u>Materials</u>

<u>Set (A)</u> 2 large blue wooden bricks

4 small blue wooden bricks

2 large red wooden bricks

<u>Set (B)</u> 4 red square cards

5 blue circular cards

2 blue square cards

<u>Set (A)</u>

Establish vocabulary for test material then ask:

Q. 1. Are all the red bricks large? Yes

Q. 2. Are all the blue bricks small? No

Q. 3. Are all the small bricks blue? Yes

Q. 4. Are all the large bricks red? No

If all questions are answered correctly go to Set (B).

If any answers are incorrect ask:

Q. 5. Are some of the blue bricks small? Yes

Q. 6. Are all of the blue bricks small? No

Q. 7. Are all of the small bricks blue? Yes

(i) If Q's 5, 6, 7 answered correctly ask Q's 1, 2, 3, 4 a second time then go to Set (B).

(ii) If Q's 5, 6, 7 are answered incorrectly go to Set (B).

Set (B)

Establish vocabulary for test material then ask:

Q. 1. Are all the red ones square? Yes

Q. 2. Are all the squares red? No

Q. 3. Are all the blue ones round (circles)? No

Q. 4. Are all the circles blue? Yes

If all questions correctly answered then stop. If any questions incorrect ask:

Q. 5. Are some of the blue ones circles? Yes

Q. 6. Are all of the blue ones circles? No

Q. 7. Are all of the circles blue? Yes

If Q's. 5, 6, 7 all correct repeat Q's. 1, 2, 3, 4 then stop. If Q's 5, 6, 7 incorrect then stop.

CLASS INCLUSION (Unequal Partition)

Scoring Instructions

Set (a) Each item scored 1 - 0.

Sets (b) and (c) (scored similarly)

5 Q. 7 answered correctly first time.

4 Q. 7 answered correctly following success with S. 1.

3 Q. 7 answered correctly following success with S. 2.

2 Q. 7 answered incorrectly following success with S. 1.

1 Q. 7 answered incorrectly following success with S. 2.

0 failure with Q. 7, S. 1 and S. 2.

Set (d)

Q. 8 3 correct first time.

2 if correct after prompt.

1 if reply includes words 'dogs' and 'animals.'

0 no attempt or hopelessly wrong.

Materials

(a) One card which shows 2 girls, 2 boys, 1 cat and 1 dog.

(b) Set of eight cards of which 6 show figure of a boy, 2 show figure of a girl.

(c) Set of eight cards of which 6 show a robin, 2 show a budgie.

(d) Set of eight cards of which 6 show a dog, 2 show a cat.

Method

Part 1

Put out card defined in (a). Then say:

Q. 1. Point to the cat.

Q. 2. Point to the dog.

Q. 3. Now point to all the animals.

Q. 4. Point to the boys.

Q. 5. Point to the girls.

Q. 6. Now point to the children.

Part 2

Put out (b) cards, without separating the two sub-sets. Ask:

Q. 7. Are there more boys here or more children, (pause) more children or more boys?

S. 1. If reply to Q. 7 is (a) correct, proceed to next set.

(b) false, ask:

How many boys are there? How many children?

S. 2. If reply to S. 1 is false, ask:

How many boys? How many girls? How many children?

Repeat Q. 7 if S. 1 or S. 2 answered correctly.

Set (c)

Proceed as for Set (b), substituting robins for boys, budgies for girls, and birds for children, taking care to repeat the form of Q. 7.

Set (d)

Proceed as for Set (c) substituting dogs for robins and cats for budgies. Ask:

Q. 8. What is the question I am going to ask you this time?

If C fails, prompt by showing Set (c) and saying: "When we looked at these I asked you, are there more robins or more birds, now look at these. What question do you think I am going to ask?"

INTERSECTION (overlapping enclosures)

Scoring Instructions

T. 1. 1 - 0 both sets correctly allocated

T. 2. 1 - 0 both sets correctly allocated

T. 3. 4 spontaneous exhaustive success

3 exhaustive success following initial prompt or single demonstration only

2 spontaneous partial success on which C fails to improve

1 partial success following initial prompt or single demonstration only

0 no success <u>or</u> 2-3 demonstrations needed for exhaustive allocation

T. 4. 4 spontaneous exhaustive success

3 exhaustive success following prompts

up to 2 marks may be awarded to children who do not fit the above two categories but who:

1 mention the overlapping dimensions

1 allocate two shapes following prompts

<u>DISCONTINUE</u> if less than 2 scored on T. 4.

T. 5. 4 spontaneous exhaustive success

3 exhaustive success following prompts

2 3 intersections correctly filled after prompts

1 2 intersections correctly filled after prompts

0 less than two intersections filled

<u>Materials</u>

(a) 3 rings of different colours

(b) The following plastic shapes:

2 large yellow squares 2 large red circles

2 large yellow circles	1 large red triangle
2 small yellow squares	2 small red triangles
1 small yellow circle	2 small red circles

(c) The following markers:

yellow red square round large small

Part 1

Lay out the shapes and two rings with a short distance separating them. Establish vocabulary for the test material. "I want you to put a yellow shape in this ring (indicate) (R. 1) . . . now another . . . we put yellow shapes in this ring and to help you remember what belongs in this ring I am going to put this yellow marker in it." Repeat the above procedure for R. 2 with two red pieces and the red marker. If C makes any mistakes, lead correction with "No, we'll have this one, shall we?"

T. 1. Ask C to allocate the remaining yellow and red shapes. If C does not exhaust the relevant shapes, score 0 and draw his attention to shapes omitted.

T. 2. Repeat the above procedure with all red shapes for R. 1 and all square shapes for R. 2.

Part 2

Material as for Part 1, ring now overlap.

T. 3. The procedure for Part 1, T. 2 is followed with all yellow shapes in R. 1 and all small shapes in R. 2. If C allocates the two classes but fails to intersect draw his attention to the dimensions which intersect: "What about this one? (small yellow circle). But isn't it small (if classed with yellow)?" . . . If C now classes it with smalls: "It is small but it's yellow too, isn't it?" If C still fails to place the first small yellow correctly, DEMONSTRATE. "But that's just small (yellow), there is small and yellow." Similarly, if necessary, draw his attention to the other neglected dimensions. DEMONSTRATE again if necessary, always explaining verbally, e.g. "If we put it in here it's in the yellow ring (gesture) and in the small ring (gesture)." If C still fails to place the intersecting elements then place the elements one at a time in their correct position.

T. 4. Repeat with all large shapes in R. 1 and all round shapes in R. 2. If C fails to spontaneously allocate the elements correctly ask him to explain the problem. If C mentions the problem of the overlapping dimensions but still fails to allocate the pieces, then demonstrate. If, in answer to the 'problem' question C fails to mention the overlapping dimensions, then draw his attention to them, using up to three prompts altogether with up to two pieces, as in T. 3.

DISCONTINUE if, given the 3 permitted prompts, C fails to place at least 2 pieces correctly in the intersection.

Part 3

Use three rings and all the shapes.

Arrange the rings and markers thus: 

T. 5. R. 1 - yellow shapes: R. 2 - round shapes:

R. 3 - small shapes.

Up to five prompt questions (e.g. 'This one is yellow, but it's also small isn't it?'), irrespective of number of pieces may be made (deal with triple intersection last of all), the DISCONTINUE and score.

CROSS-CLASSIFICATION (L1)

Scoring Instructions

Tasks 1 and 2

2 correct classification following screened demonstration

1 correct classification if open demonstration has been necessary

Tasks 3 and 4

3 correct classification following the screened demonstration

1 partial success (screened), i.e. C able to classify the elements for one part of the total sequence

1 correct classification following an open demonstration

(i.e. C may be awarded a total of 2 if both criteria are satisfied.)

Tasks 5 and 6

1 complete success

0 partial success

Task 7

3 complete success without prompt

2 complete success following prompt

1 double classification achieved but not treble

<u>Task 8</u>

2 complete success without prompt

1 complete success following prompt

0 one classification only

<u>Apparatus</u>: <u>For all tasks</u>

2 'post' boxes 6" x 6" x 6", open at bottom and with a 3" slot at the top

2 soft sponge pads, slightly larger than the base of the boxes

<u>Material (a)</u>

Blue shapes - 2 squares and 2 circles

Yellow shapes - 2 squares and 2 circles.

<u>Material (b)</u>

Red shapes - 2 triangles and 2 rectangles

Yellow shapes - 2 triangles and 2 rectangles

<u>Material (c)</u>

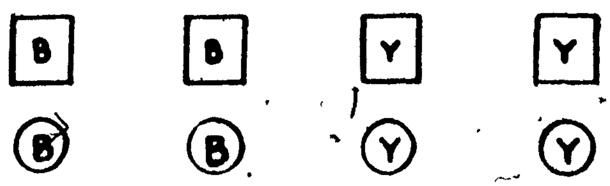
8 shapes consisting of squares and triangles, small and large, blue and red, figuring every possible combination as a unique examplar

<u>Material (d)</u>

8 cards, animals, birds, domestic, wild.

<u>Test situation</u>

E sits beside C at the table or desk. The two 'post' boxes are placed, side by side, on sponge pads between E and C. A gap of about 3" is left between the boxes. The pieces are randomly scattered on the table. E then asks C to sort the pieces into two groups. If C sorts the pieces by colour, E asks C to see if it is possible to sort the pieces any other way. E gives similar instructions if C sorts by shape. E assists if necessary and eventually places the pieces in the standard arrangement position:



The pieces are then shuffled and C is asked to rearrange them. Assistance is given if necessary. E then shows the boxes to C, explains their structure and function, then allows C to post one or two of the pieces. E shows C that when the boxes are removed, whatever has been posted is left on the sponge pads.

Notes on procedure - Tasks 1 - 4

At no time is C told the names of the shapes or their colour. C is always encouraged to assist when the pieces are being placed in their standard-arrangement position. Each sorting may have both a screened demonstration and an open demonstration. In the screened demonstration, while C has his eyes closed, E sorts. If C attempts the sorting but fails, E openly sorts the pieces one at a time. In the open demonstration, the sorting is carried out so that all the elements which belong to one set are posted first; then the elements of the remaining set are posted. After the open demonstration, C is again asked to perform the sorting. If C is still unable to perform the task correctly, then testing is discontinued.

Task 1

E says, "I want you to close your eyes while I sort the pieces. When I've finished, look at what I did and see if you can do the same." E sorts the pieces by colour, asks C to open his eyes, and then removes the boxes so as to reveal the pieces on the sponge pads. E says, "Now, can you see what I did? Let's put the pieces back as they were before and then you can have a go."

A similar procedure is adopted when E demonstrates any sorting.

Elements arranged

C performs one sequence at a time

C sorts (1) by colour

(2) by shape

Task 2

Elements disarranged:

C performs one sequence at a time

C sorts (1) by colour

(2) by shape

Task 3

"Now this time you will have to close your eyes two times. First you close your eyes and I'll do something. Then, you look at what I did, close your eyes again, and I will do something else. I want you to try to remember everything I did because when I've finished, it will be your turn. Do you think you can do that?" E ensures that C's eyes are closed and then sorts by colour. At the end of the first sorting, E says, "Open your eyes and see what I have done." E places pieces in the standard arrangement, asks C to close his eyes, and sorts by shape. On completion of the whole sequence, E says, "Now open your eyes again and look at what I did. Then, see if you can do both steps as I did them."

If C fails, E says, "Watch me while I do it again. When I'm finished, you try the whole thing again." E sorts by colour, then by shape, and then asks C to do the whole thing.

Elements arranged:

C performs total sequence

C sorts first by colour and then by shape

Task 4

Elements disarranged:

C performs total sequence

C sorts first by colour then by shape

Task 5

Present transfer material (b) in the Task 3 arrangement and proceed as for Task 3. The child is asked to post the pieces two ways as he did with the main test material.

DISCONTINUE if C fails.

Task 6

Proceed as for Task 4 using transfer material (b).

DISCONTINUE if C fails.

Task 7

Introduce transfer material (c) disarranged, saying: "This time there are three ways you can do it. See if you can post them three different ways to get different piles in the boxes each time." After the second posting, if C stops, say: "Can you do it another way still?"

Task 8

Introduce transfer material (d) disarranged, saying "This time the pieces aren't exactly the same but you can still put them together to make them belong, and you can still do it in two different ways. See if you can do it in two different ways." If C stops after one successful sort, say: "Is there another way you can do it?"

TRANSFORMATIONS (L2)

Scoring instructions

All items are scored 1 - 0.

Apparatus

Tray holding plastic shapes

Shapes: rectangle (R), triangle (T)

Colour: Yellow (Y), blue (B)

Size: large (L), small (S) (five pieces of each coloured shape)

Cards with coloured shapes painted in position (for use in double and triple transformations)

Small stiff white card, divided into two equal parts to act as test surface for single transformations

Introduction to test situation and material

E sits alongside child with C to the right. The shapes are placed before and between E and C. The top row of shapes is yellow and the arrangement of pieces, from right to left, is large rectangle, large triangle, small rectangle, small triangle. A selection of pieces is scattered before C who is encouraged to play with them for a few moments, then is asked to replace them in the tray.

Introductory 1-1 matching exercises

E presents C with the test surface card and points out that he is going to work on the half nearest to himself whilst C is to work on the other half. E says: "Watch very carefully because the game is for you to work out what you have to take out of the tray. So, if I take this (large yellow rectangle) and put it here (E's half of the card), then you have to take this (large yellow rectangle) and put it here (C's half). I wonder if you can see why you would have to take that one?" C is allowed to look at the pieces then is encouraged to help replace the pieces in the tray. The procedure is restarted with another piece. After placing the stimulus, E pauses and asks C to anticipate the response. If C succeeds, the procedure is repeated, this time with a different sized shape. Give as many demonstrations as are necessary for the child to grasp the matching strategy, and, as soon as C correctly completes two successive matchings, go to Size Transformations.

DISCONTINUE if C is unable to grasp the 1-1 matching strategy.

Notes on procedure

At no time is C told the names of the pieces or their colour. All responses must be in the form of a construction even though C might show that he is clearly capable of a correct verbal response. At the start of each new transformation situation point out that the game is to be changed and C's task is to spot how the game has changed. During demonstrations tell the child if his response is correct. If C is unable to give the correct response with test item one (within each block), then correct. An incorrect response in the demonstration item is countered with a remark such as: "I think that the answer is .... Can you see why I chose this one?" At all other times give oblique encouragement with remarks such as: "You're doing well."

PART ONE Single Transformations

The first two items in any block are demonstrations with C being allowed to participate if he wishes. Each transformation consists of four items. A correction procedure is used for the first two, i.e. demonstrate correct answer, saying: "Do you see why?" (Verbal response is not scored.)

Size Transformations

SHAPE and COLOUR held constant: SIZE transformed

Colour Transformations

SHAPE and SIZE held constant: COLOUR transformed

Shape Transformations

SIZE and COLOUR held constant: SHAPE transformed

DISCONTINUE if total score for Single Transformations is 5 or less.

PART TWO Double and Triple Transformations

For these problems use the cards with the coloured shapes painted in position. E says, "Each game is made up of four cards. I will show you how the game works with the first two cards. Then those cards will be put up here so that you can look back at them. Remember to use them to help you decide what to do in the last two cards."

For demonstration #1 say, "Watch carefully because this is a new game. If I put down this shape, then you take this one (pointing to the correct plastic shape) and put it here. I wonder if you can see why?"

For demonstration #2 say, "If I put this down, then you take that one. Can you see why? Now you do the next two." Move the demonstration material to make space for the problems, but avoid placing the demonstration material directly above the problem material so that cues of symmetry are not given.

For problems #1 and #2 say, "Now if I put down this one, which one would you put down?"

Below is an outline of the shapes that are painted on both the demonstration material and the problem material. A code in which the first letter is the size, the second the colour, and the third the shape has been used; thus, LYR stands for a large yellow rectangle, and SBT stands for a small blue triangle. Besides showing what shapes are painted on the cards and what shapes are the correct responses, the outline also shows the order in which the material is presented in the testing situation.

Double Transformations

(A) Colour held constant, Size and Shape transformed

	Painted Shape	Correct Response
1. Demonstration #1	L Y R	S Y T
2. " #2	S B T	L B R
3. Problem #1	L B T	S B R
4. " #2	S Y R	L Y T

(B) Size held constant, Colour and Shape transformed

	Painted Shape	Correct Response
5. Demonstration #1	L Y T	L B R
6. " #2	L Y R	L B T
7. Problem #1	S B T	S Y R
8. " #2	S B R	S Y T

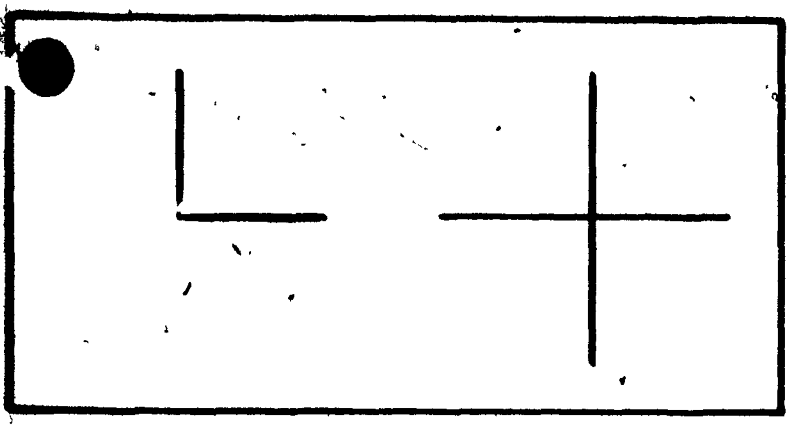
(C) Shape held constant, Colour and Size transformed

	Painted Shape	Correct Response
9. Demonstration #1	S B R	L Y R
10. " #2	L B R	S Y R
11. Problem #1	S Y T	L B T
12. " #2	S B T	L Y T

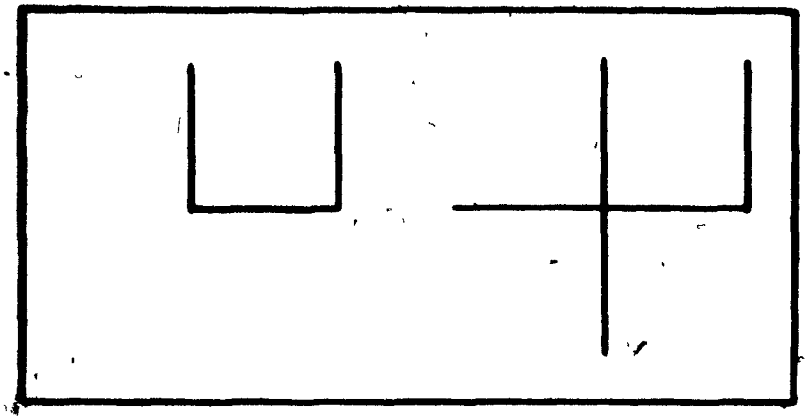
Triple Transformation Colour, Size, and Shape transformed

	Painted Shape	Correct Response
13. Demonstration #1	S B T	L Y R
14. " #2	L B R	S Y T
15. Problem #1	S Y R	L B T
16. " #2	S B R	L Y T

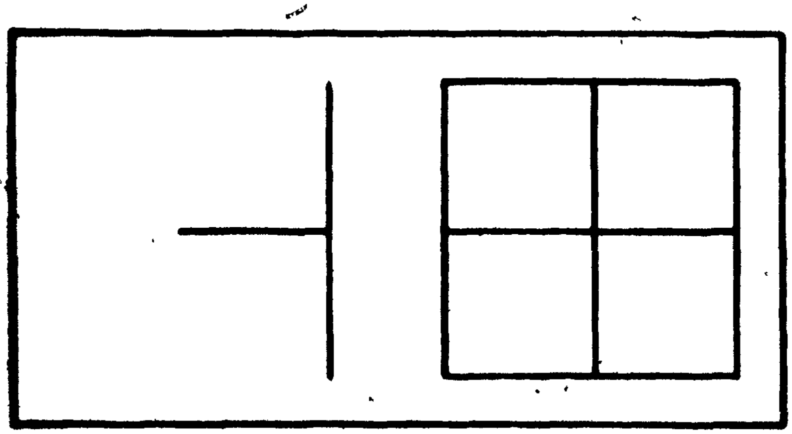
GOTTSCHALDT EMBEDDED FIGURES



In this space I have two drawings. Watch me color the lines in this one on the left. Now I want you to take a pen, and find the same lines in the drawing on the right, and then color them in. You should start here--(pointing). Good.

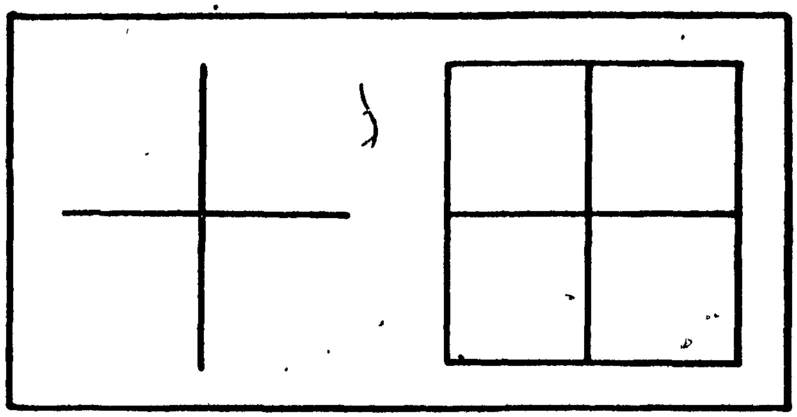


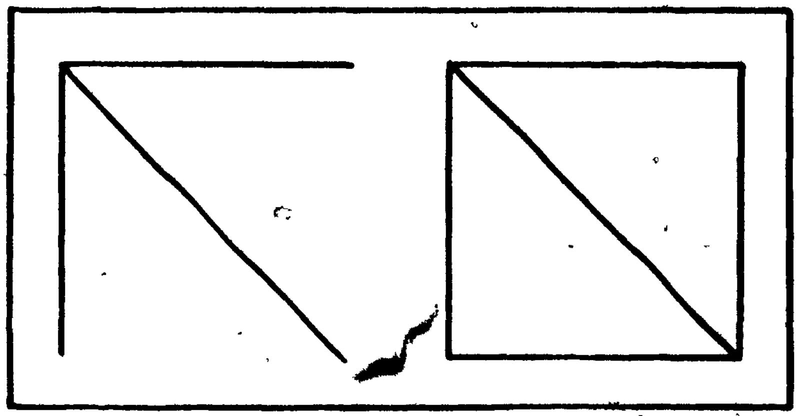
Now let us look at the next one. First we color the lines in the one on the left. Can you do that? Now starting here, we find the same lines hidden in the drawing on the right and we color those. Can you do that? Good.

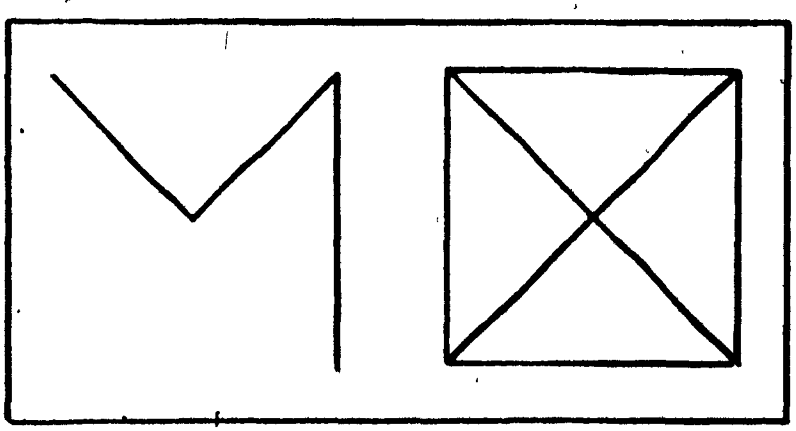


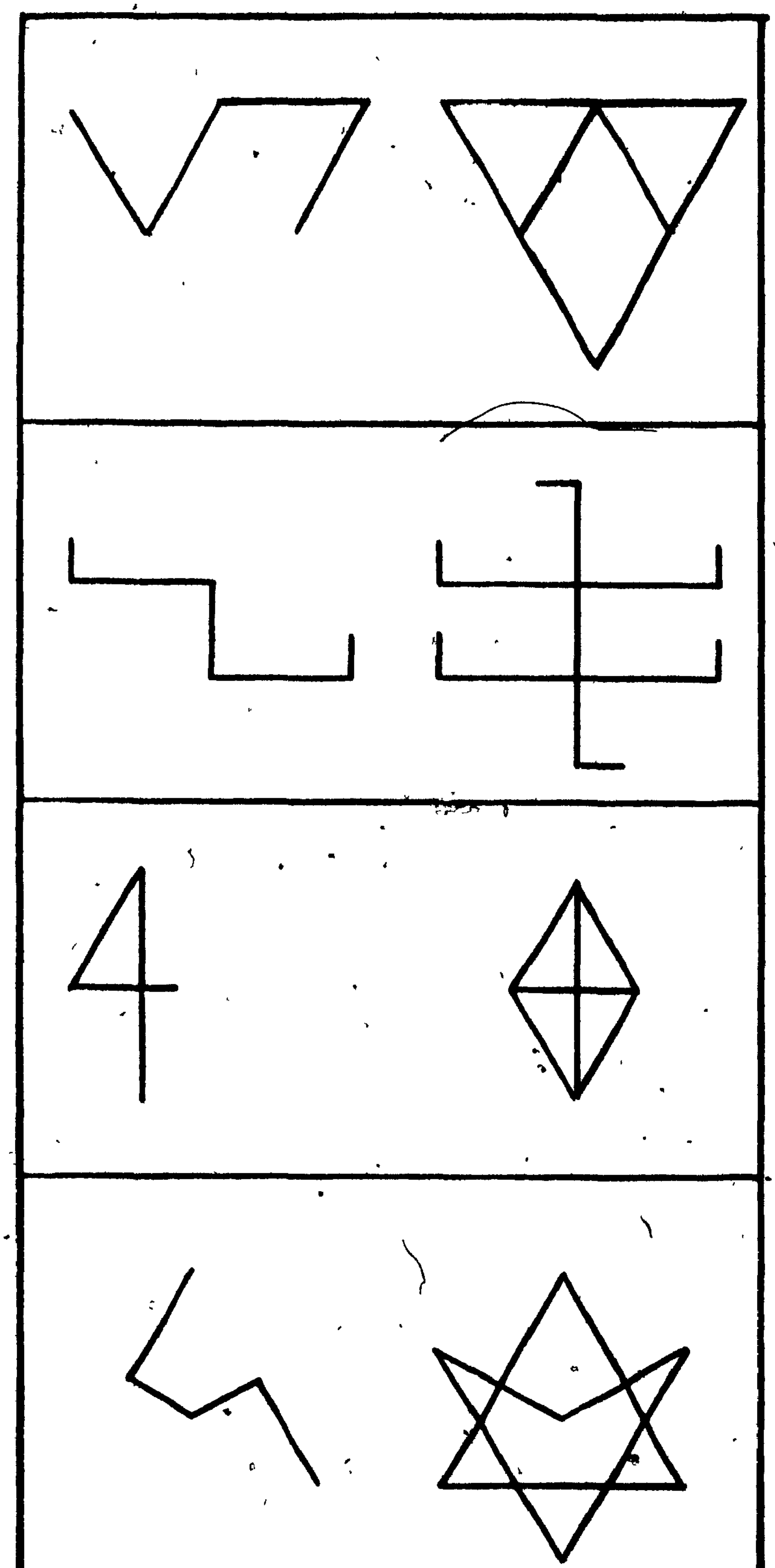
Now let us look at the third one. First, we color the lines of the drawing in the left. Good. Now we find the same lines which are hidden in the drawing on the right. Can you see them? Good. Now we color them.

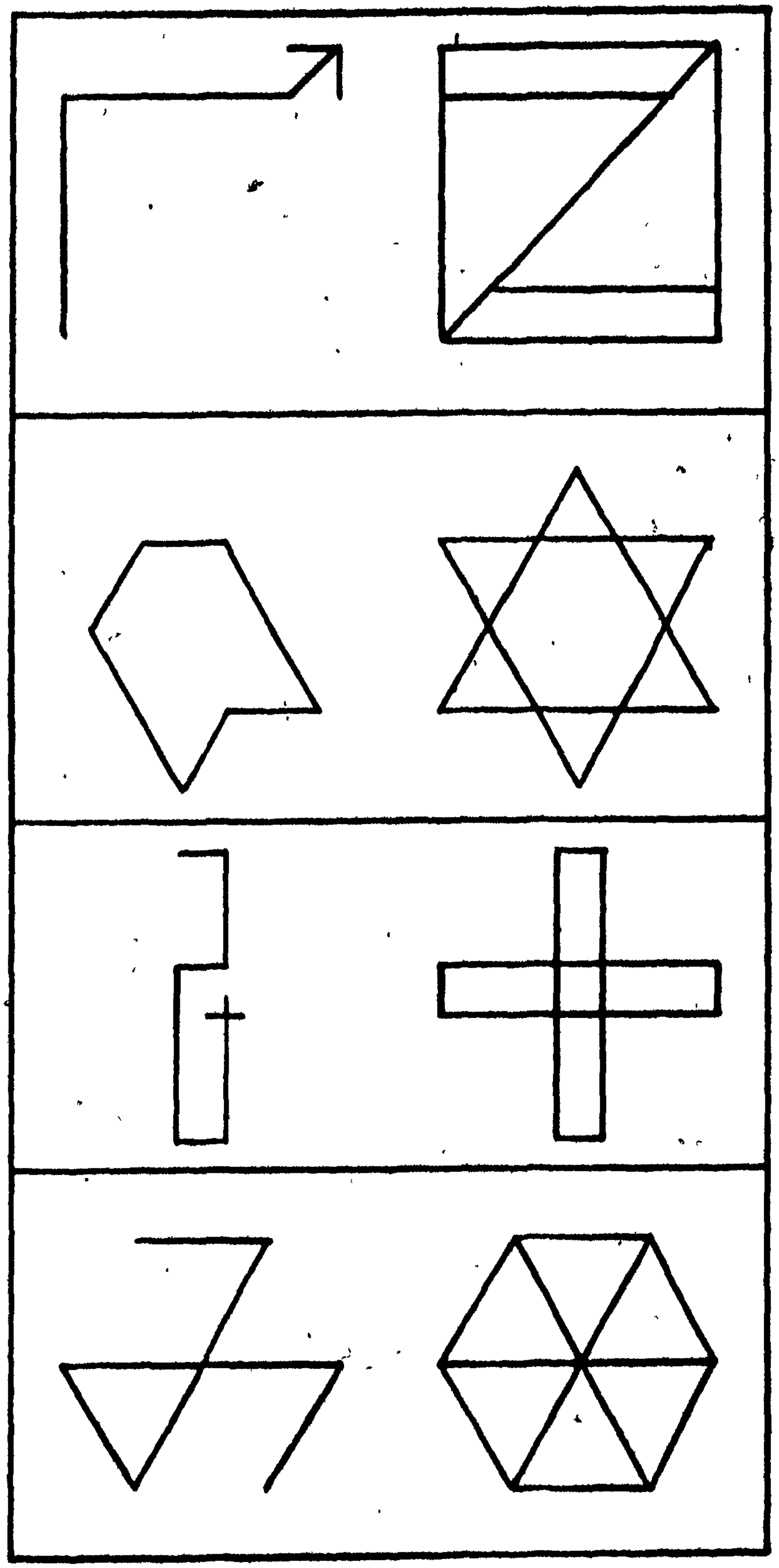
In all the remaining ones we do the same thing. First, color the lines of the drawing on the left. Then see if you can see where they are hidden in the drawing on the right, and when you can, you color them as well. Take your time, and we will do one at a time.

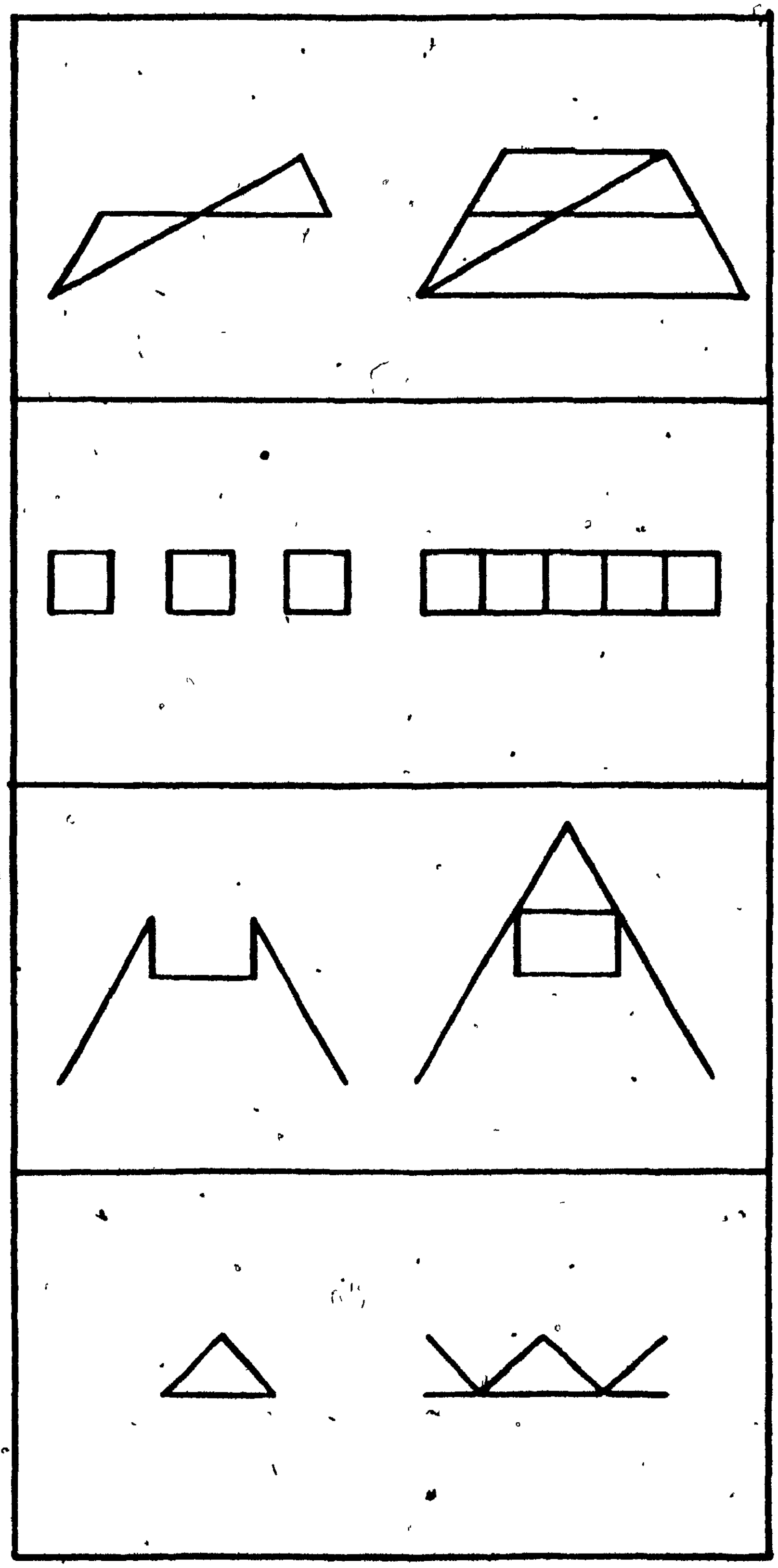


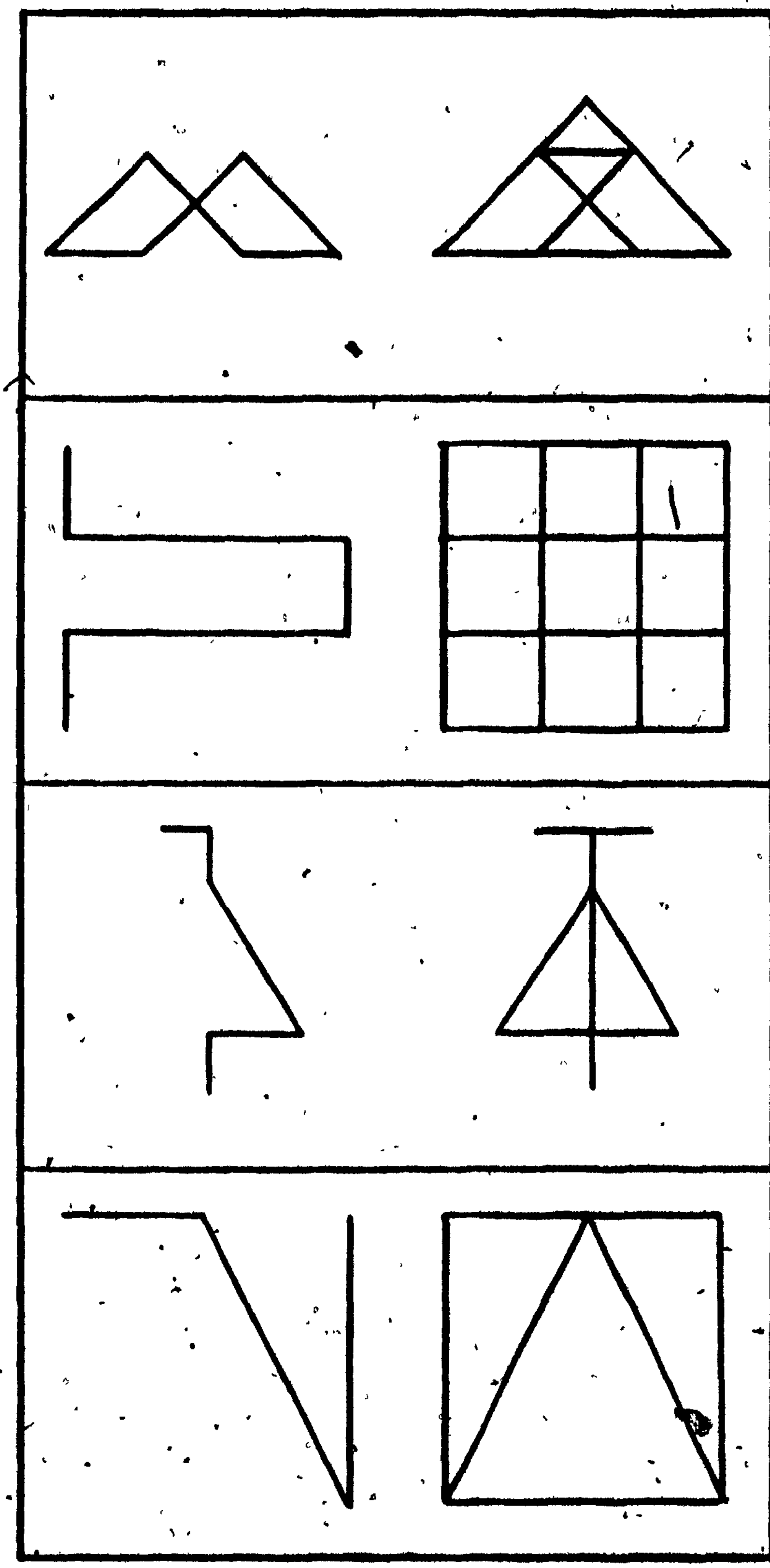












Appendix B

Correlation Coefficients

	VAR 1	VAR 2	VAR 3	VAR 4	VAR 5	VAR 6	VAR 7	VAR 8	VAR 9	VAR 10
VAR 1										
VAR 2	599									
VAR 3	390	266								
VAR 4	304	241	515							
VAR 5	117	158	212	394						
VAR 6	029	088	095	263	626					
VAR 7	370	500	361	201	157	126				
VAR 8	552	588	138	126	015	115	416			
VAR 9	223	207	082	063	-014	321	180	297		
VAR 10	001	044	099	152	223	278	-224	-088	392	
VAR 11	208	116	149	227	181	331	147	092	407	245
VAR 12	107	-067	141	038	087	173	170	146	197	-101
VAR 13	-013	048	-298	030	-074	150	014	-009	269	063
VAR 14	423	243	133	-009	-026	-048	253	248	261	-087
VAR 15	286	306	182	199	-103	058	355	158	306	043
VAR 16	221	126	143	017	076	082	209	165	179	-003

	VAR 11	VAR 12	VAR 13	VAR 14	VAR 15	VAR 16
VAR 1						
VAR 2						
VAR 3						
VAR 4						
VAR 5						
VAR 6						
VAR 7						
VAR 8						
VAR 9						
VAR 10						
VAR 11						
VAR 12	178					
VAR 13	180	122				
VAR 14	084	211	243			
VAR 15	-120	120	164	279		
VAR 16	136	128	226	162	-136	