A PSYCHOMETRIC STUDY OF ENGINEERING AND ARCHITECTURAL DRAWING, WITH EMPHASIS ON THE SELECTION OF PUPILS AND STUDENTS FOR TECHNICAL EDUCATION.

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by

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CHAPTER I

REVIEW

Introduction

Technical drawing is the language of a designer. It is spoken by the architect, the industrial designer, and the engineer. It is of great importance to modern society, but the psychological nature of technical drawing ability has not yet been revealed. A study of this ability would be helpful for an understanding of the mental abilities required of the designer, and would eventually give a guide to vocational and educational guidance and selection. With this is view, the writer attempted a psychometric study of architectural and engineering drawing abilities.

The architecture of a country has much effect on the psychological make up of the community at large. An architect is a scientist and sociologist as well as an artist. His work is not temporary in nature - it will influence the society for ages to come. The authorities of schools of architecture are conscious of their responsibilities. They know that only a few possess the talent to combine a gift of imaginative design with technical proficiency, but they are baffled how to find them from the hundreds of students who seek admission to their schools. This is a problem of applied psychology, and part of this investigation deals with the problem of selecting students for a school of Architecture.

It is generally agreed that children should be given the type of education that is most suited to their ability and nature - this is the key nota of the new system of secondary education as laid down in the Education Act of 1944.

The Norwood Report recommended a threefold differentiation of the post primary stage, viz:-

a) Technical School Education

b) Grammar School Education

c) Modern School Education

The problem of how to classify children according to their aptitudes now arises. Selection of pupils for junior technical schools takes place at two ages, 11 plus and 13 plus. The decision that has to be reached in selection at 13 plus is comparitively simple, because it is not complicated by the necessity of deciding between alternative courses as is usually the case at 11 plus. Much research has been conducted in this field, and results show that aptitude tests give better prediction than ordinary examinations. The writer has made an attempt to improve the existing method of selection of pupils for a technical school at 13 plus, and of students for a technical institute at 15 plus.

Ability and interest, as well as opportunity, are involved in educational success, but this research deals only with abilities.

This chapter carries a review of previous research in the same field up to 1952. In dealing with the background to this investigation, it seems best, first of all, to describe in a general way, the main results of the study of human abilities since the beginning of the century, gradually narrowing down to those aspects which have special significance for the present research.

The writer is particularly concerned with practical ability and artistic ability in relation to the selection of students for different types of technical education. This review gives a number of answers, or pointers to answers, to queries which have direct bearing on the present investigation. These queries are:-

1) Is it possible to measure special abilities, over and above general intelligence?
2) What is the role of special abilities in vocational and educational guidance and selection.
3) What is the psychological nature of "technical aptitude"?
4) Can this aptitude be satisfactorily measured by a group test?
5) How far are different types of practical ability tests related to each other?
6) At what age does this ability develop sufficiently to justify selection for technical schools?
7) What is the psychological nature of artistic ability and is it general or specific, innate or aquired?
8) To what extent does artistic ability depend upon general mental ability?
9) Is there any relationship between spatial ability and artistic ability?
10) Is it possible to measure artistic ability with objective tests?
11) What is the predictive value of practical ability tests in technical education?
12) Is there any predictive value in tests of artistic ability?

1. Early Tests to Measure Human Abilities.

As early as 1882, Sir Francis Galton (1883) attempted to measure mental capacity by psychological tests. His tests were designed to measure sensory powers, perception and discrimination, motor responses and memory. Galton's interest centered around the study of individuals, rather than groups.

Soon afterwards, J. McCattell took those tests from Germany to the United States where he devoted considerable time to the measurement of individual differences. In 1890 he published in "Mind", an article in which the term "mental tests" was used for the first time in psychological literature. However, doubts were thrown by Wissler (1901) on the value of sensory and motor tests, as measures of general intelligence.

Having failed in this line, testing gravitated into the sphere of mental process. Alfred Binet, a French psychologist, devised a new form of test in 1904, to separate the genuinely mentally deficient amongst school children, from those who had adequate educability. His success lay in the fact that he used everyday experiences as test items. He constructed his test on the basis of his idea of the nature of intelligence. Binet's scale, published in collaboration with Simon in 1905, opened a new era. Binet introduced the idea of "test norms", Stern the idea of "mental quotient", and later Terman gave the quotient its modern name initials, I.Q.

In the early 1900's, Thorndike compiled his famous C.A.V.D. test of intelligence, and in 1910 he published his handwriting scale. In 1917, Pintner and Paterson brought out the first well standardized scale of performance tests. At the same time, Cyril Burt, in England, was producing different types of tests. In the United States, Arthur S. Otis devised the famous Army Alpha and Army Beta tests - the Alpha test a group intelligence test, and the Beta test a non-verbal test constructed for use with illiterates and non-English speaking recruits.

The development of tests was greatly assisted by the use of statistical technique. Galton introduced the idea of correlation, and later, Karl Pearson gave the theory of correlation its present form. Spearman further extended the use of correlation in the factor analysis of mental ability.

2. Group factors in Different Theories of Human Abilities.

Spearman (1904), published in 1904, an article in which he reviewed in a critical way, previous tests. He discovered that the various tests of abilities showed more or less close correlations, and further, he noticed that their intercorrelations tended to form an orderly system or hierarchy. On the basis of his experimental findings, Spearman (1927) formulated his theory of general ability, or theory of two factors. According to this theory, when a table of intercorrelation between the scores of individuals on different tests exhibits the hierarchical order, an individual's performance can be explained in terms of two factors - one general g, and another specific s - peculiar to each and every test. Spearman refused to identify his g with intelligence, to avoid controversy. His g was involved invariably and exclusively in all operations of an eductive nature. He said that it depended on the general mental energy with which each individual was endowed, and that the effects of heredity upon g were very large.

Spearman's theory was contested by many other psychologists e.g. Burt, Thomson and Thurstone. Thomson (1916,'25,'35, '50) showed that an entirely different theory of intelligence would explain the fact of hierarchy. According to his "sampling theory", the mind is assumed to be made up of many Independent bonds or powers. When two different tests sample the same bonds, then a general or common factor can be said to exist between them. The "sampling theory" admits the general factor, group factors and specific factors. A test which is specific in one battery may be general in another, depending on the nature of the assembly of tests used.

Peel (1953) gave an alternative model to Thomson's. According to him the bonds have a central tendency and those tests sampling a similar number of bonds have to draw on the more "central bonds".

Burt (1949) is of the opinion that the mind has a hierarchical structure based on the specific sensory motor activities. In this theory there all types of mental abilities - general, group and specific. According to him there are four different levels in mental proccesses, each type of process being assignable, according to its relative complexity, to one or other of these levels. The lowest level consists of simple sensations or simple movements, which can be artificially isolated and measured by tests of sensory "thresholds" and by the timing of "simple reactions". The next level embraces the more complex proccesses of perception and co-ordinated movement, such as apprehension of form and pattern and compound reaction. The third level is the associative level, which includes memory and habit formation. The fourth and highest level consists of the apprehension or application of relations. "Intelligence" says Burt, "as the integrative capacity of the mind is manifested at every level, but these manifestations differ not only in degree, but also (as introspection suggests) in their qualitative nature." Recently, one of Burt's students, Moursy (1952), has isolated factors more in line with Burt's hierarchy.

It is apparent if we accpet Spearman's theory of two factors, that the use of tests in educational and vocational guidance would be very limited, since we would know nothing more about the testee than his general intelligence.

Spearman's inability to yield evidence of group factors may be attributed to the fact that he tested small groups of people in his experiments. Hence any residual overlap that appeared was usually not statistically significant - it was attributed to chance errors in the correlations.

As early as 1909 Burt suspected the existence of group factors. In 1917, he (1917) analysed marks in school subjects by his new technique of "simple summation" and found verbal, numerical and practical group factors in addition to the general factor. In a similar study of 613 10-year-old children, Burt (1939) found a verbal factor common to composition, reading, dictation, Art, Geography and Science. Many other studies were reported in 1921 at the symposium (1921) on "Intelligence and its Measurement". Thorndike, Matier, Wells and others stated that verbal tests and performance tests did not measure the same thing. Though the evidence of group factors was strong, it was not universally accepted. Davey, for example, considered that the two types of tests measured the general factor, and could be directly compared. Davey (1926) found a group factor running through most of his verbal tests. Brown and Stephenson (1933) in their attempt to test the two factor theory, gave a battery of 20 varied tests to

300 10-year-old boys. They noticed that the matrix of correlation did not conform to hierarchical order, unless the influence of the "specific overlap" amongst certain groups of tests was removed. Later Blakey (1940) re-analysed the same correlations by Thurstone's centroid method and was able to identify verbal, perceptual and spatial group factors.

In America, the resistance to Spearman's two factor theory of mental ability, already started by Thorndike, was developed by Kelly and Thurstone.

Kelley (1928) applied a battery of tests to three groups of children aged about 3½ to 6 years, 9 years, and 13 years. Analysing the result of each group separately, he established much the same pattern of verbal, numerical, rote memory, spatial and speed factors at each level. This finding led him to consider that these factors were little affected by teaching, were established early in life, and could be attributed to "original nature".

Thurstone developed his centroid technique of analysis in 1931. In 1938 he published the results of the factor analysis of scores by teams of 218 students aged from 16 to 25 in a battery of 56 tests. He could find no evidence of a general factor underlying all mental ability, but was able to isolate several primary group factors which might overlap each other. These were the factors of V - verbal intelligence, W - word fluency, N - numerical ability,-S- space or visualisation, P - perceptual speed, M - associative memory, I - inductive reasoning, and D - deductive reasoning.

Alexander (1935) applied Thurstone's method of analysis to the results of large batteries of verbal and non-verbal intelligence tests, and certain performance tests, given to 4 grou groups of subjects aged 11 upwards. Analysis of his data gave four group factors in addition to g - a v factor in the verbal tests, a practical factor F, common to some of his performance tests, a persistence or will to succeed factor, which he called X, and a factor Z, uninterpreted but proposed as related to school achievement.

The wisdom of multiple factor analysis (rotating the axis before attempting to identify factors) has been questioned by many investigators, but the evidence of group factors is irrefutable. Holzinger and Harman (1938), carried out an alternative analysis of Thurstone's data. They found the existence of g, as well as several group factors. Similar results were reported by Pemberton (1952) in his recent research.

Spearman, while asserting the existence of a general factor, considers that there can be "overlapping factors", and he thus admits the existence of group factors. Thurstone (1947), on the other hand, introduces a general factor among his second order factors.

Most psychologists today agree that group factors exist over and above the general factor, but they do not agree as to their relative importance. In both selection and guidance, the educational or industrial psychologist is almost compelled to admit the existence of special abilities. The existence of group factors makes it possible to differentiate between the different types of abilities necessary in various educational persuits and types of occupation.

Spearman (1927) once insisted that those who tried to measure special abilities were living in a "fools paradise" - though this might not be true, there is still no reason to be too optimistic.

Group factors are generally more limited in scope than the general factor. Various researches have shown that the g factor takes about 30 to 50 per cent of the total variance, whereas the group factors take only 10 to 20 per cent, and the specific variance takes the balance. Beyond the general factor, the overlap between tests and school or occupational success is very small. Further, in some research a separate group factor called X emerges, (Alexander 1935, Holzinger and Swineford '39, Bradford '46, Eysenck '47) from school marks, which makes the picture more gloomy. This X has been interpreted as a scholastic factor, influence by the personality, interest and industriousness of the pupil, and the "halo" effect of examination or assessment.

One of the concerns of this investigation is with technical aptitude, and in the next section an attempt will be made to evaluate its nature.

3. The Nature of Technical Aptitude.

"Technical ability" is a broad, general term used to denote ability in many branches of art and science, when emphasis is placed on practical skill, proficiency in the manipulation of tools and instruments, and ability in constructional work of all kinds. Burt (1947) said that practical ability was sharply distinguished from manual (or motor) ability and seemed to "depend largely upon the power to appreciate relations in space".

Different aspects of technical ability have been studied by different types of tests. Factorial studies reveal three important group factors - one underlying practical tests, one underlying mechanical tests, and one underlying tests of spatial relation. These factors are not entirely independent - there is a certain amount of overlapping, which suggests that they could be sub-factors of a broad group factor of spatial ability.

In an attempt to eliminate the influence of the verbal factor from tests of general intelligence, performance tests were devised. These tests are indispensable for testing dull and defective children who are handicapped verbally, and for testing illiterate or foreign adults. Burt (1947) maintained that individual performance tests were more effective than group tests of special aptitudes. Bradford (1948) also stated that non-verbal tests could not be safely substituted for practical tests. But in Peel's (1949) view, it is possible to find a paper test which would be as efficient as an individual performance test.

Early examples of performance tests are those due to Healy and Fernold (1911) and Knox (1914). Pintner and Paterson (1923) issued a modified version of these tests. Many other performance tests have since been published by psychologists e.g. Dearborn, Shaw and Lincoln, Arthur (1933), Alexander (1935) and Drever and Collins (1936). These tests have been widely used in clinics and for vocational guidance to measure the practical type of intelligence.

There has been some difference of opinion among psychologists as to whether or not these tests actually measure intelligence. Terman (1919) stated that since intelligence was the power of abstract and conceptual thinking, it could not be adequately measured by practical tests. On the other hand, Drever and Collins (1928) suggested that a good scale of performance tests was superior to a scale of verbal tests, since non-verbal tests were free from the effect of schooling. Gaw (1925) found sufficient positive inter-correlation between Binet's intelligence test and performance test to support the view that performance tests do measure general ability. Kohs (1923) reasoned that intelligence was the ability to analyse and synthesize, and that since both operations were brought into play by his block tests, they must be measurers of intelligence. Porteus (1924) the originator of maze tests, stated that success in his tests was mainly due to the complex which is ordinarily described as common sense. Spearman considered that performance tests were merely unreliable g tests. Alexander (1935) thought that practical ability could be measured by performance tests of intelligence. His research into concrete and abstract abilities led him to postulate a group factor F for practical ability, which in addition to g, was essential in such tests. The scores in the Pintner-Paterson picture tests, Kohs' Block Design tests, Cube Construction tests, the Pintner-Paterson form board tests, and Alexander's own Passalong test, were all influenced by the F factor to a certain extent. Later Yela (1949) re-analysed Alexander's data and confirmed his findings.

The main disadvantage of practical tests is that they are mainly individual tests. This makes it almost impossible to use them for large scale projects of selection. To overcome this difficulty, psychologists devised paper and pencil tests on the basis of the same principles as the Army Beta test. It was believed that the solution of a practical problem could be successfully achieved by the arrangement of imagery, prior to or simultaneous with the manipulation of the concrete data. On the basis of this assumption, the

N.I.I.P. started constructing tests like the Form Relation, Memory for Design tests etc.

Kelley (1928) identified a factor common to his space tests (power), meaningless symbols test, meanful symbols test, and arithmetic (power) tests. All these tests had something to do with the manipulation of spatial relationships, mentally.

In his search for a special factor over and above the g factor, in non-verbal intelligence tests involving the ability to deal with spatial material, El Koussy (1935) was able to isolate a group factor to which he gave the symbol **k**. In his experiment he gave a battery of 26 tests to 162 boys aged from 11 to 13 years. He used a modification of Spearman's tetrad difference technique, partialling out the influence of g, by means of the reference tests for g. He concluded "There is no evidence of a group factor running the whole field of spatial conception ... spatial tests are primarily tests of g. But some spatial tests involve a group factor over and above this g content. This group factor, called the k factor, receives a ready psychological explanation in terms of visual imagery". According to El Koussy, the letter k was suggested by the word "kurtosis". Burt (1949) maintained that it was orginally applied to the space factor because kinaesthetic imagery was believed to be essential for success in such tests.

Later, Emmett reanalysed El Koussy's results by the centroid method, and after rotation he was able to identify a group factor presumed to be k, in 17 tests of the battery, whereas in El Koussy's analysis the k factor was present in only 8 tests.

Thurstone (1938) included numerous spatial tests in his primary mental abilities investigation, and obtained a space factor to which he gave the symbol S. As S is most marked in tests involving the imaginative manipulation of shapes, many psychologists have suggested that it is obviously the same factor as El Koussy's k factor.

Holzinger and Harman (1938) and Eysenck (1939) analysed Thurstone's "Primary Mental Abilities" data by different methods and confirmed his findings.

In an attempt to isolate some of the components of ability in the complex known as mechanical aptitude, Thurstone (1951) applied a battery of 32 group tests of spatial ability to 350 boys - juniors in technical high schools. The intercorrelations among the 32 tests were analysed factorially, yeilding 9 interpretable factors. Of these the second factor seemed to be the most differentiating as far as mechanical experience and interest were concerned. Thurstone's interpretation was that the second factor S_2 represented the ability to "visualize a configuration in which there is movement or displacement among the parts of the configuration."

Emmett (1949) has gone one step further by suggesting that the space factor may be resolved into two independent spatial factors - one representing two, and the other three, dimensional perception. But this suggestion has not yet been proved experimentally.

El Koussy (1948) re-analysed Thurstone's "Primary Mental Abilities" data relating to space tests. He claimed that on the whole, the three dimensional tests provided a better measure of the space factor. He concluded "The deciding character does not seem to be whether the test is two dimensional or three dimensional, but that it calls for the ability to carry and manipulate the spatial material in the mind".

Emmett (1949) revealed that both the two and three dimensional sections of the Bains (1946) test were loaded with the same space factor, but the three dimensional section had the higher loading.

On the other hand, Renshaw (1950) found that on the whole the two dimensional section had slightly higher spatial loading than the three dimensional tests. He found no evidence of differentiation between the two types of tests. He concluded that the test which had the highest loading was the one in which "the subject has to visualize the form of an object, when it is moved to an alternative position, irrespective of whether the object is two or three dimensional."

Thurstone did not attempt to study the relationship between the two dimensional and three dimensional tests. But his latest study (1951), mentioned above, shows the superiority of three dimensional tests over two dimensional ones. Three out of four tests in his battery which had significant second factor S_2 loading were three dimensional in nature.

Cox (1928) studied the nature of mechanical ability with paper and pencil tests with pictures of mechanical models. These tests were mechanical diagrams, mechanical explanation, mechanical completion and mechanical models. He tested three groups of subjects - 114 elementary school boys, 84 commerce students, and 228 trained mechanics. He used the tetrad difference technique of factorization. The results showed the presence of more than one factor, i.e. besides the general factor, a group factor which entered into those operations in which the subject was called upon to deal mentally with mechanical movement. He called this factor m, the capacity for comprehending and employing mechanical relationship and principles. As to the genetic nature of m, Cox regarded it as an innate aptitude, rather than an aquired ability.

ElKoussy (1935) suggested that the group factor m depended to some extent on previous aquired knowledge of levers, pulleys etc., and was therefore not wholly innate. Some psychologists consider that m might be due to a special knowledge of and interest in mechanical things.

Alexander (1935) administered Cox's tests in his experiments described in earlier pages. In the youngest group the tests appeared to measure intelligence, but among the older youths they seemed to measure a special ability which could be identified with F.

Earle and McRae (1935) reporting on tests of mechanical ability, said that the nature of the m factor was "eductive thinking" and "spatial relations". These, however, could not be separated and a test such as the N.I.I.P. Form Relation test had both. This statement would seem to form a link between Cox's m factor and El Koussy's k factor.

Slater (1940) analysed the Cox and Vincent model tests in his study of spatial tests among apprentices. He used an adaptation of the Spearman-Holzinger bi-factor technique. His results provided no evidence to support the hypothesis that there was a special "mechanical ability" which could be differentiated both from general intelligence and spatial judgement. Kerr (1942) using a battery of verbal intelligence tests, spatial mechanical and clerical tests, together with certain school subjects, found a "mechanical and spatial" factor and thus confirmed Slater's findings.

Shuttleworth (1942) in seeking a battery of tests for selecting entrants to a junior technical school, used mechanical and spatial tests in a battery, and also included hand and eye co-ordination tests, tests of manual dexterity, group tests of intelligence and clerical tests. He identified two factors, one of which he called practical intelligence, and the other mechanical spatial aptitude. The loading of the two latter groups of tests in his factors were remarkably even, and seemed again to support the idea that there is a common element throughout tests of these two types.

Price (1940) investigated the relationship between Alexander's F and El Koussy's k factors. He gave a battery of verbal and non-verbal tests, space tests and performance tests to 85 university students. He analysed his results both by the Thurstone and the Spearman methods, and found two factors only. Accordingly, this investigation demonstrated that Alexander's practical factor F and El Koussy's k factor were substantially the same.

Drew (1944,'46) applied a comprehensive battery of tests to four groups of subjects : a) 181 boys at 11 plus, b) 172 boys at 12 plus, c) 118 boys at 13 plus, and d) 88 boys at 16 plus. The battery consisted of verbal intelligence, Spearman's gvk test and Alexander's performance tests, together with teachers' verbal ratings and practical ratings. The resulting four tables of correlations were analysed by Thurstone's centroid method. In groups A and B, three factors were identified - g,v and F. In groups C and D there were five factors - g,v,F,X and k. He concluded "The group test of spatial relations in the research, measures the k factor at 16, but not at 13. The spatial factor k is distinct from the F factor".

But Vernon (1950) pointed out the main fallacy of Drew's work as being his identification of F with passalong scores. He stated "This is the least reliable test in Alexander's battery, and when the Kohs' Block and Cube Construction tests are also considered, the identity of F with k is obvious.

Emmett (1949) also re-analysed some of Drew's figures, and he found a common factor in Alexander's battery, a k test, and a non-verbal g test.

Williams (1948) included Alexander's scale in an analysis of verbal, mechanical, spatial and non-verbal tests among 250 12-year-old boys. The v,m and k tests gave distinctive group factors, and Alexander's tests fell in the same cluster as the k ones.

Leff (1949) tested 176 boys of 12 years. She used verbal and non-verbal intelligence tests, spatial tests, mechanical tests and performance tests. She concluded that F and k tests did not appear to be measuring the separate kinds of special ability.

Gharieb (1949) tested four groups of Egyptian boys aged from 16 to 17 years. She identified five factors - g,F,k,p and X, a factor of schooling. She concluded that practical ability was complicated and included not only general intelligence, but also such factors as F,k and p. She said that the practical factor and the space factor should not be identified with one another. Gharieb's findings cannot be given much importance, because the number of boys she tested in each group was too small to get a reliable result by factor analysis. Also, the partition between k and F is not so distinct as he suggested.

Another type of test which attempted to measure mechanical ability was devised by Stenquist (1923). Stenquist used a number of simple everyday objects as his test material, which those taking part in the tests were asked to assemble. The scores were assessed both on the testees' success in putting together the parts of these objects, and on the time they took to complete the process. He obtained the correlation of the test scores of 6th, 7th and 8th grade boys with shop-work marks, and found that it varied from .42 to .90. The number of gases in each group was small (4 to 17) but all the correlations were significant at the 1 per cent level.

The same idea was incorporated in the Minnesota tests of mechanical ability, when Paterson (1950) and his colleagues set out to cover a varied range of activities which they considered measured practical ability. They included mechanical assembly tests, spatial tests, and a few dexterity tests. The results indicated the presence of a prominent general factor, presumably a mixture of g and k:m. Their packing block and card sorting tests showed a dexterity factor which overlapped into the first five mechanical and spatial tests.

Wittenborn (1945) analysed the Minnesota data by the centroid method. The results showed that assembly tests involve no factor which is not measured by paper and pencil tests of k, and information.

On the whole, the evidence is in favour of the view that there is a strong link between F,k and m. It may be, even, that the three groups of tests are associated with one and the same factor. Burt (1950) regards them as sub-factors of the fairly broad group factor of practical ability. Vernon (1949) is in agreement with this view. He says "A rather general practical or k:m type of ability does exist, but it is so amorphous and hetrogeneous that it would seem to be not so much a positive ability, as an aggregate of the non-symbolic capacities and abilities, unaffected by primary schooling. It is hardly possible in our present state of knowledge to identify the underlying or essential psychological nature of the factor. But we do know that not only mechanical and spatial, but also physical, manual and some non-verbal g tests, perceptual and performance tests, together with practical occupational abilities, have something in common on and above g". Vernon's k:m factor for practical-mechanical-spatial-physical abilities implies the close linkage between them.

Regarding sex difference, nearly all psychologists agree that boys are superior to girls in all forms of practical ability tests, but are poorer in linguistic tests (Emmett 1949). As Vernon (1950) suggests, this might be due to the operation of hereditary influences.

4. Evidence of the space factor at 11 Plus.

In most technical schools pupils are selected at 13 plus, though the Education Act of 1944 recommended selection at 11 plus. This is because the authorities are not convinced that the space factor is sufficiently mature at this age. Some psychologists think that the space factor does not develop until puberty or after. Burt (1921) asserted that the abilities of young children are less specialized than those of older children, and he questioned the wisdom of allocating children to different types of schools at the age of 11. "At eleven" Burt (1947) wrote, "the wide differences in innate general intelligence can be established with reasonable accuracy by means of standardized tests. But special aptitude and interests, especially those of a practical, technical or mechanical character, cannot be assessed very accurately at that age, except in a comparatively small proportion of cases". Alexander (1917) on the other hand, seemed to be more optomistic. He wrote, "Technical aptitude can be assessed with a sufficient degree of reliability and in a sufficient number of cases, (at 11 plus), to make allocation to technical courses possible."

McRae (1935) in an investigation into the vocational guidance of children, used both the Form Relation and the Memory of Design tests. He found that the abilities called into play by these tests could be measured with greater accuracy above the age of 12 than below 12. Burt (1941) in an experiment with 82 boys at 11 plus, gave construction and squares tests, together with the N.I.I.P. Group Test 70 and verbal and non-verbal intelligence tests. He found no trace of a factor associated with spatial judgement.

Slater (1940, '41, '43) in his experiments with children of 11 plus and 13 plus, found no space factor, whereas with trade apprentices aged about 18 years, he clearly found a factor running through almost all the spatial and mechanical tests. Slater's interpretation of his results was not convincing, because he identified the unrotated second factor for both groups as a verbal factor, on the grounds that the verbal factor has considerable negative weights, while spatial and non-verbal tests have all smaller positive weights. Although the magnitude of the weights varies, if the two poles of the factor are compared, this would still seem to be a verbal-non-verbal split, and to give some evidence of a possible bi-polar factor linking these tests. Adcock (1948) however, analysed Slater's data by both the multiple and group factor techniques, and found clear v and k factors in addition to g. Emmett (1949) also analysed Slater's data and found a significant third factor at 11 plus, associated with the spatial variables. He reduced his 17 variables to 9, by pooling the correlations of similar tests, and the correlations were factorized by Lawley's maximum likelihood method.

Evidence of a space factor around 11 to 13 years, and even earlier, has been reported by El Koussy (1935), Kelly (1928), Thurstone (1938) and others. Drew (1944,'46) also found a space factor in all his experimental groups with boys of 11, 12, 13 and 16 years. An alternative analysis of Drew's data was carried out by Emmett (1949) and confirmed Drew's results. Emmett also factorized by Lawley's method Mellone's (1944) data of the sub-tests of her 7 plus picture tests, and found a significant group factor, other than verbal, amongst both boys and girls. Another analysis was reported in the same article by Emmett with "The Moray House 11 Plus Enquiry Group". He factorized two verbal, two numerical, three non-verbal intelligence and two spatial tests. The spatial tests gave a distinct factor, which was none other than El Koussy's space factor k. Emmett asserted "The Moray House space test is almost as good a measure of g and k, as the verbal test is of g and v".

Peel (1949) set out to discover the average age at which the degree of specialization is adequately defined to justify selection based on specific aptitude. He gave nine tests to three groups of 70 to 80 boys and girls aged around 11, 12½ and 13½ years. In each group the second bipolar factor contrasted two performance and space tests with three verbal tests. Two non-verbal tests of g were intermediate between the verbal and practical spatial tests. Peel concluded "It appears that if a practical factor can be said to exist at the age of 13, it is equally evident at 11."

From the evidence given here it seems that the spatial factor is sufficiently developed at the age of 11 years to justify selection. Hence there are no psychological grounds on which to be hesitant to recommend enforcing selection for junior technical schools at that age.

5. The Predictive Value of Practical Ability Tests.

The main idea of constructing tests is to be able to predict success in the future. Since the beginning of test construction, the predictive value of practical ability has been evaluated. Persons highly endowed with the space factor will achieve success in subjects such as draftsmanship, woodwork, metalwork,modelling, architecture and most scientific subjects like biology, surgery and dentistry.

As early as 1919 Link (1919) showed the connection between tests involving spatial relations and success in practical work. He found that perception of form as tested by the form board and construction tests was essential for success in shell inspection and assembly and tool making. Paterson (1930), using a paper form board test with boys of the 7th and 8th grades, found a correlation of .55 with quality of shopwork, .57 with mechanical information, and .65 with a combined criteria.

The value of practical tests in vocational classification was demonstrated at a large scale research conducted by the Birmingham Education Committee. The committeee started its work in 1924 and six reports were published, (Allen and Smith 1931,'32,'34,'39; Hunt and Smith 1940,'44). Three of the reports dealt with vocational guidance given to boys and girls leaving school, and the other three dealt with the vocational selection of boys for skilled engineering work. It was revealed that if position in engineering school subjects was taken as indicative of success in school, the test battery was of more prognostic value than was the academic entrance examination. About 90 per cent of the youngsters who took recommended jobs reported satisfaction, while only about 30 per cent of those in "non-accordance" jobs did. Also, those who took recommended jobs retained their positions longer than those who did not. The control group, however, showed no difference.

Similar research was reported by Rodger (1937) in his study with 400 inmates of the Feltham Borstal Institute. Space tests were found to show larger differences in mean scores between satisfactory and unsatisfactory groups of fitters, plumbers and woodworkers, than differences found for similar groups of farmers, labourers, cooks and bankers.

In 1934 McFarlane Smith (1948) tested groups of boys aged about 13 years in Scotland with paper and pencil tests designed to measure ability to recognize spatial relationships, and to manipulate them mentally. He suggested that the group factor measured by these tests might be useful, for certain occupations, and that an improved form of these tests might prove of value in selecting pupils for technical courses.

Alexander (1935) gave a large battery of verbal and non-verbal intelligence tests and certain performance tests to groups of about 100 American secondary and technical school pupils aged from 16 to 17 years, and compared their test scores with school examinatia marks. The performance tests gave the highest correlations with shopwork.

Holliday (1940,'41,'42,'43) also demonstrated that space tests have predictive value of technical proficiency.

In a recent research Holliday (1950) pointed out the weakness of the common practice of selecting draftsmen at different levels, and he suggested that considerable improvement could be achieved by using intelligence and aptitude tests. According to him, "The ability to think in solid, which is at the very heart of Draftsmanship, is distinguishable from and relatively independent of general intelligence. And this ability is essential in all levels of Draftsmanship." He concluded that aptitude tests were more successful than intelligence tests in enabling subsequent success at the engineering drawing and design examination, to be picked out, and subsequent failures to be rejected.

Shuttleworth (1941) tested 109 students at 13 plus with mechanical tests, space judgement tests, eye-hand manipulation and manual dexterity tests, intelligence tests and clerical vocational tests. Also he obtained teachers' ratings on scholastic subjects after one year. He correlated the criteria first with the test scores and then with the results of the academic examination by which the boys were selected for the schools. The results showed that the tests gave a better forecast of success in technical courses than did the academic examination. Afterwards, he reduced his battery to four tests and suggested that the scores for these could be used to ascertain whether or not a boy possessed an aptitude for education with a technical bias.

Drew's researches were based upon the problem of selecting suitable candidates for pre-apprenticeship courses. On the basis of his results Drew (1947) concluded than an ability index on a scale that was weighted for g, coupled with an assessment for a special aptitude, constituted a sounder basis of selection.

Howard (1945) attempted to study Engineering Drawing at the junior technical school level. He gave 19 tests to 74 entrants at 13 plus, and compared the test scores with the results of his own Engineering Drawing achievement tests. The mechanical tests and spatial tests gave correlations with the criteria in the region of .45. He calculated the regression equation by Aitken's method with nine chosen tests and found the prediction to be as high as .7488.

Holzinger and Swineford (1946) found that space tests correlated highly with shopwork and mechanical drawing. Bradford's (1946,'48) research pointed to the same findings. He gave a battery of nine paper and pencil or performance tests to 105 technical school boys. He compared the test scores with examination marks on five varied subjects at the end of the first year. The practical tests and the k tests gave higher correlation with mechanical drawing than other tests. By factorizing, Bradford found a general factor and a bipolar factor separating all the school marks from all the tests. The first factor seemed to be of the gk type, rather than g alone.

In this paper, Bradford attempted to distinguish between the technician and the craftsman. The technician, he said, had to couple precision with ideas of function, whereas the craftsman had to couple precision with beauty. The technician was absorbed in functional arrangements rather than in feeling and personal expression.

Peel (1949) pointed out that the aesthetic aspect of craftwork had been neglected, and he devised a space test called "The Peel Group Tests of Practical Ability", which had a marked aesthetic quality. Peel (1951) found that his practical ability test correlated to the extent of .64 with Woodwork, in a population based on several modern schools. He reported correlation of the order of .4 and .5 between his practical ability tests and art and mechanical drawing in art school and technical school populations.

In a technical school with a highly selected population Peel (1949) found an average correlation of .283 with practical subjects (Woodwork, Metalwork, Technical Drawing). Two tests of a practical nature gave an average correlation of .263 with the same subjects. On the other hand, the average correlation of a Moray House test and the Otis test with the same subjects was .076. The superiority of the practical test and the space tests over the intelligence tests is apparent.

In America, standardized tests of engineering and science aptitude are widely used in selecting engineering students (Treumann and Sullivan 1949, McClanaham and Morgan 1948, Birdie and Sutter 1950, Birdie 1951). These "aptitude" tests, however, are more in the nature of achievement tests than of native ability tests i.e. scores are influenced by the amount and nature of previous training. For this reason, no account of these researches is given here.

During the last world war, psychological tests were widely used for personnel selection for forces in the United Kingdom and in the United States. Several follow-up studies in the British Forces by Vernon and Parry (1949) showed that k:m tests had relatively higher validities in work of a practical nature.

In one study of apprentice tradesmen, about 1,000 boys who took examinations and certain space perception tests on entry at 14 years, to a Forces Training Centre, were followed up over a period of 1 to 3 years, during which time they were trained in different trades. The results showed that the space judgement test and the assembly test had greater validity than other tests. A similar study with 850 naval artificer apprentices showed moderate correlations with such tests. In the A.T.S. squares test results were outstanding among draftswomen and certain anti-aircraft personnel. On the whole, the use of psychological tests in the Forces was not so successful as in schools. This was perhaps due to lack of suitable criteria. Also, it has been suggested, (Vernon 1950) that the tests which were devised for purposes of measuring school children's abilities, might not be applicable with the same confidence to adults, whose k:m factor was liable to alteration due to skills acquired in training and in hobbies.

6. Experimental Studies of Artistic Ability.

Artistic ability is not only essential in all forms of art activity and craftsmanship, it is also important in many science subjects, like plastic surgery, dentistry etc. Thus a person with good artistic ability is likely to find this ability of value in many spheres of life. The chief reason for attempting a study of aesthetic activities was practical rather than theoretical. For educational and vocational guidance and selection, it was necessary to determine the precise psychological nature of artistic ability, and to measure such abilities if they exist.

Fechner may be called the father of experimental aesthetics. He investigated the existence of the golden section of Zeising. Experiments of Pierce (1894), Puffer (1903), Angiers (1903), Bullough (1907) were concerned with balance, symmetry and proportion. Valentine (1914), Winch (1909), Williams (1933), Bullough (1908) and others, investigated the problem of colour preferences of children and adults. Bullough (1908) classified colour appreciation into four different types viz. physiological, associative, objective and character types. These early researches on experimental aesthetics were confined to the formal and colour aspects of appreciation.

However, tests of art appreciation were devised by Karweski and Christensen (1925), McAdorey (1929), Meier (1939) and others, to test the more complete aesthetic experience. Karweski and Christensen and McAdoery included paintings, architecture, dress materials, industrial design etc. in the material of their tests. But Meier preferred works of established merit to avoid the influence of changing taste.

Meier (1933,'36,'39) and his colleagues of the University of Iowa, produced a considerable amount of research concerning the nature and distribution of artistic abilities. In reviewing extensive biographical and experimental studies conducted over 10 years, Meier offered a theory of the nature of artistic talent. According to him six intellectual traits or factors were needed to account for the ability. Three of them - craftsman ability or manual skill, volitional perseveration, and aesthetic intelligence were primarily hereditary in nature; while the other three - perceptual faculty, creative imagination and aesthetic judgement, referred primarily to learning, although their development was conditioned by a "genetic constitution".

By hereditary, Meier meant "simply stock inheritance or, in other words, merely that the present individual comes from a line of ancestors who found the acquistion of skill in artistic pursuits relatively easy. The present individual, coming from the same stock, likewise finds the acquistion of the skills easy".

According to Meier, aesthetic judgement was one of the most important, if not the most important, single factor in artistic competence. He regarded it as the basis of success in the field of art. Artistic creation of all kinds, on analysis,could be reducable to the operation of a few relatively simple principles such as balance, harmony, rhythm etc. Meier's test of Art Judgement purported to measure the ability to recognize these functions. Meier claimed that his test was primarily a test of natural capacity, which did not depend upon general intelligence, information about art, general maturity or classroom training. In this test the colour aspect of art appreciation was neglected.

Meier's "factors" are not to be confused with "factors" of the mind. Much work of an exploratory nature has been done by the Iowa School, but the reults require the support of further work based on the modern statistical techniques.

In this country, valuable work has been done on aesthetic preference and appreciation by Burt, Dewar, Eysenck, Peel and others. They applied the method of person correlation to aesthetic rankings. Burt (1933) compiled 50 postcard reproductions of miscellaneous paintings and got them arranged in order of aesthetic merit by a group of artistis. He suggested that the correlation of the individual tested, with the standard, may be used as a measure of his capacities, and that a factor analysis of the correlation between persons may yeild more exact criteria for the determination of aesthetic types. Burt and his co-workers, Pelling, Bulley and Dewar, found that the test showing the highest reliability and the greatest validity was a mixed or omnibus test, rather than a homogeneous test. The matrix of person correlation was subjected to factor analysis, and they identified a "general factor of artistic taste", influencing the aesthetic judgements of the group of persons, and in addition, several less obvious factors, producing more specialized types of appreciation (somewhat similar to Bullough's types, and apparently related to more general temperamental tendencies.

Stephenson (1936) used homogeneous material - fifty reproductions of Japanese vases, all of "approximately equal merit". He found that the bipolar factor predominated, as would be expected from the nature of his test. He assumed that the bipolar factor measured "good and bad taste". It would seem that this bipolar factor was related to more general temperamental traits, rather than aesthetic differences.

Dewar, (1937,'38) used a modified form of Burt's picture postcard test. She applied the test to a group of nine professional artists and art critics, and analysed their order of preference by different types of factor analysis. She described the general factor as the measure of an individual's general powers of appreciation,and the bipolar factor as a different type of artistic appreciation, along the same lines as Bullough's types. The condition of Dewar's experiment was conducive to producing a strong general factor, for the test used was heterogeneous, and the population homogeneous.

Eysenck (1940) confirmed the discovery of a general and a bipolar factor in the appreciation of aesthetic material. He set out to construct a test free from all kinds of "irrelevant association", due to "civilization, technical excellence, or familiarity". He compiled 18 sets of pictures of wide heterogeneous material, representing all degrees of artistic merit, from reproductions of the masters, to the crudest birthday card. The 18 subjects who took part in his experiment were drawn from various walks of life. On analysing his data, he found a general factor accounting for 20.6 per cent of the variance, and a bipolar factor, accounting for 13.7 per cent of the variance. He defined the general factor as the general objective factor of aesthetic appreciation. As applied to persons, this factor is called "good taste"; T. As applied to pictures it accounts for what is called "beauty". And as applied to tests it is the measure of good taste. The bipolar factor seems to divide the "formal" from the "representative" picture.

In his next experiment, Eysenck (1941) set out to study the types factors in aesthetic judgements. He selected five tests with a view to making them "equal in goodness". He tested a group of 15 people which included artists, students, bank clerks, typists and teachers. Person correlations were obtained, and two factors were found to be significant. The first factor was similar to T, as found in the earlier experiment. By an examination of the items of each test, he guessed the nature of the bipolar factor K, which seemed to be related to brightness - restraint of colour content and theme. After constructing a test to measure this propoerty, he found that it correlated positively with temperamental tests of extroversion-introversion, radicalism-conservatism, youth-age, preference for colour-form, and preference for dull-bright colours. It would appear that Eysenck attempted to identify the bipolar factor by concentrating on the person's temperamnet, rather than the picture's artistic qualities.

Peel (1945,'46) devised a method for identifying aesthetic types in terms of the aesthetic quality of the pictures. His method could be regarded as an extention of the person-correlation technique. In Peel's method, a team of experts were asked to arrange the items not in order of liking, but in order of different artistic qualities, such as impressionism, realism, composition and colour, quality in technique etc. Now, a person's order of liking may be correlated with each of the orders on "criteria" as he called them, and an estimate of his aesthetic choice obtained in their terms. This method of analysis has been applied to several tests of abstract and representative painting and drawing. Thus with his Landscape Tests, Peel found that non-expert adults had a parked preference for "naturalistic" landscape paintings, and the artists, on the other hand, revealed a definite preference for "good composition".

Pickford (1940,'48a,'48b) pointed out that in studies of the psychology of art, the problems of emotional expression had been neglected by Peel and Eysenck, and he set out to test the hypothesis that the essentials of art and aesthetic appreciation are integrity of expression of emotions, and the use of harmoniously organised forms and designs. His (1948b) experiments with pictures and music showed a general or aesthetic factor, which, combined with form or design, emotional expression; and a bipolar "technical" factor, which contrasted rhythm, sentimentality, and accuracy of representation, with impressionism, colourfullness and symbolic qualities.

7. The Relation of Intelligence to Artistic Ability.

A considerable amount of research has been done in this field. As a criteria of artistic ability, different measures have been used, such as success in an art school course, marks in school examinations on art, teachers' estimates on drawings or paintings, tests of drawing and of aesthetic appreciation.

Burt (1921) found correlation between drawing and intelligence was not all together linear. He said that among children, intellectual ability usually controlled graphical ability, but graphical ability did not necessarily connote intellectual ability.

Cattell (1948) stated, "It has long been established that ability to draw involves a big special factor in addition to intelligence, indeed, the former is far more important than the latter (Spearman judges it as approximately four times as important) so that the border-line defectives sometimes draw extremely well, and highly intelligent adults may be unable to do so. Much indirect evidence suggests that this aptitude is largely inborn".

Goodenough (1926) constructed an intelligence test for children based on the drawing of a man. It yeilded an average correlation of .763 with the Binet scale of intelligence. Burt (1921) constructed a similar test which also gave correlation with intelligence tests. Draw-a-man tests cannot be regarded as a criteria of artistic ability, because in the scoring the artistic standard has been completely disregarded.

Lewerenz (1928) and Bryan (1942) found that intelligence tests were of little use in predicting success in art work, and Borg (1950) found no relationship between success in art courses and linguistic intelligence tests. Bottorf (1946), on the other hand, found that artistic ability correlated fairly well with intelligence among college students.

Meier included "aesthetic intelligence" as one of his six factors which went to make up artistic aptitude. His findings were based on a survey conducted by Tiebout and Meier (1936) in which the intelligence of 51 eminent artists in the United States was measured by the Otis self-administer test. It may be suggested that the assessment of intelligence was somewhat doubtful, because the tests were sent to them by post. "Aesthetic intelligence", Meier (1942) pointed out, "simply refers to those segments of general intelligence which permit the artist type to profit from past experience. Surveys have shown that the successful artist is usually an individual of superior or very superior intelligence". He concluded, "While very superior intelligence is not an absolute requirement for outstanding success in art, it is undoubtedly a very helpful adjunct, and in all cases, probably conditions the rate of progress and the eventual success of the individual."

In his study of genius, Terman (1930) found that without superior general intelligence, special ability in art fell short of really great achievement, but artistic ability was not a common attribute among his experimental subjects. It would appear that intelligence does not play a part - at least predominately - in artistic ability, although it is a necessary ingredient if success in an artistic profession is aimed for.

Dewar (1938) gave four tests of art judgement and an intelligence test to a group of 338 children. Art teachers' assessments based upon the children's artistic performances was also obtained. The intelligence test gave low, but positive correlation with the assessment and other tests.

Dewar also found that the different tests of aesthetic appreciation correlated together, even after the influence of intelligence had been eliminated. The intelligence test correlated higher with art judgement tests than with the criteria.

Barrett (1949) in his research with pupils in a high school, reported similar results. The intelligence test gave correlation as high as .55 with the Meier Art Judgement Test, whereas it gave a correlation of .21 with a criteria of art ability, based on four judgements on each of six different pieces of work.

Moore (1951) reported a correlation of .405 between Meier's test and Cattell's Intelligence Test Scale III, Form A, among students of dentistry.

It would seem that intelligence plays a larger part in art judgement tests and in art careers, than it does in actual art work.

8. <u>The Relation of Spatial Ability to Artistic Ability</u>.

Spatial ability has often been considered as an integral part of artistic ability. Two of Meier's "factors" of artistic ability are "manual skill" and "perceptual facility". Since, however, the Iowa studies were not based on factor analysis, it is difficult to say the exact nature of these factors, but they appear to involve spatial ability.

Jones (1922) concluded from a questionnaire sent to 200 artists that the artist type is a good visualizer. In his experiments with children, he found a correlation of .83 between his visual memory test and drawing ability.

Burt (1921) found that boys were infinitely superior to girls in his draw-aman test. Goodenough (1926), on the other hand found that girls did better than boys her her draw-a-man test.

The different findings regarding sex difference in these two tests is due to difference in the methods of scoring. Since Goodenough's drawings were scored mainly for the inclusion of appropriate details, rather than for the correct representation of shapes, it is not to be expected that the results would depend on the space factor. Barrett (1950) in a comparative study found that boys were superior to girls in art appreciation tests and in artistic ability as assessed by teachers. These findings give indirect evidence that the spatial factor is involved in the ability.

Oakley (1940) gave a drawing of a man test, together with the Standard Binet N.I.I.P. Test 34, Form Relation, Memory for Design, Cube Construction, Pictorial Completion and Mechanical Assembly tests, to 430 boys and girls. The test which had highest correlation with the drawing test was the Memory for Design Test.

Burt (1917) found three group factors in school subjects in addition to a general factor. The practical factor included handwork, drawing, writing quality and speed. El Koussy (1935) included marks in drawing and woodwork with the variables in his test battery. His analysis of the table of correlation showed that marks in drawing and woodwork had almost equal spatial loadings - .19 and .20 respectively. Morrow (1938) analysed the correlations obtained from a battery of tests of mechanical, artistic and musical ability. By factor analysis, he extracted two factors. The first factor was common to all the tests of artistic and mechanical ability, and he called it "analysis of spatial relations." The second factor, a bipolar factor, contrasted the mechanical and musical tests. This study showed some connection with between artistic and mechanical ability as measured by the Meier test, the Lewerenz test, and the test of mechanical ability.

Barrett (1945) showed that extreme scores obtained on the revised Minnesota Form Board, differentiated art majors from his control gooup. Borg (1950 a) found that art students scored higher on the Bennett-Fry test of mechanical comprehension, than would be expected from persons in non-mechanical occupations. In another study Borg (1950 b) suggested that a large perceptual factor is present in art school success, and probably in artistic ability. It is possible that this large perceptual factor is none other than the space factor k. All this experimental evidence leads up to the same conclusion that spatial ability is related to artistic ability.

9. Artistic Ability - General or Specific?

The prevailing idea that artistic ability is a compound of a number of more specialized abilities, has long existed. Thus Manuel (1919) showed that the concept of common ability was erroneous. Dreps (1933) was unable to find a single psychological characteristic present in persons gifted in graphic art. Meier considered that artistic ability was complex in nature, and included six general "factors" to account for this ability.

By factorial analysis of tests of aesthetic appreciation, a general factor for artistic ability has been established (Burt 1940,'49; Dear 1938, Eysenck 1940,'41) and others. This factor is idependent of general intelligence. It is also claimed that this general factor for artistic ability enters into not only all forms of visual art, but also into every manifestation of aesthetic taste, auditory or visual, verbal or concrete.

It must be bourne in mind that work in this field did not extend to examination of actual skills required in art work.

From the evidence reported here, it would appear that the "general factor of aesthetic appreciation" forms the core of artistic ability, and it may be said that artistic ability is an integration of this general factor, and a number of specific factors, such as manual dexterity, hand-eye co-ordination, the spatial-perceptual factor, and certain temperamental traits.

10. The Predictive Value of Art Tests.

The prediction of success in different fields of art activity is only in its earliest stages. A variety of tests of artistic ability have been devised for both purposes of educational and of vocational guidance. The Meier test of Art Judgement, the McAdoray Test of Art Judgement, the Lewerenz Test of Fundamental Abilities in Visual Art, and the Horn Art Inventory, are among the promising preliminary attempts in this field. The reliabilities and validities of tests are far too low to permit final judgement of talent from test scores of a single test. Moreover, intercorrelation of different tests is so low, that it may be assumed that it is measuring different aspects of the ability (Dewar 1938, Morrow 1938, Moore 1938, Barrett 1949,'50).

Drew (1938) gave her picture postcard test and three other art judgement tests such as McAdoray's, Meier's and Bulley's, together with an intelligence test, to a group of girls. These tests were compared with a criteria based on teachers' estimates of their creative ability. Results showed that the degree of art appreciation varied to a great extent with the content of the test. The correlation of the estimate and the average of all the art tests was higher (n = .42).

Barrett (1949) gave four art tests - Meier's,McAdoray's, Knauber's, Lewerenz's - and an intelligence test, to sixteen groups of pupils in a high school. An art ability criteria representing four judgements on each of six different pieces of work was obtained. The result showed that the critical judgement as measured by these tests does play a part in determining success in art. And these tests are superior to the intelligence tests in this field.

For example, the criteria gave a correlation of .35 with Meier's test, whereas with the intelligence test it gave a correlation of only .21.

Moore (1951) showed the usefulness of the Meier test in a field other than art. He included this test in his battery to predict success in a dental course. The correlations between the Meier test and teachers' assessments on operative dental surgery, children's dentistry and orthodontics, and oralpathology were .266, .514 and .255 respectively.

Conclusions.

Summing up, it can be said that since the beginning of the century there has been a rapid development in both the theoretical and practical aspects of intelligence and aptitude testing... largely due to the application of statistical methods to problems of mental testing.

The movement of mental measurement has been closely connected with the emergence of the theory of the structure of human abilities.

Psychologists have put forward various theories of mental structure, but today, all of them agree one one point - group factors exist over and above the general factor of the mind. These factors include the verbal (v), spatial (k or S), numerical (n), and aesthetic (T) factors, but it is with the spatial and aesthetic factors that this investigation is chiefly concerned.

The space factor is one which appears to be well established. It involves visual imagery, and is the key to success in practical work of all kinds. Spatial testing has indicated that the factor's genetic nature is mainly innate, and that it is sufficiently developed at the age of 11 to justify the use of spatial tests in selecting pupils for junior technical schools.

Factorial studies reveal that the three main types of practical ability tests - performance, mechanical and paper and pencil spatial tests - all measure the same space factor k. It is safe to say that performance and mechanical tests can be replaced by paper and pencil spatial tests, without impeding the predictive value. These tests are also more reliable, economical, and easy to administer, than performance and mechanical tests. There is some indication that three dimensional items are better measures of the spatial factor than two dimensional ones.

Although several standard spatial tests are commercially available, there is a need to devise new ones, in order to avoid familiarity, and to improve them with the knowledge gained from previous research.

It has been suggested that practical tests may be profitably used for providing additional information about pupils, when sorting out borderline cases for the various types of secondary education. This points to a need for constructing new performance tests.

The validity of practical ability tests has been well established, and today, these tests form a regular feature of selection of pupils for technical schools. More research, however, is needed to improve the method of selection.

The aesthetic factor of artistic appreciation, like the space factor, is fairly well established. This factor has often been identified with artistic ability, but artistic ability is not unitary in nature - it would appear that it is a complex of several specific aptitudes of which the aesthetic factor is the core. Artistic ability appears to be mainly innate, and is independent of general intelligence, while it appears to have a definite connection with the space factor.

Attempts to measure artistic ability have not been so successful as those to measure spatial ability. This is mainly due to the complexity of its nature. Most research gravitated into the field of artistic appreciation, and several tests of artistic appreciation were produced. Low intercorrelation between these tests suggest that they measure different aspects of the ability.

Art appreciation tests have been used for prediction success in the field of art, but research in this line is only in its very earliest stages. Results of this type of test indicate that they could be fruitfully used, not only in connection with art, but also in other fields where artistic appreciation is required.

It has been assumed that artistic appreciation is an integral part of design draftsmanship, and this is certainly true of architectural design. It is generally assumed that architectural drawing ability is an integration of artistic creation and technical proficiency. But there is no empirical evidence as to the exact psychological processes involved.

Another subject which calls for a thorough investigation is engineering drawing, because although this subject has attracted the attention of several psychologists, evidence of its psychological nature is very scrappy.

The success of test validation depends as much upon the criteria as the tests themselves.

In the researches outlined in this chapter, three types of criteria have been used as a measure of success - examination results, achievement tests and teachers' assessments. Examination marks are prone to be very unreliable and they are not very often used as a criteria of success in technical subjects. Neither can achievement tests be regarded as a reliable criteria, because they give spurious correlation with test results. Most investigators have accepted teachers' assessments as the most satisfactory criteria for success, because although these assessments are liable to be affected in a small degree by irrelevant influences, they are far more dependable than examination results, or achievement tests.

Most investigators in the field of aptitude testing have assumed that the ability under investigation is uni-dimensional and can be represented by a single criterion. But aptitudes are frequently complex in nature, and can not be satisfactorily assessed by a single representative measure, or by an arithmetical summation of scores into a single total.

Psychologists confined themselves to a single criteria, because the statistical means of predicting complex criteria were not available. But recent research* has overcome this difficulty, and it has provided the opportunity to explore the possibilities of predicting a complex criteria, by means of a battery of tests.

In composing their criteria, investigators have often included diverse subjects. But such a wide criterion may be too composite to justify estimating success by any single class of tests. Only criteria which are considered to be fundamental and peculiar to the aptitudes concerned, should be considered.

In multiple correlation, the ordinary procedure is to validate test performances by means of an external criterion, and in factor analysis they are validated with reference to an internal criteria. Most of the investigations outlined in this chapter failed to make full use of more than one type of validation, although in almost every new field of enquiry, both types of analysis are indispensable.

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* Peel (1947)

CHAPTER II

THE PROBLEM.

1. The Aims.

In one way or another, technical drawing influences every aspect of modern life, yet the psychological study of technical drawing ability has been curiously neglected. The previous chapter shows that the subject matter of practical ability and the nature of artistic ability, have been discussed in several researches. But there is no scientific evidence as to the mental processes involved in the different types of technical drawing. In view of this, it was felt that a study of architectural and engineering drawing would be helpful for an understanding of architectural and draftsmanship abilities. This study would be the stepping stone to vocational and educational guidance and selection in these fields.

The main reason for attempting to analyse these abilities is practical, rather than theoretical, because before they can be measured, it is necessary to ascertain, as far as is possible, their precise psychological nature. In this investigation an attempt has been made to measure, objectively, the abilities required of a technical designer, and to find a way of predicting success in the different fields of technical education.

Technical school pupils in the Birmingham area, where this investigation was undertaken, are selected on the basis of a qualifying examination, which consists of:

a) achievement tests (English and Arithmetic)

b) a verbal intelligence test

c) non-verbal tests - 1 intelligence and 4 spatial

Weights are given in the ratio of 2:1:1 for a:b:c. It would appear that this method is not entirely satisfactory for predicting success in technical education. Too much importance, it seems, is given to the v:ed factor, because although the value of the k:m factor has been admitted, its predictive value has not been fully realized. Further, the method of allocating the entrants into the Engineering and Building Departments is not without fault. Due to the higher prestige of engineering work, the top 50 per cent of the entrants go automatically to the Engineering Department, while the remainder are accepted in the Building Department. This investigation includes an attempt to effect some improvement in the existing method of selecting entrants, and also in allocating them to the different departments according to their aptitudes.

This work was extended to research on the prediction of success in a technical course, of a group of engineering apprentices aged 15 plus, attending a part time course at a Technical Institute.

As in the technical schools, the method of selecting students for the school of Architecture is also open to criticism. Prospective students are selected chiefly by means of an interview, at which their personality, interest and suitability for an architectural course are assessed. Since this method of selection does not give any consideration to the aptitudes of the students, it was felt that there is a need for an improvement. This enquiry set out to fulfil that need.

2. The Method.

Aptitude testing aims at the prediction of performance in a given subject, before definite training in that subject has been given. The fundamental assumption is that it is possible to put together a battery of tests, which, when administered to testees before the training starts, will predict success later. There is a further assumption that the criterion and the tests have certain elements in common (determiners) and that these elements are additive. The tests themselves are aggregates of these weighted determiners.

The first step in aptitude testing would be to study the whole process of the job activities under consideration, and to list the basic abilities underlined in such activites.

In order to estimate the success of the testees, teachers' assessments in different subjects may be taken as the criteria. A battery of tests is then compiled - e.g. intelligence, space perception, aesthetic appreciation etc., in order to measure the psychological traits revealed by job analysis. These tests are given to representative samples of the population.

On applying the product moment formula, the test scores and the criterion scores are intercorrelated, which may be symbolized as:

$$\begin{array}{c|c} R_{aa} & R_{ab} \\ \hline R_{ba} & R_{bb} \end{array}$$

The matrix of correlations is then factorized to find out how the variates group themselves, and to ascertain the tests which will predict the complex criteria efficiently. In factorizing, the centroid method of analysis is applied. If considered necessary, the group factor method of analysis is also carried out.

The usual account of test validation calls for a multiple correlation between the "predictors" (b variates) and an external criterion(a variates). The criterion is estimated by means of an equation:

$$u_1a_1 + u_2a_2 \dots + u_pa_p = w_1b_1 + w_2b_2 + \dots w_qb_q$$

where u and w are the vectors of weights assigned to the variates a and b respectively. Coefficients have to be found for the weights w_1, w_2, w_3 ... (regression coefficients) such that the correlation between the two batteries is maximum, giving arbitary weights to the criterion battery. This is done by means of a regression or prediction equation. The regression coefficients are determined by the formula given by Peel (1947)

$$w' = u'R_{ab}R_{bb}^{-1}$$

The maximum correlation is given by:

$$r_m = \sqrt{\frac{u'R_{ab}R_{bb}^{-1}R_{ba}u}{u'R_{aa}u}}$$

In addition, maximum prediction in the Hotelling sense is calculated to assign the weights u and w to the components of teams a and b, which cannot be equalized or excelled, no matter what other weights are chosen.

From a critical study of the multiple regression equations and the factor matrices, it is possible to throw some light on the psychological nature of the abilities under consideration.

3. The Population.

In composing the population for the prediction experiment, due consideration should be given to the following requirements:

1) The experimental group should, as far as possible, constitute a representative and unbiased sample of the population concerned.
2) Sound and reliable criteria to assess the success of the population should be available.
3) The number of individuals in the sample should be large, in order to minimize sampling errors.

While it is not very difficult to satify the third requirement, it is not so easy to obtain a representative sample, and at the same time a reliable criterion. A criterion is available only of those children who are already in the school, so the sample cannot be representative of the true population. The need of a reliable criterion necessitates the use of a homogeneous sample.

In this investigation, four groups of students are to be tested. The composition of these groups is given in Table 1.

Table 1.

The Composition of Experimental Groups.

School	No. students	Age range
A. School of Architecture (2nd,3rd and 4th year)	75	20 - 28
B. Selly Oak Technical Inst. (9 Preliminary Classes)	225	15 - 17
C. Broadsley Green Technical School (Engineering Dept Forms 1-6)	180	12 - 16
D. Ditto (Building Dept. Forms 1-6)	180	12 - 16

CHAPTER III

THE EXPERIMENTS.

1. Job Analysis.

The first step in the prediction experiments was to make a careful pscyhological analysis of draftsmanship and architecture, in order to gain an insight into the abilities required in the jobs. This analysis was used as a basis for the selection and invention of tests designed to measure those abilities, and for selecting the key subjects to compose the criteria. The fundamental resources of job analysis should come from first hand experience by the psychologist concerned, or from the opinions of experts. Since the writer had very little experience in technical fields, he had to depend mainly upon the views of people well acquainted with the subjects under consideration. Teachers, by virtue of their many years experience are experts in their subjects - they have acquired unique insight into the causes of success and failure of their pupils. In this investigation they provided the main source of information. Interviews with them were conducted through systematic interrogation, as well as through formal and casual contact. A few students from different classes were also interviewed to determine the exact nature of their difficulties and problems. As a result of these enquiries, it was revealed that the following mental qualities are required of the architect and draftsman:

A. The Architect:

i) General intelligence: The architect should have a high degree of general intelligence, to be able to unify the various formal, technical, social and economic problems that are connected with building. General intelligence also has direct bearing on the more theoretical aspects of architectural work, such as Structural Science, Mathematics etc. The architect requires all the essential qualities of intuition, reasoning, analysis and synthesis, in terms of the medium of space relations, as well as the verbal and linguistic medium.

ii) Spatial ability: Some degree of spatial ability is required in the make-up of the architect. He is called upon to visualize the appearance of objects in three dimensions from two dimensional diagrams, and vice versa. He is also required to retain visual images and to reproduce them later.

iii) Artistic-creative ability: Aesthetic judgement is one of the most important factors in architectural drawing. The architect has to organize his subject matter intelligently, through the masterful attainment of the functioning of principles. He needs creative imagination to give his work an aesthetic character, by organizing the parts in accordance.

iv) Drawing ability: The architect should be able to convey his ideas in drawings and sketches.

B. The Draftsman:

i) General Intelligence: In the first place a certain amount of general intelligence is required in the make-up of the draftsman. It has direct influence on success in the more theoretical lines of engineering work which the draftsman must learn. Moreover, the design draftsman should be distinguished from the routine draftsman. A man with average intelligence may be a very successful routine draftsman, but to be a design draftsman a high degree of intelligence is absolutely necessary, over and above other aptitudes.

ii) Practical ability: Engineering drawing demands a high degree of spatial ability i.e. the ability to visualize pattern and relationships. In the daily work of the draftsman, this factor is involved in his translations of two dimensional diagrams into three dimensional objects, and vice versa. The ability to draw and to read drawings, and generally to be able to think fluently in the solid, is the heart of draftsmanship.

iii) Aesthetic ability: This ability does not play any appreciable part in the make-up of the routine draftsman, but it is a vital factor in the case of the design draftsman. The design draftsman needs artistic ability, because in his work he has to combine efficiency with beauty.

iv) Drawing ability: Since the aptitude activity of draftsmanship is obviously of the pencil and paper variety, the draftsman should have the power to express his ideas quickly and clearly by means of freehand sketches.

To sum up, the analysis of draftsmanship and architecture revealed that the architect must be endowed with a high degree of intelligence (verbal and non-verbal), artistic ability and a certain amount of spatial ability. The design draftsman must be endowed with intelligence and artistic ability, over and above spatial judgement. But in the case of the routine draftsman, the space factor is of prime importance.

Over and above intelligence and aptitude, there are certain temperamental traits which contribute much to the making of a successful architect and a good draftsman. These, however, are beyond the scope of this investigation.

2. The Tests.

Having performed the psychological analysis of the jobs, the next step was to assemble a battery of tests to measure the trait complexes thus revealed. On the basis of the job analysis, 7 tests were selected from the existing pool of tests, and four more were constructed specifically for this investigation. These last were given a preliminary try out, and as the result of a careful item analysis, unsuitable items were rejected, and a revised version of the tests produced (See Appendix 1).

It will be seen that no attempt was made to select tests of high factorial validity. Factors measured by some of these tests are very much overlapping: the main consideration was to achieve high correlation with the criteria.

Each test was preceded by a short practise test, the purpose of which was to ensure that every subject understood what he had to do, and how to record his answers.

Table 2.

THE TEST BATTERY

	Abbrv.	Name	Source	Nature	Time	Items
1	Otis	Otis Group Intelligence Scale, Advanced Exam.	Otis George A Harrop & Co. Ltd.	Verbal Intelligence test	42	20
2	V-14	V.S.14 Part I	Peel, E.A Unpublished	Verbal Intelligence test	13	53
3	S-14	V.S.14 Part II	"	Spatial test 2-D Design	25	46
4	Mat.	Progressive Matrices	Raven J.C.	Non-verbal Intelligence test	40	60
5	TS.8	T.S.8.	Peel, E.A Thos. Nelson Ltd	Spatial test 2-D Design	20	54
6	MH.S	Moray House Space Test	Bain, J.T, Ed. Dept. Moray House, U of Edbgh	Spatial test	31	100
7	F.R.	N.I.I.P. Form Relation Test	Earle & McRae N.I.I.P.	Spatial test	18½	40
8	P&E.	Plan and Elevation Test	Experimental	3D Spatial test	19	50
9	3D.S	3 Dimensional Space Test	"	"	16	35
10	Draw	Drawing Test	"	Drawing Ability test	40	4
11	Blck	Block Test*	"	Performance test	20	40
12	M.AJ	Art Judgement Test	Meier, State U of Iowa	Aesthetic appreciation test	40	100

* For School of Architecture Pupils the time was cut to 15 minutes.

Table 2 gives the names of the tests used in the experiments, together with details of the number of items they contain, the time allowance, and the sources.

This battery of tests was considered to be satisfactory in view of the limitations as far as time and other facilities were concerned. The battery covers almost all the hypothetical traits revealed by job analysis.

3. A Short Description of the Tests Used.

i) Otis Group Intelligence Scale: The Otis test is an instrument to measure native mental ability. It is a verbal intelligence test containing 10 sections i.e. following directions, opposites, disarranged sentences, proverbs, geometric figures, arithmetic, analogies, similarities, narrative completion and memory. It has been used extensively by the United States Army, as well as by educational authorities and industrial psychologists.

ii) Raven's Progressive Matrices 1938: The Progressive Matrices test was constructed by J. C. Raven on the basis of Spearman's principles of noegenesis. It is a test of the analogy type. It consists of 60 problems, divided into five sections of 12. The Progressive Matrices test was used extensively as the primary general intelligence test in the services during the last world war. Numerous factor analyses have shown that this test is almost a pure g test, but it also involves the spatial factor to a small extent.

iii) V-S 14 Test: The V-S 14 test was constructed by E.A. Peel. It consists of two parts - verbal intelligence and practical ability. The verbal part is of the multiple choice and creative response type, and consists of analogies, opposites, synonyms, mental arithmetic and dial

The practical part is a spatial test which requires a sensitive reaction to form and pattern. Two of the three sub-tests consist of a series of time patterns, in each of which there is a deliberate fault. The subject has to first grasp the basis of the pattern, then discover the fault and mark it with a cross. The third sub-test is simple matching - two similar patterns are printed side by side, one correct all the way through, and the other with a single fault printed in a rotated position. The subject has to turn round the figure mentally, find the part which is different from the others, and mark it with a cross.

iv) The Peel Group Tests of Practical Ability: This test, similar to the non-verbal part of V-s 14 was devised by Peel for younger children. The solution of two sub-sections requires an appreciation of the essential form of patterns. The third sub-section, one in which two diagrams are printed side by side, requires part by part comparison. The test is primarily one of spatial ability, but it also appears to possess a marked aesthetic quality. This test gives an appreciable correlation with shopwork, technical drawing, craftsmanship and art work.

v) The Moray House Space Test: This is a spatial judgement test devised by J.T. Bain. It embodies a space factor, the essence of which is the use of visual imagery for the mental manipulation of space relations. The test includes different types of spatial problems, such as knots, surface counting, identification of alphabet parts, similarities, block counting, block construction etc. It has 100 items divides into five sections - 39 items are three dimensional in nature, and the rest two dimensional.

Factor analysis shows that the three dimensional items have higher spatial factor loading than the two dimensional ones. This test has been widely and fruitfully used in the classification of children for courses in technical subjects requiring spatial judgement.

vi) Form Relation Test: This test was constructed by Earle and McRae in 1925 for the N.I.I.P. The subject is asked to identify shapes that will fit exactly into other shapes from which pieces have been cut. Rotations and reverslas are introduced. The test has eight section, each containing five items. The last two sections deal with objects in three dimensions.

The test has been widely used both for vocational and educational selection, as a test of spatial judgement, and for predicting success in technical subjects like Wood-work, Metalwork and Engineering Drawing. Many factorial studies of the test have been calculated to have loadings on the k factor ranging from .4 to .6

vii) Plan and Elevation Test: The Plan and Elevation Test was devised by the writer to measure spatial ability involved in the translation of two dimensional figures into three dimensional figures and vice versa. The test has 58 items, divided into nine sections. In the first section, the subject is required to identify a plan or side view for models drawn in perspective. In the second section the process is reversed - the testee is asked to find the models for plan or side elevation drawings. This test was initially given to 100 pupils aged 13 plus in a modern school, and compared with technical drawing ability as assessed by teachers. The correlation coefficient was .65.

viii) The Three Dimensional Space Test: The 3D-S test was designed specifically for this investigation, to measure the three dimensional aspect of spatial ability. The subject is required to visualize a configuration in three dimensions. He is asked to identify shapes that will fit into other shapes, from which pieces corresponding exactly to the first shapes have been cut.. The testee has to imagine that the pieces are picked up, turned over, round, or both, and to join those pieces to complete the original shapes. The test has six sections, each containing six items.

ix) The Block Test: This test is a performance test devised specially for this investigation. It is a modified and enlarged version of Peel's Practical Test 3. In each test item, the subject has to place one or two blocks and assemble them according to two diagrams, a plan, and a front elevation. The test consists of 40 items, 19 of which have one block, and the reamining 21 two blocks, each. They are arranged according to difficulty. Only entirely correctly placed items are credited - no credit is given for one block test being placed correctly in those items which contain two blocks.

This test was tentatively used in a modern school (100 boys at 13 plus) where it gave a correlation of .47 with general practical ability as assessed by teachers on a five point scale. In another study with 18 boys and girls in an art school, low but positive correlation with industrial design was obtained.

x) The Drawing Test: Since technical drawing activities are obviously of the paper and pencil type, a battery would not be complete without a drawing test. To meet this requirement a simple test of drawing ability was constructed. If consists of four photographs of objects - a wooden block, two wooden blocks assembled together, a tennis ball and a jug. The testee is asked to copy them in full size, without giving too much attention to details. The assessment on each separate item was done on a three or five point scale.

This test was tentatively given to a group of 18 students from an art school, and compared with teachers' ratings on industrial design - it gave a correlation of .43.

xi) Meier Art Judgement Test: This test ia an outcome of the Iowa investigation of artistic ability. The test studies the extent to which the subject is a good judge or appreciator of aesthetic qualities. The test material is devised on the basis of works of established merit. The subject is presented with two versions of the same picture, almost identical, yet one having some principle such as form, balance, rythym etc. impaired. The test is to decide which of the two presentations is the more pleasing. The record sheet tells the subject what aspects of the composition have been altered. The test contains 100 items - no time limit is imposed. In the present investigation a time limit of 40 minutes was imposed. This limit, however, gave ample opportunity for the testee to attempt all the items in the test.

4. The Criteria.

The question of a sound and reliable criterion is one of the most difficult problems in prediction studies. In this investigation, the subjects were students, so no estimate of their success in work and in life was obtainable. It is hoped that if a satisfactory selection procedure can be devised for schools, it could be modified and adapted for predicting success in occupations. Hence, achievement in school work was used as the criteria of success.

Teachers were asked to assess on a 15 point scale, the abilities of their pupils on the basis of all-round school performance. The 15 point scale was selected, because it appeared to give the right amount of discrimination that the teachers were capable of making, and the number of intervals was convenient to use in correlating the results of the tests.

In preparing this scale, no set frequency distribution was used, but the teachers were asked to make full use of the 1 to 15 point scale, eight being taken as average. Thus it was ensured that there would be a tendency for clustering about the average. Irrelevant influences such as the "halo" effect entering the assessments were fully discussed.

At the Broadsley Green Technical School, the population is made up of boys ranging in age from 12 to 16 years. Pupils are divided between the Building department and the Engineering Department, and in both departments there are six forms, each consisting of approximately 30 boys.

Because of this it was difficult to obtain a satisfactory criterion for each department as a whole. But this obstacle was overcome by obtaining the assessmnents of teachers in the junior forms, through whose hand all the boys in the school had passed.

These teachers combined their opinions with those of the form masters throughout the school.

This problem did not arise when dealing with the other two populations tested, because samples of each student's class work were available, and assessments were based on the combined opinions of the various class teachers.

No attempt was made, when choosing the criteria, to include all the subjects taken by the students concerned - only those aptitudes which were considered to be fundamental and peculiar to the courses concerned were taken into consideration.

The criteria used were as follows:

A. School of Architecture:

1. Architectural Design
2. Building Construction
3. Structural Science
4. Building Science.

B. Technical Institute:

1. Engineering Drawing
2. Mathematics
3. General Science

C. Technical School, Engineering Dept.:

1. Engineering Drawing
2. Geometry
3. Woodwork
4. Metalwork

D. Technical School, Building Dept.:

1. Building Construction
2. Geometry
3. Carpentery Joinery.

5. Pilot Testing.

All the tests were first tried out with two small samples (21 trade apprentices aged 14-16 years, and 18 art students aged 17-23 years) to ensure that the tests were not too difficult, and that they obtained ample head room at the highest age at which they could be used. Some adjustments were made regarding the time limit for the T.S-8, V.S-14 and Block tests. The 3D-S test was found to be too difficult for the younger students.

6. Administration of the Tests in the Final Experiments.

In the Broadsley Green Technical School most of the testing was carried out by the teachers in charge of their respective classes. To ensure uniform conditions, a conference was held with the teachers, where the technique of test administration was discussed fully, and every teacher was provided with a copy of detailed instructions. In the other two schools the tests were administered by the writer, each class of 20 to 30 students separately. Testing was done in the morning, between 10 a.m. and 12 noon, one test each day. On the first day an easy and interesting test was placed, and the more difficult ones were introduced gradually. Care was taken, as far as possible, not to repeat the same type of test on two days running.

In all, there were over 5,500 scripts. These were corrected by the writer. Assisstance was given by the staff and students of the Education Department in administering and scoring the block test.

CHAPTER IV

STATISTICAL ANALYSIS.

For the convenience of discussion, the statistical analysis has been divided into three sections:

A. Preliminary Analysis

B. Factor Analysis

C. Multivariate Analysis

SECTION A

Preliminary Analysis.

1. The Distribution of Scores.

First of all, the distribution of the raw scores of the tests, and the criterion scores was graphed in histogram form. (See figs 1 - 52). This was done to ascertain the level of difficulty of the tests for the subjects. Inspection of the histograms showed that most of the tests and the criteria were skewed negatively.

Then the Means, Modes and Standard Deviation of each distribution were calculated. After that, each distribution was compared with a normal distribution by means of the χ^2 test. The formula for chi-square was:

$$\chi^2 = \sum \left[\frac{(f_o - f_e)}{fe} \right]$$

where f_o frequency of occurence of observed facts

f_e expected frequency of occurence.

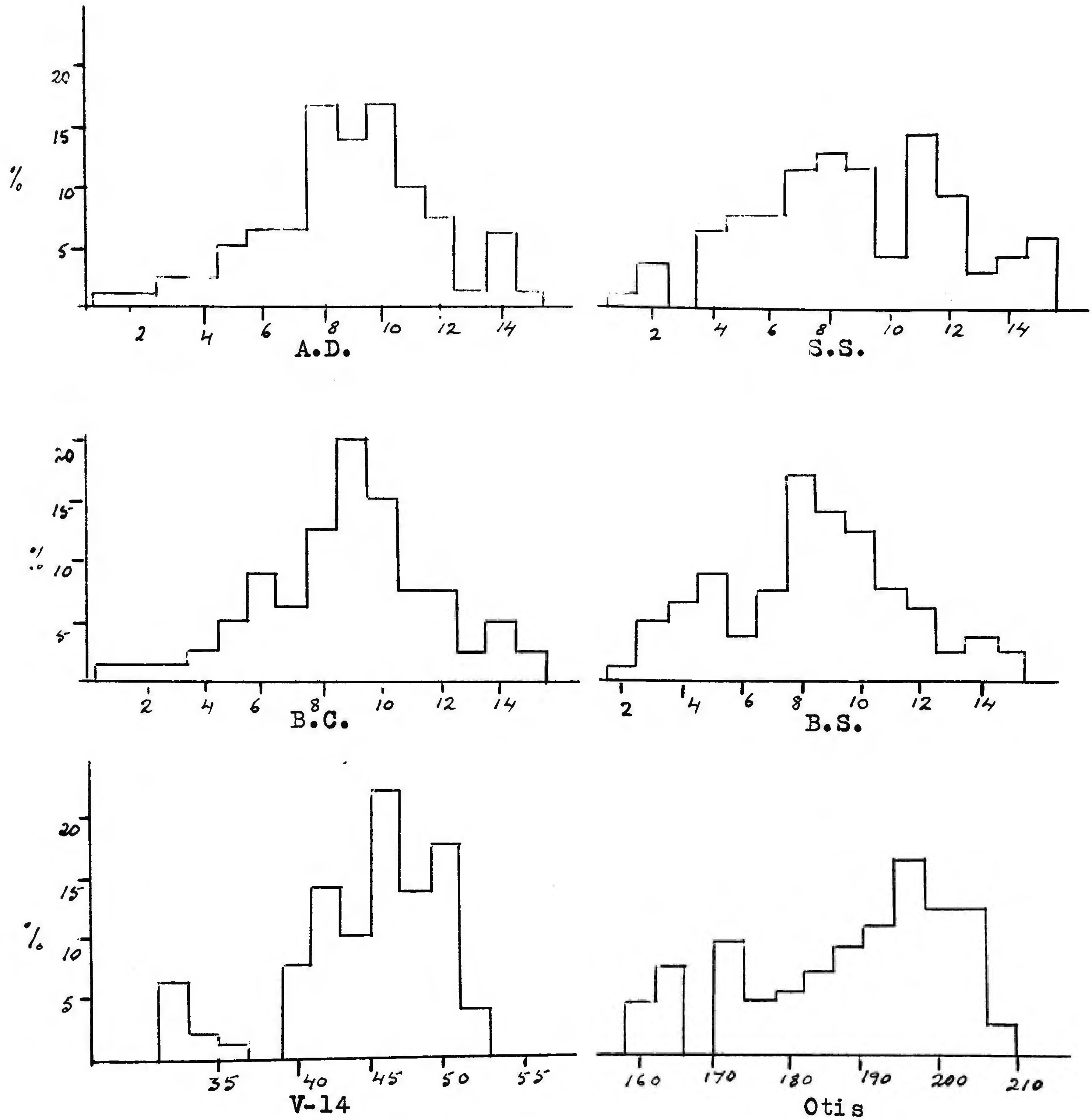
By using Fisher's table of χ^2 with the correct number of degrees of freedom in each case, the results given in the last columns of Tables 3 - 6 , were obtained. The degree of freedom was n-3. To reject the hypothesis of normality, the χ^2 would be less than that shown for the 5 per cent level (p = .05). It was found that most of the tests and the criteria were not distributed normally. The question then arose whether or not to normalize the score distribution before calculating the correlation, because the theory of correlation is based on the assumption that the variables are normally distributed. To study the effect of skewness upon the correlation coefficients, the distributions of one assessment score and three tests were normalized and the inter-correlations before and after were compared (See Table 7). The difference was insignificant in comparison to the standard error of the correlation, and it was decided, therefore, to correlate the raw scores directly without normalizing them.

Table 7.

Difference in r: Before and After Normalization

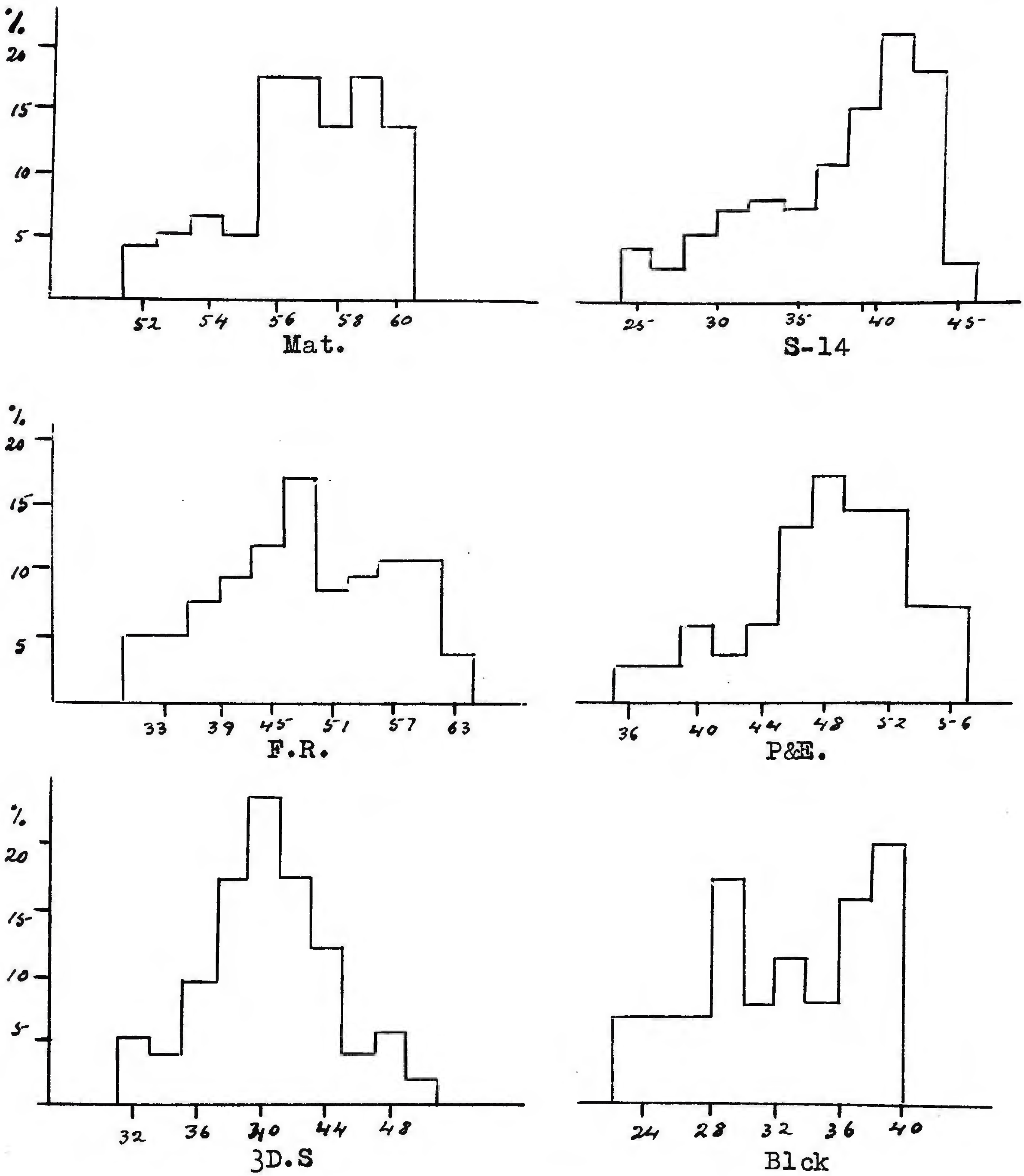
Technical School: Engineering Department.

	E.D.	Otis	M.H.S.	S.E.r
E.D.				
Otis	.0083			
M.H.S	.0175	.0281		.0745
P&E.	.0159	.0090	.0237	



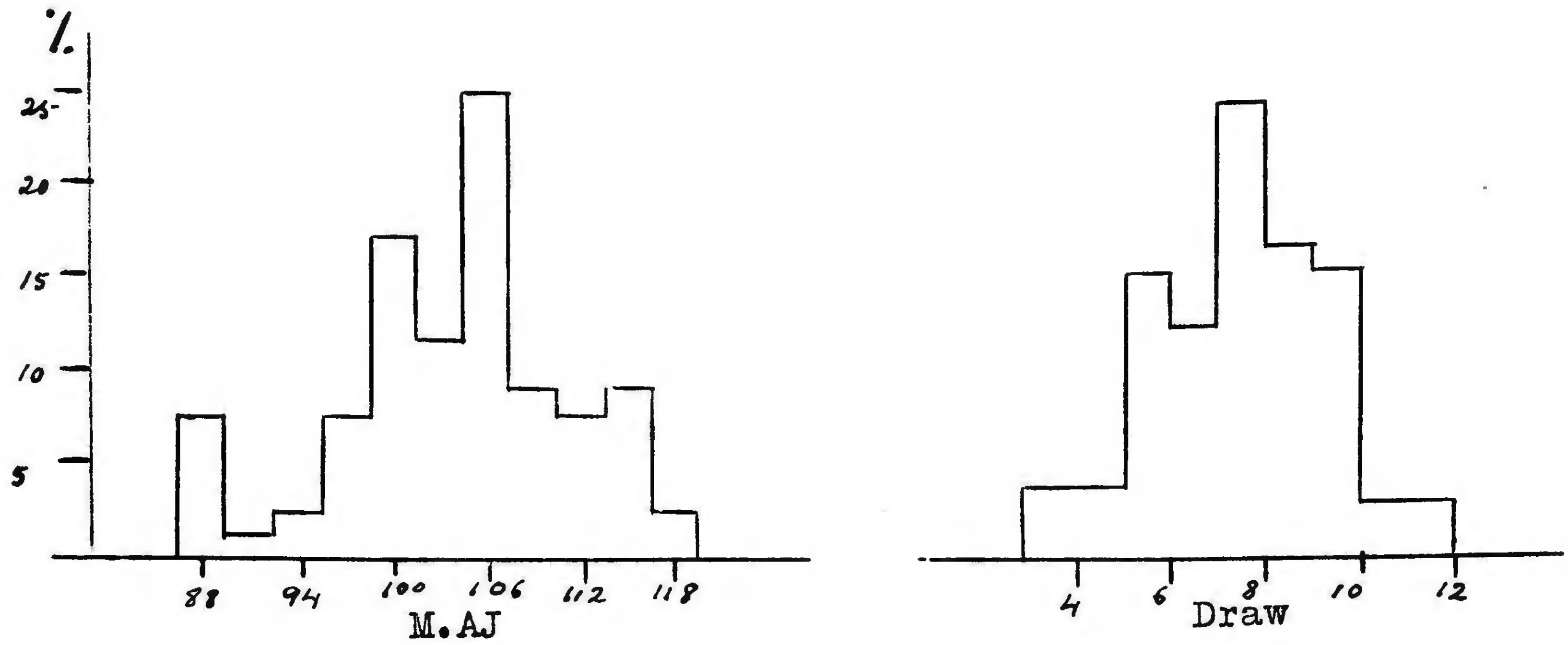
Figs 1-6

Distribution of Scores:School of Architecture



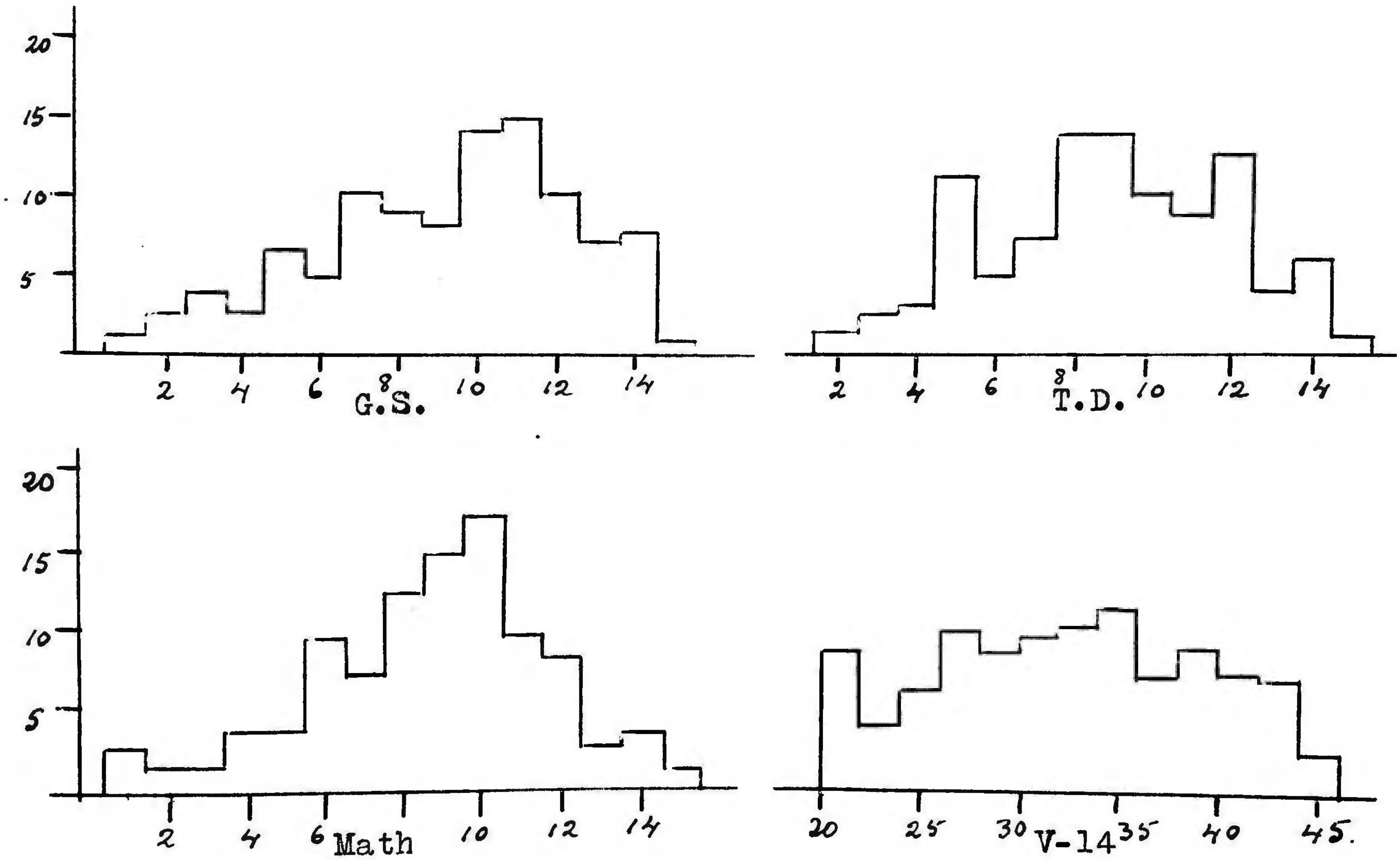
Figs 7-12

Distribution of Scores: School of Architecture



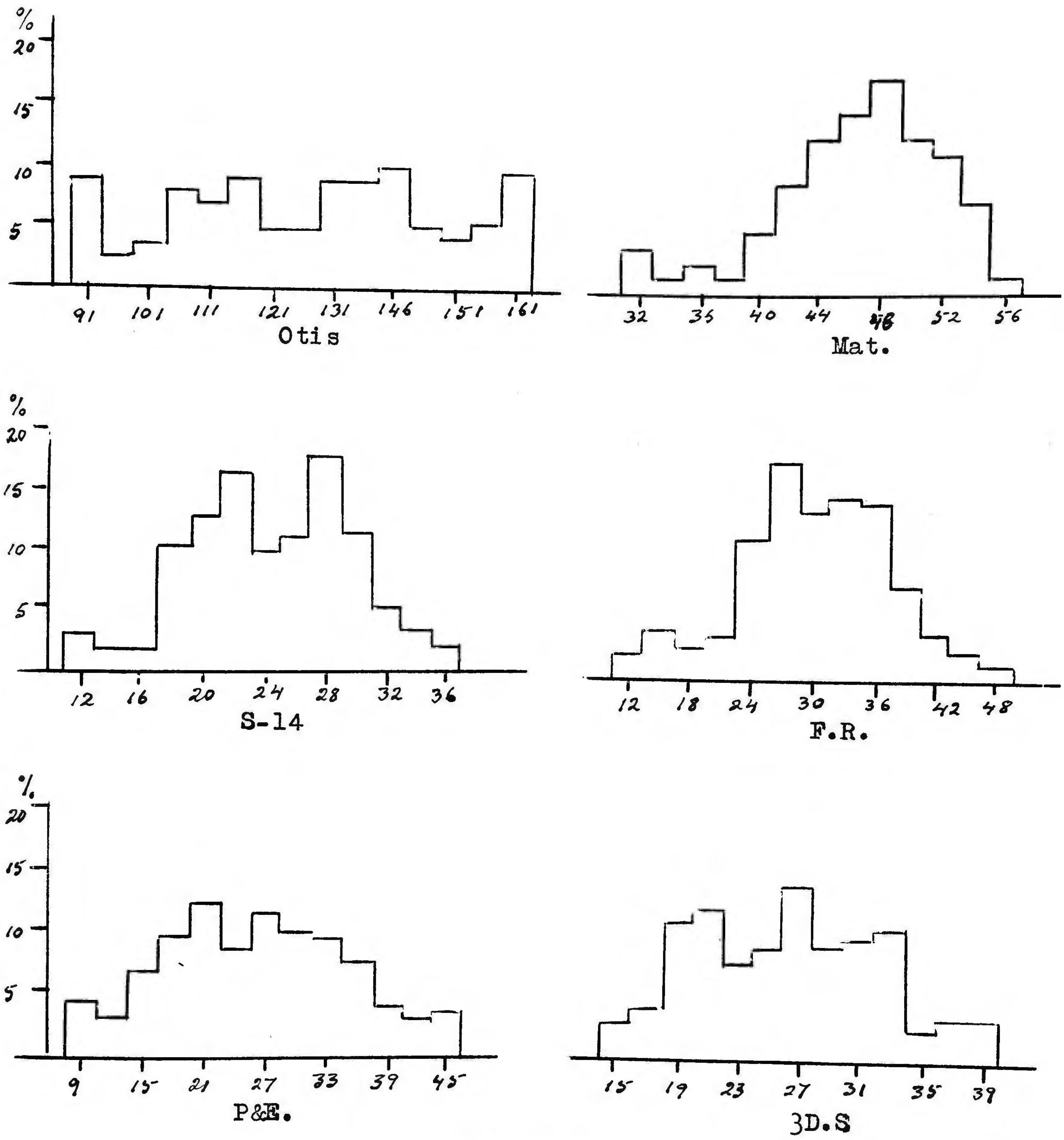
Figs 13 & 14

Distribution of Scores: School of Architecture



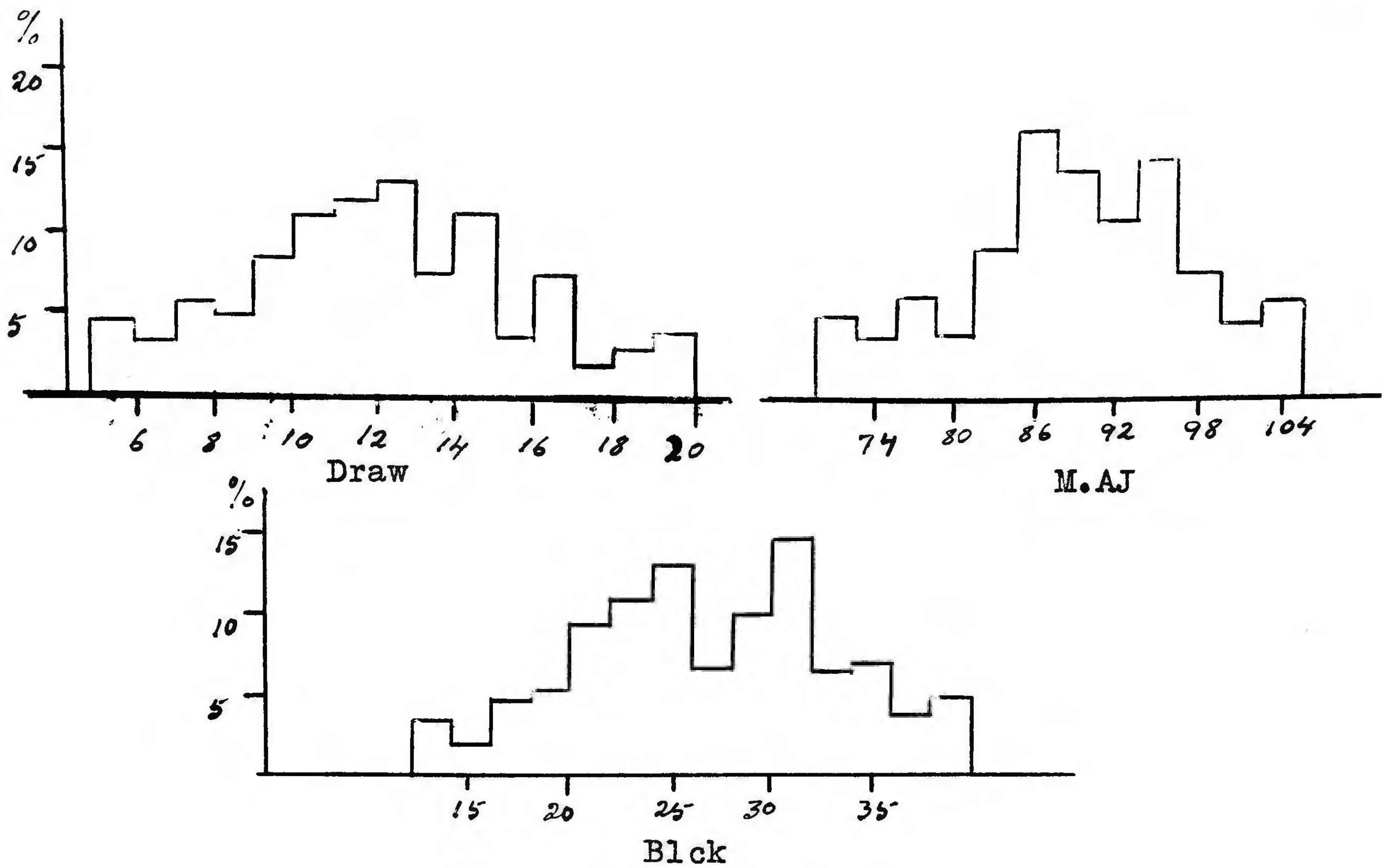
Figs 15-18

Distribution of Scores: Technical Institute



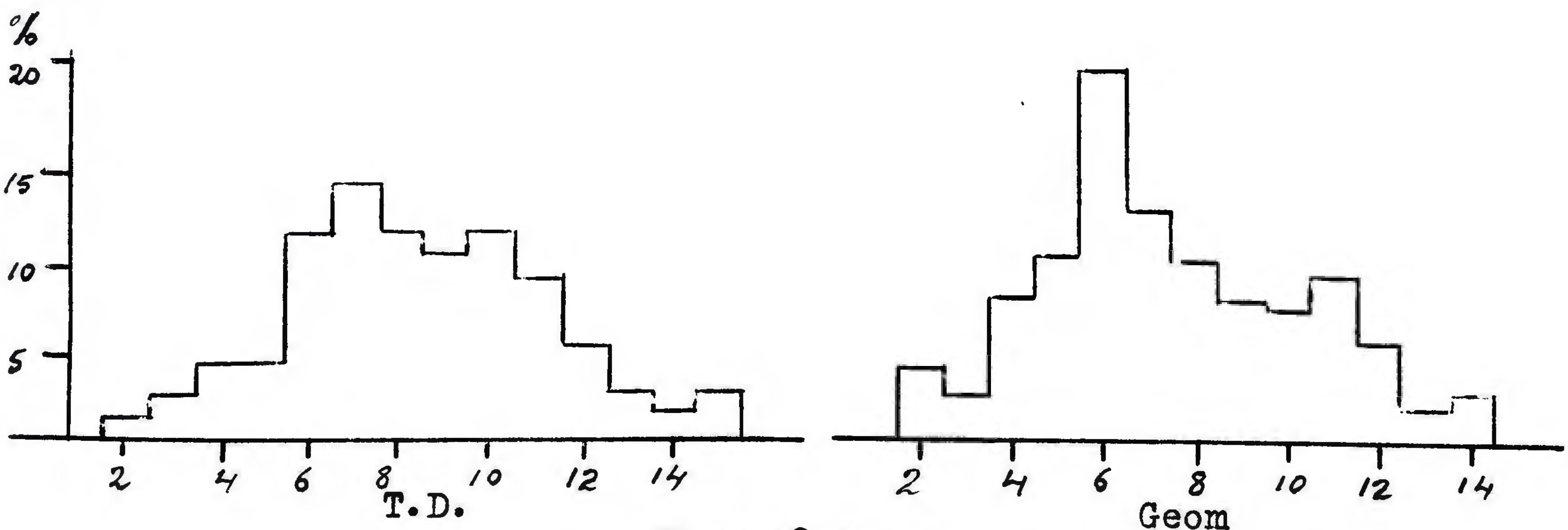
Figs 19-24

Distribution of Scores: Technical Institute



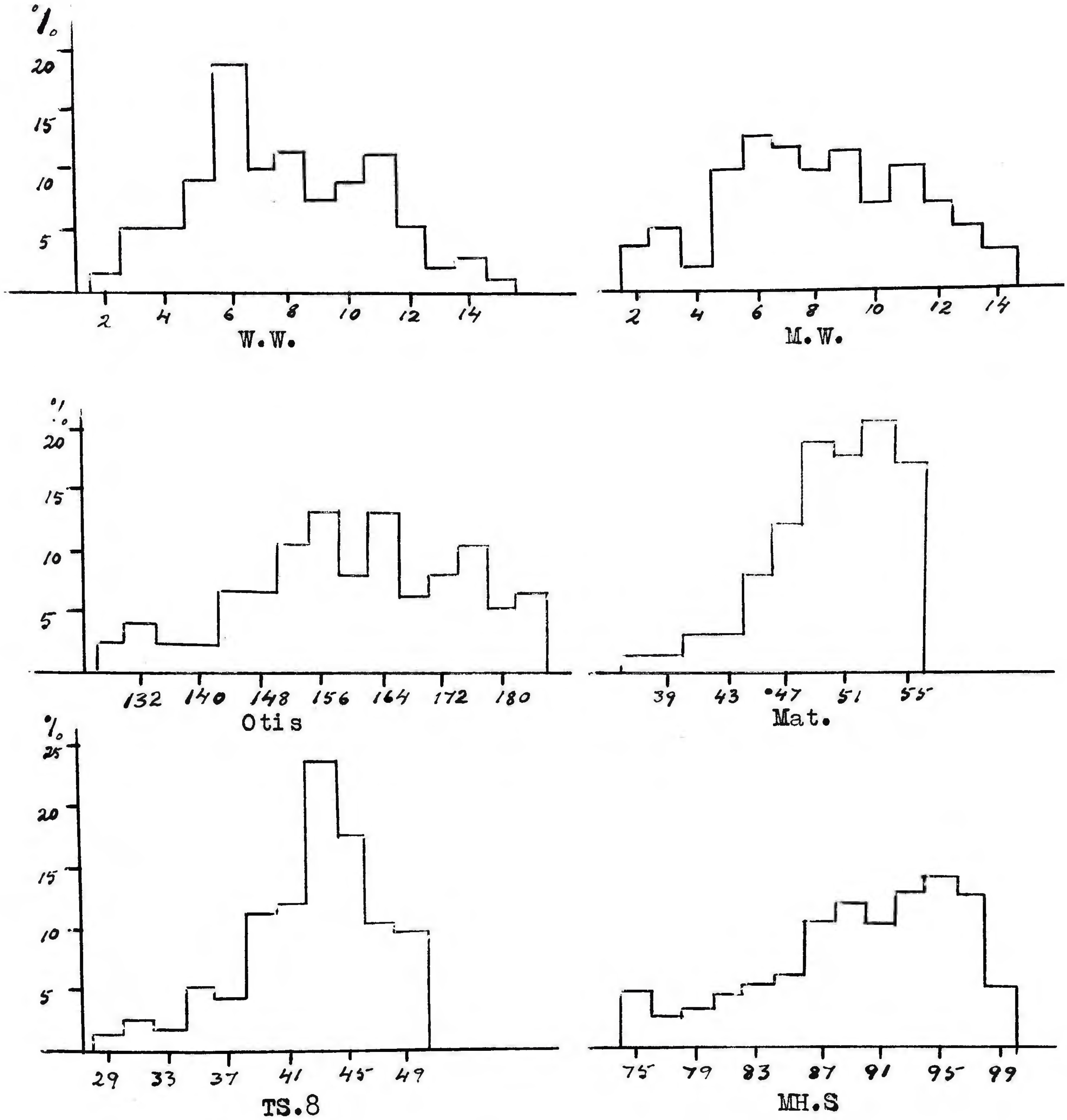
Figs 25-27

Distribution of Scores: Technical Institute



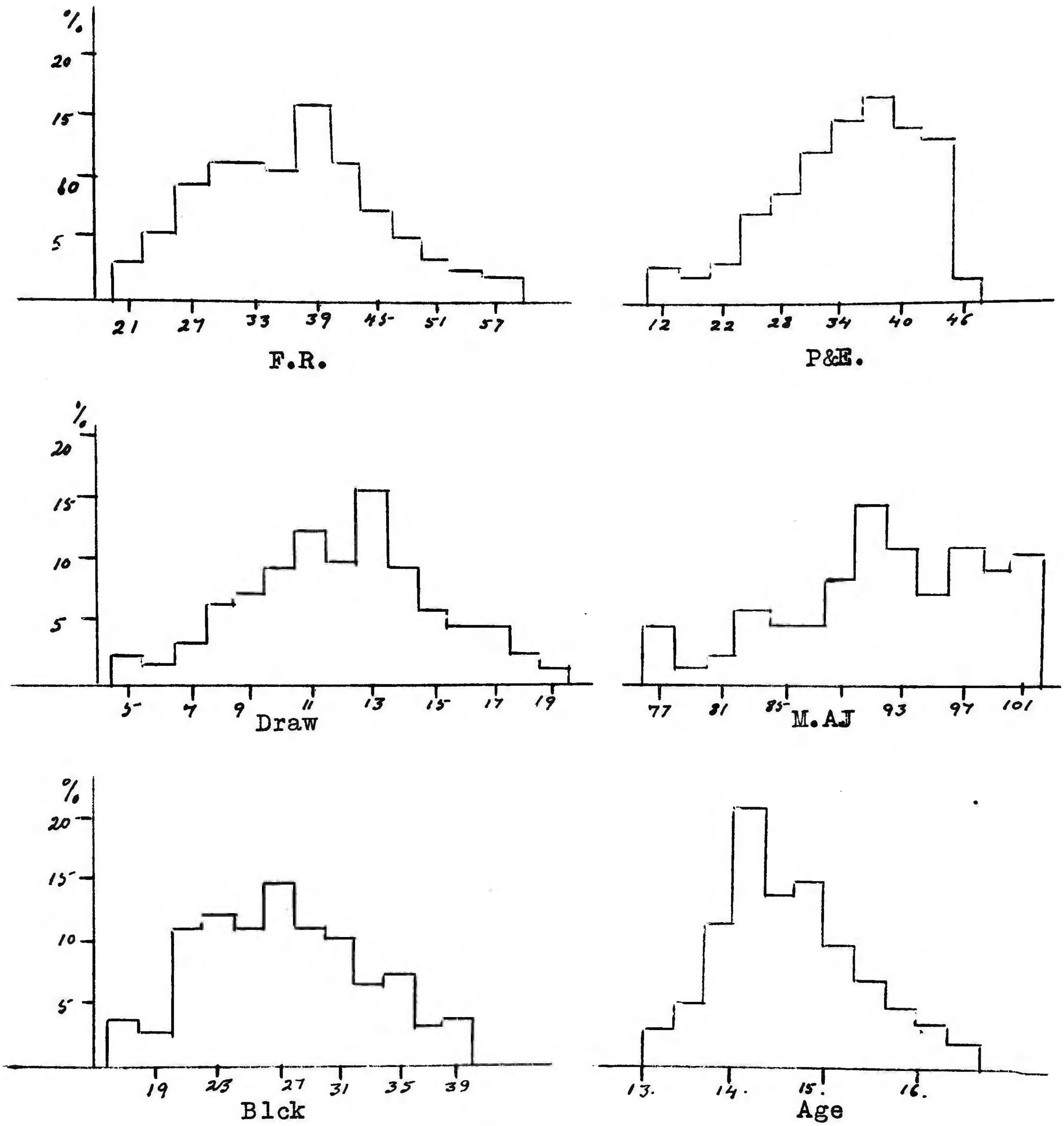
Figs 28 & 29

Distribution of Scores: Tech. School, Engineering Dept.



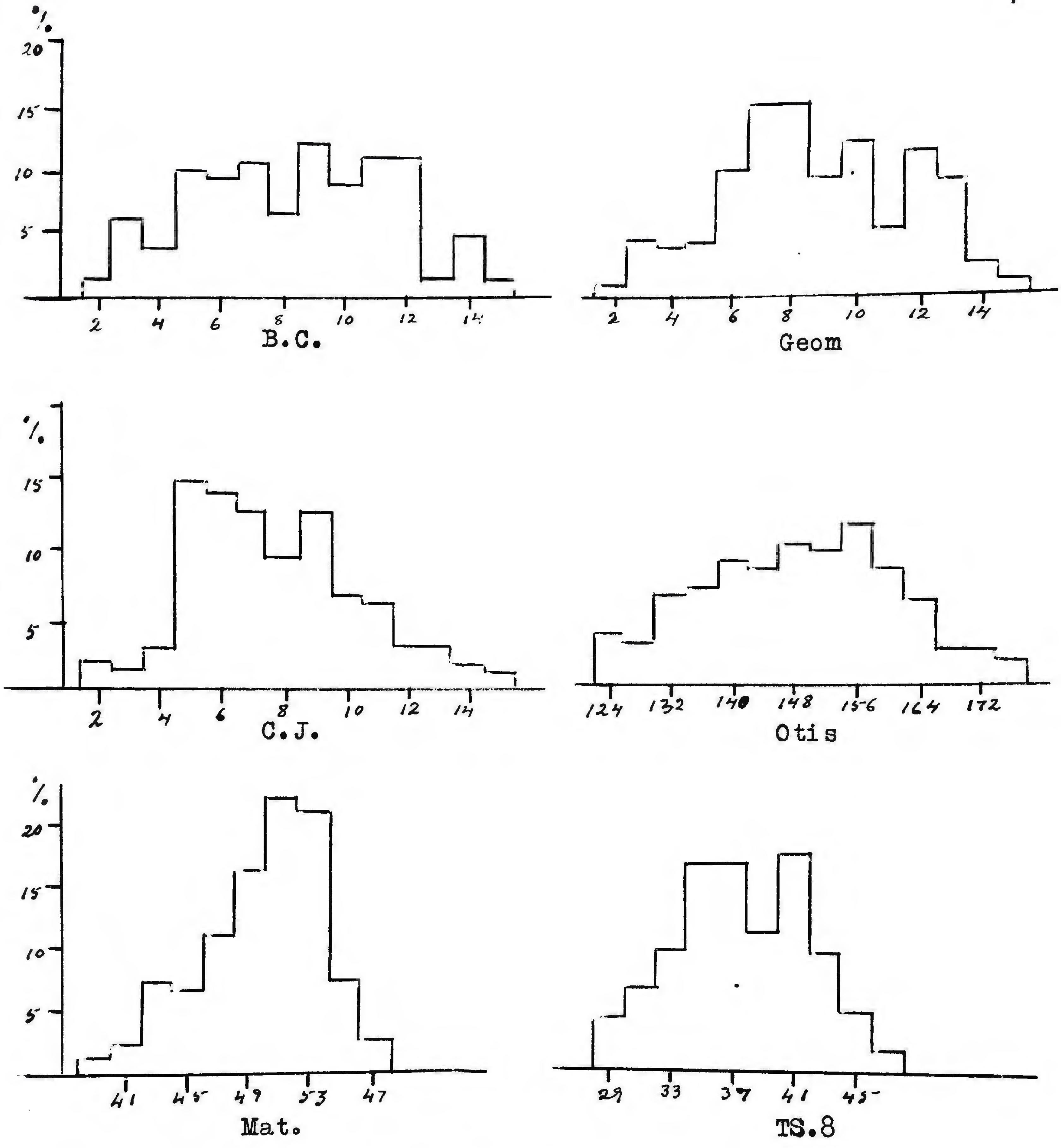
Figs 30 - 35

Distribution of Scores: Tech. School, Engineering Dept.



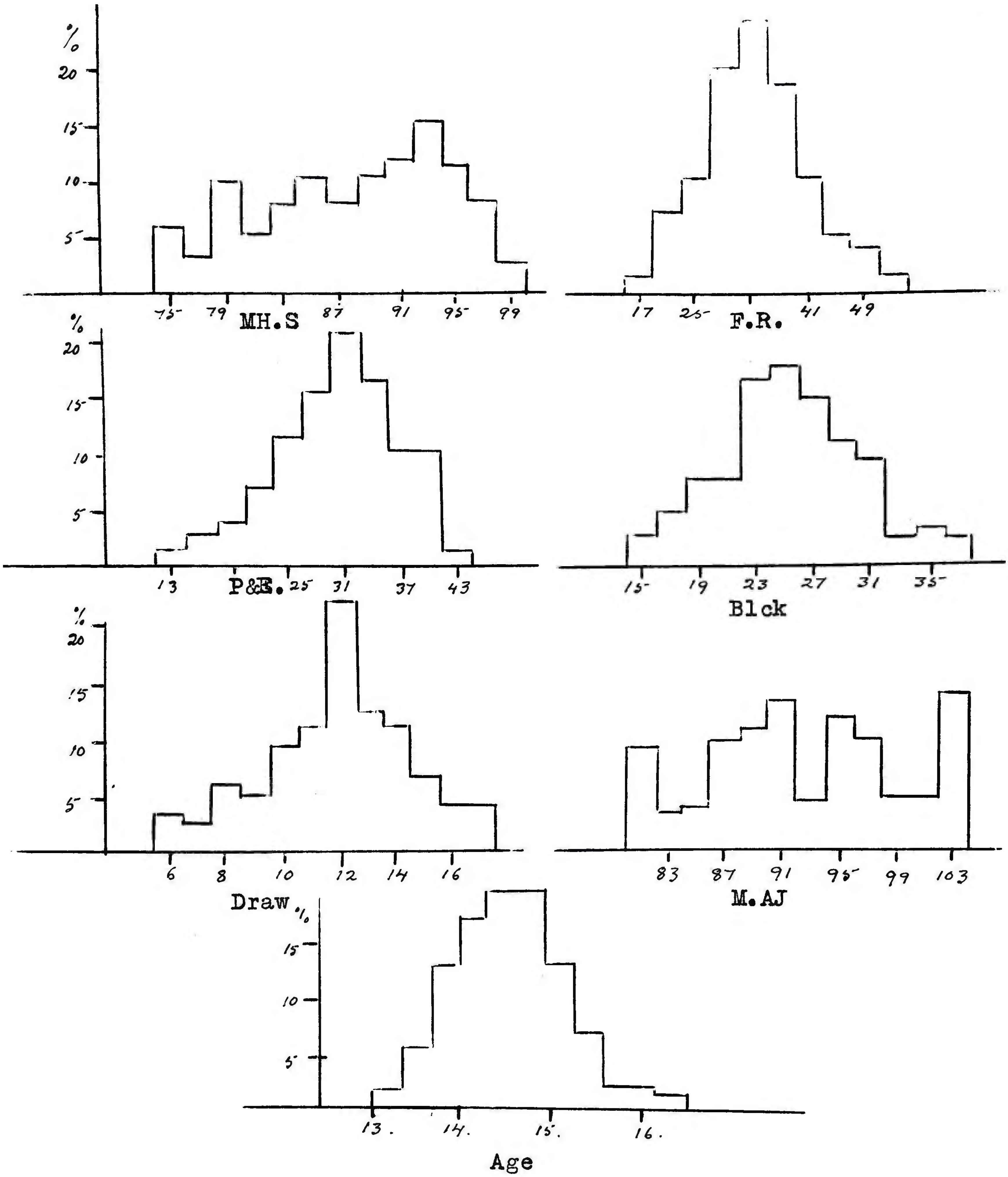
Figs 36-41

Distribution of Scores: Tech. School, Engineering Dept.



Figs 42-47

Distribution of Scores: Tech. School, Building Dept.



Figs 48-54

Distribution of Scores : Technical School, Building Dept.

Table 3.

<u>Mean, S.D. and Test of "Goodness of Fit".</u>

(School of Architecture)

N = 75

	Variable	Mean	S.D.	df	χ^2	P
	Arch. Design	8.89	3.12	10	6.49	.680
	Struct. Sci.	8.46	3.17	10	27.48	.002
	Build. Const.	8.92	3.01	10	5.98	.740
	Build. Sci.	8.41	3.10	10	16.21	.070
1	Otis Int.	184.47	13.64	9	58.39	0
2	V.S.14 Part I	44.86	5.50	7	28.22	0
4	Matrices	56.95	2.31	7	18.85	.003
3	V.S.14 Part II	36.69	5.22	8	57.22	0
7	Form Relation	49.19	8.19	8	11.65	.120
8	Plan & Elev.	45.56	5.02	8	7.11	.430
9	3-D S	40.26	3.96	8	68.10	0
10	Drawing Test	7.84	1.92	7	6.14	.420
12	Meier's A.J.	104.31	7.41	8	9.71	.210
11	Block Test	32.15	5.26	8	95.61	0

Table 4.

Mean, S.D. and Test of "Goodness of Fit".

(Technical Institute)

N 225

	Variable	Mean	S.D.	df	χ^2	P.
	Tech. Drawing	9.18	2.99	12	63.32	0
	Mathematics	8.55	3.00	12	57.46	0
	General Sci.	8.72	3.05	12	83.72	0
1	Otis Int.	128.23	21.60	12	424.00	0
2	V.S.14 Part I	32.27	6.64	12	109.59	0
4	Matrices	45.73	4.47	8	9.44	.220
3	V.S.14 II	24.66	5.54	12	22.59	.021
7	Form Relation	31.00	7.34	12	12.70	.320
8	Plan & Elev.	27.92	9.18	12	37.38	.001
9	3-D.S	27.42	6.02	12	43.86	0
10	Drawing Test	11.63	3.45	12	80.68	0
12	Meier's A.J.	88.93	9.35	11	19.66	.034
11	Block Test	26.37	6.02	12	107.04	0

Table 5.

Mean, S.D. and Test of "Goodness of Fit".

(Technical School:Engineering Dept)

N 180

	Variable	Mean	S.D.	df	χ^2	P
	Tech. Drawing	7.95	3.08	11	43.18	0
	Geometry	7.56	2.72	11	38.78	0
	Metalwork	8.05	3.07	11	44.20	0
	Woodwork	7.86	2.92	11	38.98	0
1	Otis Int.	154.57	14.16	10	176.98	0
4	Matrices	50.47	4.02	7	30.92	0
5	T.S.8	41.15	4.62	9	70.69	0
6	M.H.S.	89.88	6.40	9	85.03	0
7	Form Relation	37.36	8.79	12	27.32	.004
8	Plan & Elev.	33.00	7.14	9	18.38	.018
10	Drawing Test	12.4	3.16	10	30.62	.001
12	Meier's A.J.	90.80	6.64	10	45.62	0
11	Block Test	27.75	5.74	10	19.42	.022
	Age	14 yrs 8.4mth	9.28 mth	9	16.49	.03

Table 6.

Mean, S.D. and Test of "Goodness of Fit".

(Technical School: Building Dept)

N 180

	Variable	Mean	S.D.	df	χ^2	P
	Build. Const.	8.45	3.13	10	52.60	0
	Geometry	7.62	2.85	10	71.74	0
	Carp. Joinery	7.51	2.69	10	36.25	0
1	Otis Int.	154.38	12.60	10	74.14	0
4	Matrices	48.84	3.92	8	28.83	.004
5	T.S.8	38.81	4.52	9	23.03	.004
6	M.H.S.	88.35	6.20	9	97.68	0
7	Form Relation	36.23	6.75	8	6.28	.520
8	Plan & Elev.	31.13	7.20	8	19.05	.008
10	Drawing Test	11.92	2.74	8	12.80	.080
12	Meier's A.J.	91.26	7.15	9	94.19	0
11	Block Test	26.67	5.96	10	5.90	.750
	Age	14 yrs 7.6mth	8.01 mth	8	8.48	.290

2. Matrix of Correlation Coefficients.

The correlation coefficients between the variables were calculated by the product moment formula for grouped data, using the scattergram technique.

$$r_{12} \quad \frac{\frac{\Sigma x_1 x_2}{N} - \frac{\Sigma x_1}{N} \cdot \frac{\Sigma x_2}{N}}{\sqrt{\frac{x_1^2}{N} - \left(\frac{x_1}{N}\right)^2} \cdot \sqrt{\frac{x_2^2}{N} - \left(\frac{x_2}{N}\right)^2}}$$

Remembering that the pupils of Broadsley Green Technical School had an age range of 12 to 16 years, it was decided to partial out the effect of age by statistical means. The formula used was:

$$r_{12.3} = \frac{r_{12} - r_{13} r_{23}}{\sqrt{1 - r_{13}^2}\sqrt{1 - r_{23}^2}}$$

The resulting matrix of correlations was tabulated in Tables 8 to 13. Inspection of the matrix showed that all the coefficients were positive, as would normally be expected for mental ability measurements.

3. Significance of the Correlation Coefficients.

The test used for the significance of the correlation coefficients was used to determine whether or not the coefficients differed significantly from zero. The customary procedure for determining whether or not an observed r is significant, is to compute the standard error of r and describe the coefficient as significant if it is more than 2.5 to 3 times the standard error. This test was not applicable, because (a) it is inconsistent to use the obtained coefficient as an estimate of the true r, when testing the hypothesis that the true r is zero, and (b) the method assumes that the sampling distribution of standard error is normal (Linguist 1940).

The procedure adopted here for determining if an r is significant, was to compute the value of:

$$t = \frac{r}{\sqrt{1 - r^2}} \cdot \sqrt{N - 2}$$

This t was evaluated by means of a table given by Linquist (1940) using N - 2 as the number of degrees of freedom.

The value of the correlation coefficient required for significance at 5 per cent and 1 per cent levels, for corresponding the number of subjects in the experimental groups is given in Table 14.

Table 14

Values of the Correlation Coefficient Required for Significance.

Sample	No	5%	1%
School of Architecture	75	.227	.296
Technical Institute	225	1125	.172
Technical School (both samples)	180	.148	.193

TABLE 8

MATRIX OF CORRELATION.

School of Architecture

Plan & Elevation

	A.D.	S.S.	B.S.	B.C.	Otis	V-14	Mat.	S-14	F.R.	P&E	3D.S	Draw	A.J.
A.D.													
S.S.	0688												
B.S.	1805	4102											
B.C.		3384	3788										
Otis	0030	1990	2586	0608									
V-14	0765	3002	2183	0324	5481								
Mat.	1174	3274	2848	0320	1351	1712							
S-14	2981	2808	1889	1519	3867	5000	2551						
F.R.	0049	1584	1786	1552	1556	1322	1767	2654					
P&E.	2886	2786	0365	2763	0940	0587	2456	3651	1284				
3D.S	2550	2591	2209	2819	0691	0460	2714	4033	2432	5486			
Draw	5172	-0414	0755	4102	1675	1038	0925	1322	0252	0714	0850		
A.J.	5169	-0004	-0011	0359	1644	-0672	1966	1584	1043	3141	2059	1067	
Blck	0841	0683	0712	1118	2491	0983	2852	4248	2927	2886	2993	1520	-0626

(Decimal points omitted)

Largest is .5486.

TABLE 9

MATRIX OF CORRELATION

Technical Institute

	E.D.	Math	G.S.	Otis	V-14	Mat.	S-14	F.R.	P&E.	3D.S	Draw	A.J.	Blck
E.D.													
Math	5662												
G.S.	4195	6223											
Otis	1748	2717	3581										
V-14	1055	1949	2984	6533									
Mat.	2722	3715	4327	3594	3456								
S-14	3486	2939	1986	2237	3759	4503							
F.R.	3413	2253	1975	2392	1486	3103	5491						
P&E.	5350	3465	2993	3631	0564	3492	5548	5175					
3D.S	3827	2899	1973	3312	2209	3042	4512	5561	5226				
Draw	3597	3213	2052	1420	0527	2182	2054	4300	3557	3350			
A.J.	2281	0814	1241	2321	3057	1850	2769	1857	4065	1717	3333		
Blck	2652	1163	1533	2289	1404	2940	5024	4590	5084	4990	3670	2592	

(Decimal points omitted.)

Largest is .5662

TABLE 10

MATRIX OF CORRELATION.

Technical School : Engineering Department.

	E.D.	Geom	M.W.	W.W.	Otis	Mat.	TS.8	MH.S	F.R.	P&E.	Draw	A.J.	Blck
E.D.													
Geom	7523												
M.W.	6569	6098											
W.W.	6256	6125	6982										
Otis	1005	1886	0837	1236									
Mat.	2273	2904	3700	1978	0554								
TS.8	2645	3474	2478	2238	1515	3386							
MH.S	3732	4610	4560	3151	1246	2882	4148						
F.R.	4770	3274	4036	3948	1029	2336	4858	4319					
P&E.	5385	4799	4549	4627	1356	3852	3176	4389	4003				
Draw	5045	5333	4450	3883	0162	2638	3909	3449	5363	3623			
A.J.	0127	0916	1844	1028	1294	1537	3413	1577	0920	1696	1441		
Blck	3698	4038	3622	4113	1392	2425	2329	4159	3638	4771	3850	2177	
Age.	3296	3520	3741	4938	1633	2824	0473	2924	1968	3228	1154	0501	2518

(Decimal points omitted)

TABLE 11

MATRIX OF CORRELATION.

Technical School : Building Department

	B.C.	Geom	C.J.	Otis	Mat.	TS.8	MH.S	F.R.	P&E.	Draw	A.J.	Blck	Age
B.C.													
Geom	6179												
C.J.	4964	4026											
Otis	2143	3199	1231										
Mat.	3500	3416	1471	2249									
TS.8	3165	3377	3119	1721	3812								
MH.S	3557	3638	4577	2690	3945	4314							
F.R.	3343	2828	3949	1863	3871	3909	4110						
P&E.	4124	4581	4429	2560	2887	4281	5824	3923					
Draw	2337	2465	2015	0150	2983	2309	2169	2196	2457				
A.J.	1574	2129	2198	3177	2405	3202	1754	2348	3133	0485			
Blck	3292	2489	4241	1912	2357	4408	5230	3000	4575	2727	0677		
Age	5664	3777	3447	1779	1477	2285	1285	0245	2297	0930	-0478	2191	

(Decimal points omitted)

TABLE 12

MATRIX OF CORRELATION.

(Age held constant)

Technical School : Engineering Department.

	E.D.	Geom	M.W.	W.W.	Otis	Mat.	TS.8	MH.S	F.R.	P&E	Draw	A.J.	Blck
E.D.													
Geom	682												
M.W.	576	551											
W.W.	564	539	636										
Otis	051	142	025	043									
Mat.	148	215	297	070	014								
TS.8	264	353	249	231	146	238							
MH.S	306	402	391	208	082	224	419						
F.R.	446	282	363	349	073	189	497	401					
P&E.	473	413	381	369	089	324	320	381	372				
Draw	497	529	436	383	-003	243	389	318	519	354			
A.J.	-004	078	179	090	123	146	340	149	086	166	142		
Blck	312	328	299	342	103	185	229	370	339	433	370	195	

(Decimal points omitted)

TABLE 13

MATRIX OF CORRELATION.

(Age held constant)

Technical School : Building Department.

	B.C.	Geom	C.J.	Otis	Mat.	TS.8	MH.S	F.R.	P&E.	Draw	A.J.	Blck
B.C.												
Geom	5426											
C.J.	3862	3131										
Otis	1402	2771	0670									
Mat.	3259	3123	1034	2122								
TS.8	2330	2790	2550	1370	2712							
MH.S	3496	3435	4773	2524	3828	4174						
F.R.	3886	2957	4112	1850	3366	3960	4120					
P&E.	3519	4343	3754	2366	2646	3966	5758	3974				
Draw	2206	2293	1802	-0015	2889	2163	2082	2195	2315			
A.J.	2243	2108	2514	3145	2506	3413	1839	2362	3343	0534		
Blck	2552	1839	3810	1585	2105	4113	5138	3025	4286	2601	0590	

(Decimal points omitted)

4. The Reliability of the Tests.

The extent to which test results are vitiated by chance errors can be assessed if the reliability of each test is known. A test is reliable when it gives consistent results. The reliability of each test was calculated by correlating the odd and even numbered items, and the Spearman-Brown formula was used to obtain the reliability of the test as a whole, from the calculation between the test halves. The formula used was:

$$r_{nn} = \frac{nr_{11}}{1 + (n - 1)\, r_{11}}$$

in which

r_{nn} = the correlation between n forms of a test and n alternative forms.

r_{11} = the reliability coefficients of unit length

The reliability coefficients of different tests could not be compared directly, since their sizes depend upon the length of the tests. For a fair comparison, all the tests were reduced to the same length, and their reliabilities were calculated by using the same Spearman-Brown formula (See Table 15).

Table 15.

Reliability coefficients of Tests

(Raw r_{11} and Adjusted for length r_{nn})

Variable	Schl. Arch		Tech Inst.		Technical School Eng. Dept.		Build Dept	
Otis Int.	8213	8213	9557	9557	8872	8872	7720	7720
V.S.14 I	8424	9451	8870	9621				
Matrices	8140	8140	8592	8592	8849	8849	7254	7254
V.S.14 II	7968	8683	8393	8975				
T.S.8					8591	9275	7862	8853
M.H.S.					8591	8924	8210	8609
Form Relation	6604	8151	6984	8399	8279	9161	7532	8739
Plan & Elev.	7413	8635	7545	8714	8283	9146	7491	8689
3-D.S	7026	8620	8545	9390				
Draw Test	8593	8593	8732	8732	7651	7651	8088	8088
Meier's A.J.	6675	6675	6870	6870	5374	5374	5348	5348
Block Test	-	8729	-	8373	-	8373	-	8373
	r_{11}	r_{nn}	r_{11}	r_{nn}	r_{11}	r_{nn}	r_{11}	r_{nn}

The reliability coefficient of the Block Test was not available except in the case of the 100 pupils (aged 12 plus) from a modern school.

(Decimal points omitted)

SECTION B.

Factor Analysis.

Factor analysis is considered to be concerned primarily with the classification of variables observed. In the present investigation the objects of such analysis were as follows:

1) to discover what "factors" are measured by the variables used.
2) to analyse the new experimental tests in terms of the factors which have already been established.
3) to determine what tests might most usefully be applied, and how the several tests should be summed or weighted in order to obtain assessment of the complex criteria, and to choose a few assessments to be incorporated in the criterion battery.
4) to throw some light on the nature of the aptitudes under investigation.

First of all, the four matrices of correlation were factorized by the centroid method. In order to obtain further evidence about the variables, the matrices of the School of Architecture and Technical Institute were analysed by Burt's Group Factor method. The bipolar factor matrices of these two groups were also rotated by Thurstone's graphic method.

1. Centroid Factor Analysis.

The centroid or summation method of analysis was used for all four matrices of correlation. The basic formula of the method is:

$$r_{ag} = \frac{\sum r_{ai}}{\sum_j \sum_i r_{ji}}$$

where

r_{ag} = the correlation coefficient of the variable with the general factor running through all the variables analysed

r_{ai} = the correlation of the variable (a) with another variable (i)

thus $\sum r_{ai}$ = the sum of the correlations of the variable (a) with all other variables.

$\sum_j \sum_i r_{ji}$ = the sum of all the correlations in the table.

This formula was published by Burt (1917) in his summation method, and later Thurstone (1935) used it for his centroid method. There are, however, a number of points in this method of analysis where several alternative procedures can be used, such as the filling of the diagonal cells, deciding the point at which factorizing is to cease, and testing the factors for significance etc.

As an estimate of self correlation, Thurstone recommended filling the diagonal cells with the largest correlation in the column, and after extracting each factor, replacing the value left in each diagonal cell with the largest residual coefficient in its column, the coefficient sign always being made positive.

Burt (1938) criticised Thurstone's method on the grounds that it exaggerated the communalities, and therefore the size and number of the latter factors. He suggested progressive approximation - the diagonal entries to be guessed, and the analysis repeated several times, until the guesses approximate the correct values.

Thurstone (1948) lately recommended the improvement of communalities by iteration, using the sums of squares of the loadings for a new estimate.

In this study it was decided to adopt Thurstone's short cut method where the number of variables were 12 or more. But in group factor analysis where a small number of variables were involved, iteration was carried on until the estimates approximated to the true value.

The most common method of deciding the stage where the common factors extracted cease to have any statistical significance, is to compare each residue with the standard error of the original correlation, and to cease factorizing when 95 per cent of the residues sink below twice the standard errors. It was considered that this method is too strict and that it stops factorization too soon. Also, the use of the formula for the standard error of r is now frowned upon, because of the skewness of the distribution (Thomson 1950). Other methods given by various authors were considered either too lenient or over elaborate for the purposes of this investigation.

In this research, the values of the correlation coefficients required for significance at 5 per cent levels, for the size of the experimental groups, were found from Linquist's table (1940), and each residual in the matrix was compared with its corresponding value. Factorizing was continued until 5 per cent of the residues still remained significant, no account being taken of the diagonal entries (See Table 16)

Table 16.

Percentages of Significant Residuals.

After Factor	Percentage of Significant Residuals.			
	Schl. Arch	Tech. Inst.	Tech. Schl. Eng. Dept.	Tech Schl. Bld. Dept.
0	42.86	91.03	69.45	87.88
1	6.59	20.51	10.26	6.06
2	3.30	6.41	0	1.52
3	0	3.85	-	0

The significance of a single leading presented a problem where it seemed there was a lack of agreement among psychologists. In most cases, .4 loading has been chosen as a level above which the loadings are recognized as contributing something of value to the test, and below .2 leading has been regarded as negligible. In this investigation Burt and Banks' (1947) formula was used, which provided an objective ground on which to determine the level:

$$r = \frac{(1-r^2)\sqrt{n}}{\sqrt{N(n-s+1)}}$$

where $n =$ the number of tests

$s =$ the number of the factor

This formula can also be used for testing the significance of a factor as a whole. Vernon (1940) suggested that half the loadings of a factor should exceed this value to be regarded as significant.

The results of factor analysis by the centroid method are given in Tables 17 - 20. The residual factor matrix are given in Appendix III, and the distribution of correlation coefficients and residuals are shown in histogram form in figs 53 - 67.

Table 17.

Unrotated Centroid Factor Matrix.

(School of Architecture)

Variable	Factor Loading I	II	III	h^2
Arch. Design	.5024	-.3625	-.3249	.4894
Struct. Sci.	.4702	.2567	.1939	.3246
Build. Const.	.4636	-.1088	-.1825	.2600
Build. Sci.	.4478	.2222	-.0268	.2506
Otis Int.	.4889	.4587	-.0903	.4385
V.S.14 I	.4254	.6477	-.0992	.6103
Matrices	.4488	.0366	.3329	.3135
V.S.14 II	.6629	.1269	.0382	.4570
Form Relation	.3573	.0094	.2264	.1791
Plan & Elev.	.5448	-.3031	.2310	.4421
3.D.S.	.5747	-.2498	.3291	.5010
Draw Test	.3714	-.2831	-.7020	.7108
Meier's A.J.	.3366	-.3403	-.0861	.2365
Block Test	.4287	-.0878	.1645	.2186
Variance per cent	22.290	9.027	7.484	38.800

Table 18

Unrotated Centroid Factor Matrix.

(Technical Institute)

Variable	Factor Loading I	II	III	IV	h^2
Tech. Drawing	.6084	-.2809	-.2666	.1605	.5460
Mathematics	.5762	-.0266	-.5794	-.0348	.6696
General Sci.	.5503	.1571	-.5232	-.1295	.6180
Otis Int.	.5639	.4176	.1198	-.1447	.5280
V.S.14 I	.4734	.7079	.1094	.0250	.7378
Matrices	.5788	.2195	-.1112	-.1925	.4327
V.S.14 II	.6645	-.0545	.2565	-.2264	.5617
Form Relation	.6285	-.2704	.2181	-.1581	.5407
Plan & Elev.	.7157	-.1957	.1165	-.0115	.5642
3-D.S	.6427	-.2692	.2404	-.1315	.5599
Drawing Test	.5017	-.3098	-.0314	.2145	.3947
Meier's A.J.	.4260	.0928	.1490	.5064	.4687
Block Test	.5737	-.1884	.3016	-.1049	.4666
Variance Per cent	33.89	8.88	7.83	3.92	54.52

Table 19.

Unrotated Centroid Factor Matrix.

(Tech. School: Eng. Dept)

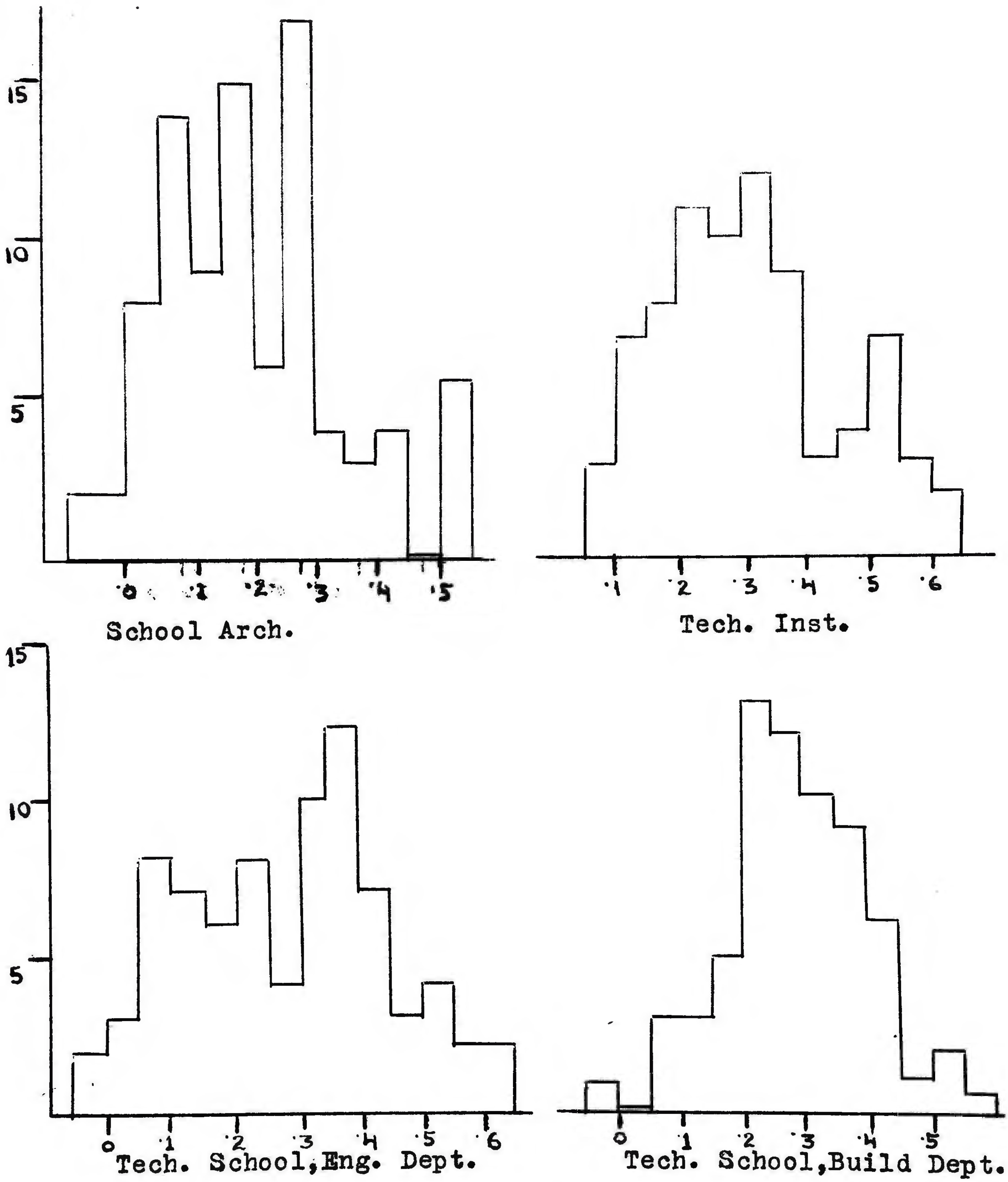
Variable	Factor Loading I	II	III	h^2
Tech. Drawing	.6982	.3986	-.1313	.6636
Geometry	.7260	.3173	-.0014	.6278
Matalwork	.7013	.3378	.0057	.6090
Woodwork	.6232	.4319	.0051	.5749
Otis Int.	.1445	-.0830	.1382	.0469
Matrices	.3657	-.1753	.2378	.2209
T.S.8	.5829	-.3481	-.2168	.5080
M.H.S.	.5687	-.1906	.0154	.3599
Form Relation	.6198	-.1894	-.4748	.6455
Plan & Elev.	.6355	-.0825	.1241	.4261
Draw Test	.6575	-.0204	-.1879	.4680
Meier's A.J.	.2836	-.2762	.2231	.2065
Block Test	.5502	-.1435	.1080	.3350
Varaince per cent	33.20	6.89	3.70	43.79

Table 20 .

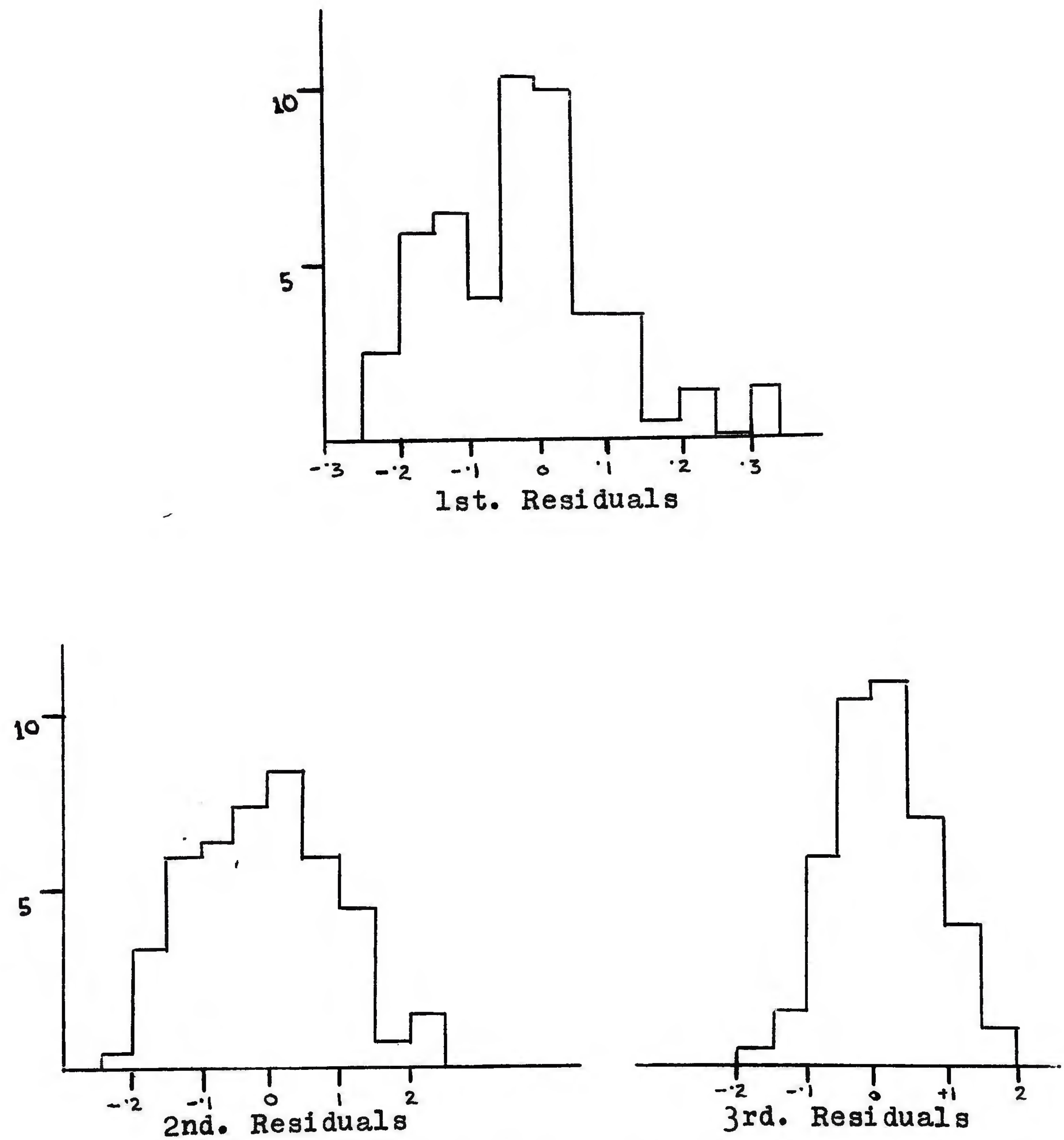
Unrotated Centroid Factor Matrix.

(Tech. School: Build Dept)

Variable	Factor Loading I	II	III	h^2
Build Const.	.6015	-.2509	.3465	.5449
Geometry	.6019	-.2639	.1307	.4490
Carp. Joinery	.5586	.1713	.0100	.3415
Otis Int.	.3482	-.3064	-.1314	.2324
Matrices	.5226	-.1670	.2396	.3584
T.S.8	.5879	.0577	-.0215	.3494
M.H.S.	.7125	.2442	-.1004	.5774
Form Relation	.6063	.0244	-.0521	.3709
Plan & Elev.	.6989	.1282	-.1352	.5232
Drawing Test	.3637	.1011	.3153	.2419
Meier's A.J.	.4253	-.2173	-.5334	.5126
Block Test	.5585	.4784	-.0683	.5455
Variance per cent	31.37	5.42	5.26	43.06



figs 53-56
Distribution of Correlations

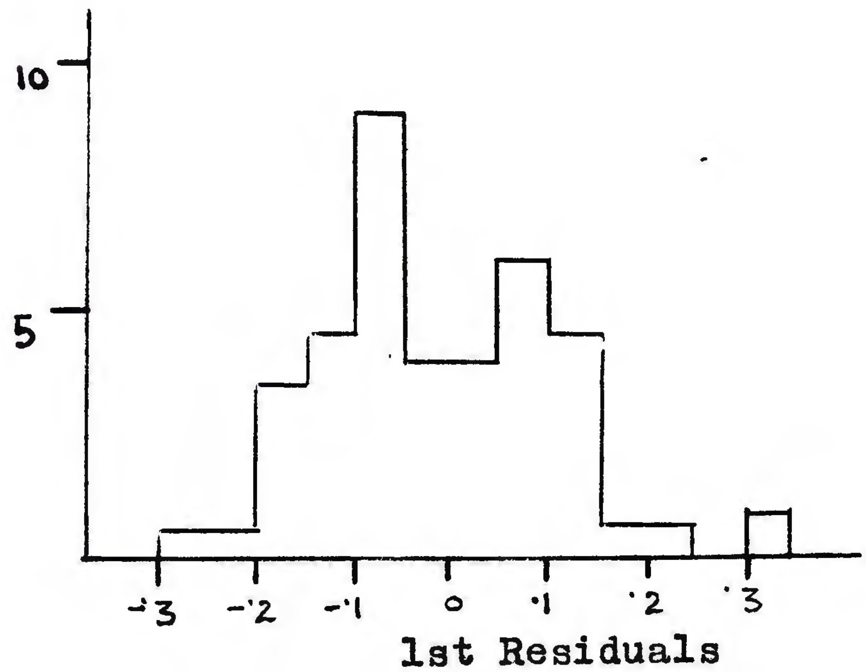


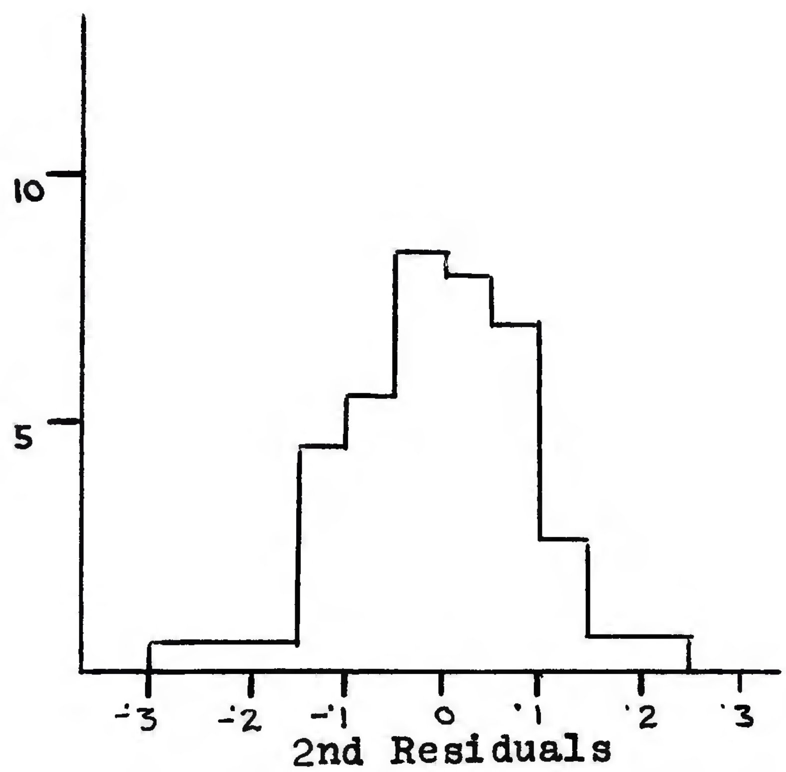
Figs 57-59

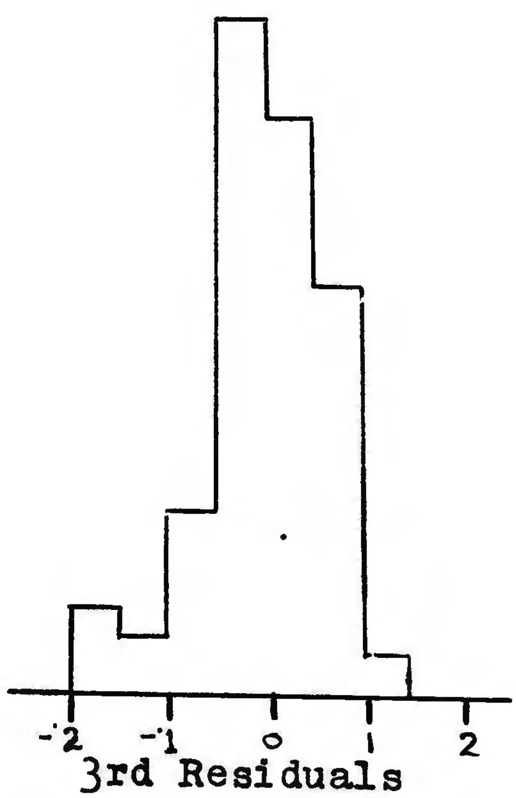
Distribution of Residual Correlations
School pf Architecture

Distribution of Residual Correlations

Technical Institute.



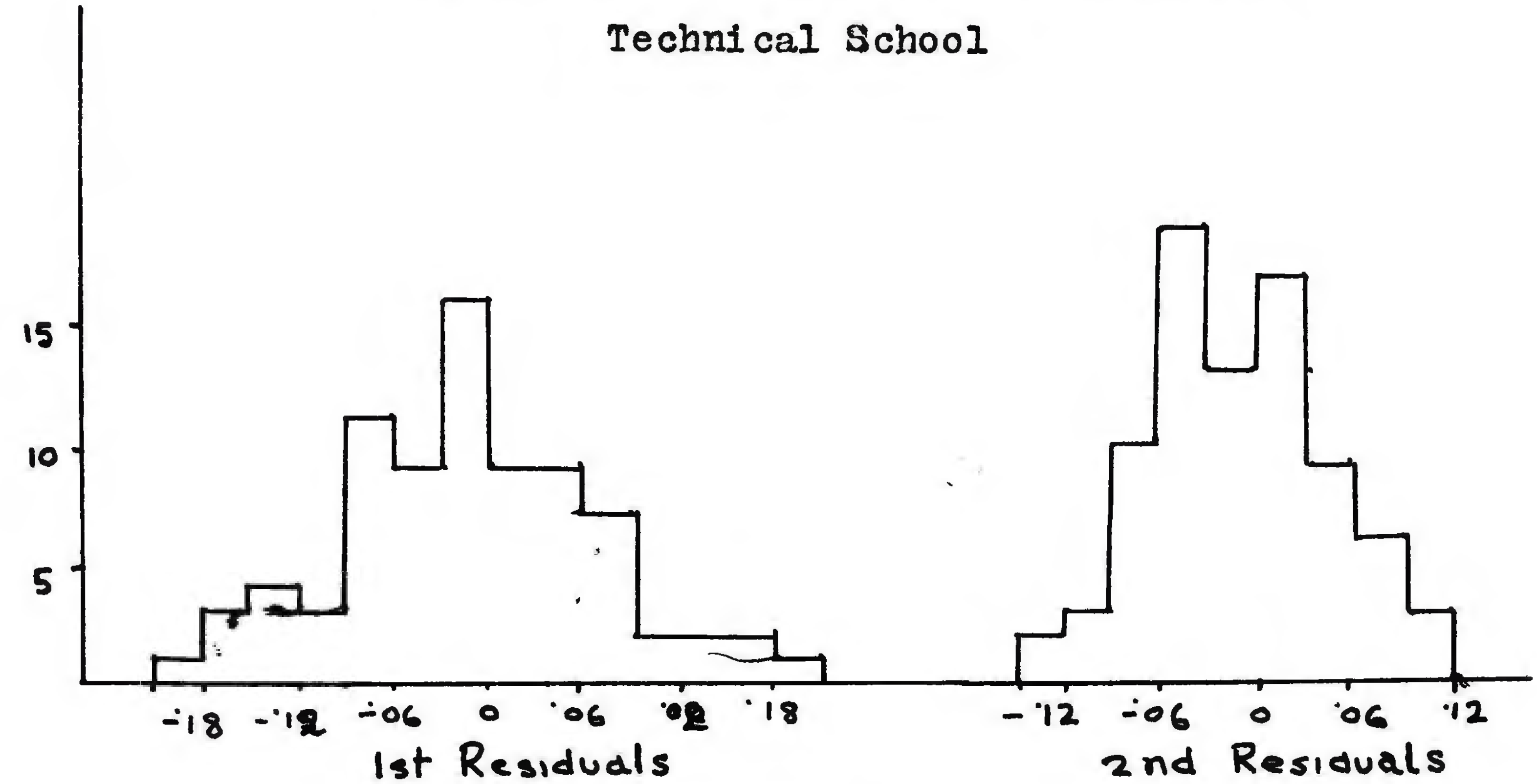




Figs 60-62

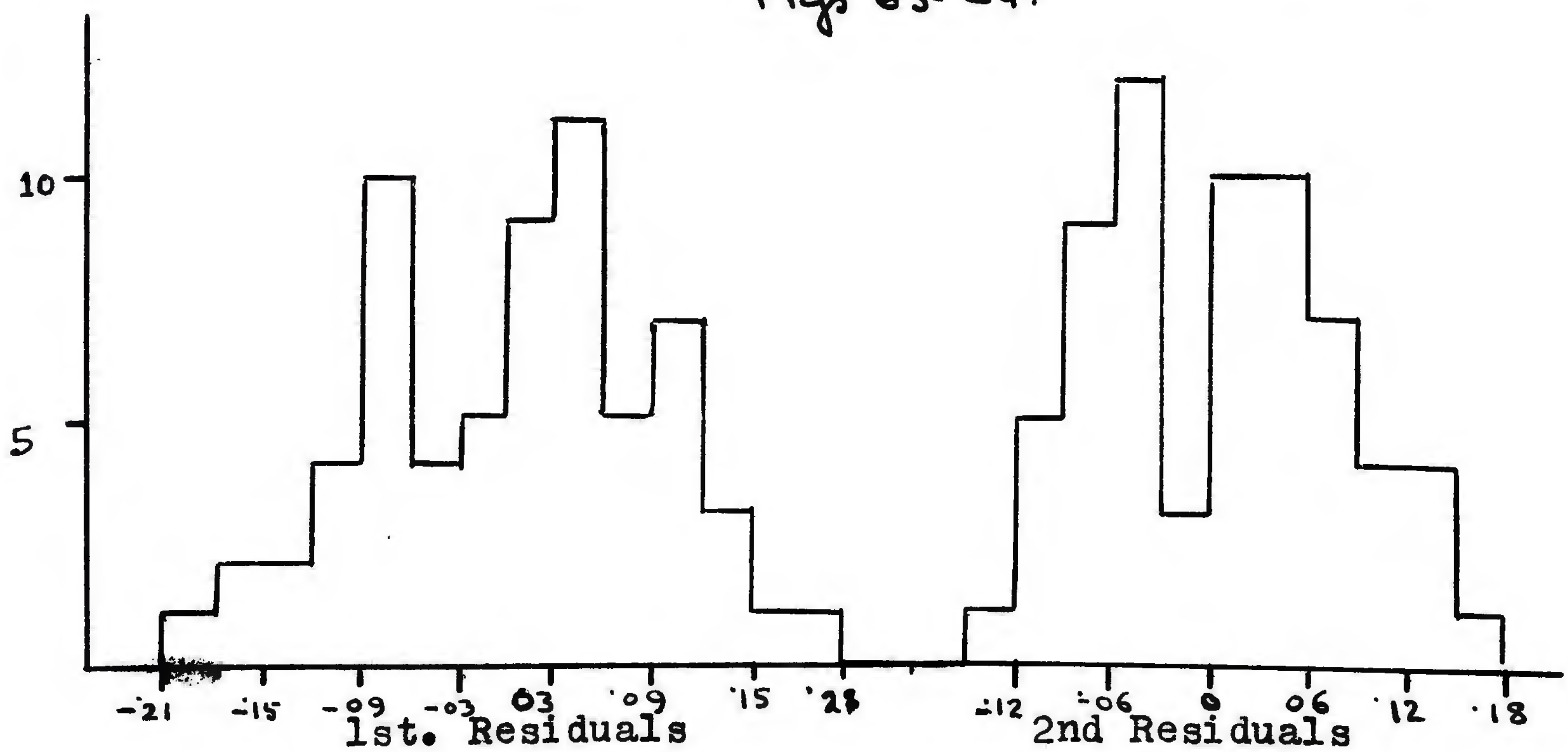
Distribution of Residual Correlations

Technical School



(ENGI. DEPT.)

Figs 63-64.



(Build. Dept.)

Figs 65-66

2. Graphic Rotation to an Orthogonal Simple Structure:

Thurstone considered the bipolar analysis obtained by the centroid method to be the first step to factor analysis, and he proceeded to rotate the arbitary reference frame to a preferred or simplifying position. He suggested that to secure a simple structure it was necessary that there should be:

a) At least one zero loading in each row

b) At least as many zero loadings in each column as there are columns

c) At least as many XO or OX entries in each pair of columns as there are columns

By XO entry he meant a loading in the one column opposite a zero in the other.

Thurstone emphatically insisted on the need of rotation if the factors were to have psychological meaning. Bur many other psychologists seem to be content not to rotate the axis. Burt pointed out that factors were merely a convenient form of classification, and as such the negative and positive dichotomy of a bipolar factor would often tell all that it was needed to know.

Thurstone's graphic rotation method has been crticised on the grounds that it lack uniqueness. Burt, Raeburn, Taylor and others have found fault with the subjective method of deciding the scheme of rotation, maintaining that this might yield the factors that were looked for.

To avoid any risk of non-independent findings, Cattell prefers to rotate the axis "blindly" as far as psychological meaning is concerned.

In this investigation the process was carried out blindly by the two-by-two method (Thurstone 1948, Thomson 1950). The tests were represented by numbers and plotted on a graph paper, using the centroid loadings as co-ordinates. Then the new axes were drawn at right angles, so that all the new loadings disappeared or attained minimum values. The new loadings were calculated using the general formula:

$$k'_2 = k_1 \cos\theta + k_2 \sin\theta$$

$$k'_2 = k_2 \cos\theta - k_1 \sin\theta$$

These calculations were checked by obtaining approximate new loadings by measurement from the graph. Figs 68-72 show the stages in the rotation, and the rotations are given in Tables 21-22. The calculations were finally checked by comparing the communality for each test in the unrotated factor matrix for approximate identity. The rotated loadings are given in Tables 23-24. It may be seen that the pattern of saturations approximates, on the whole, to the required criteria for simple structure.

Table 21.

Steps of Graphical Rotation.

(School of Architecture)

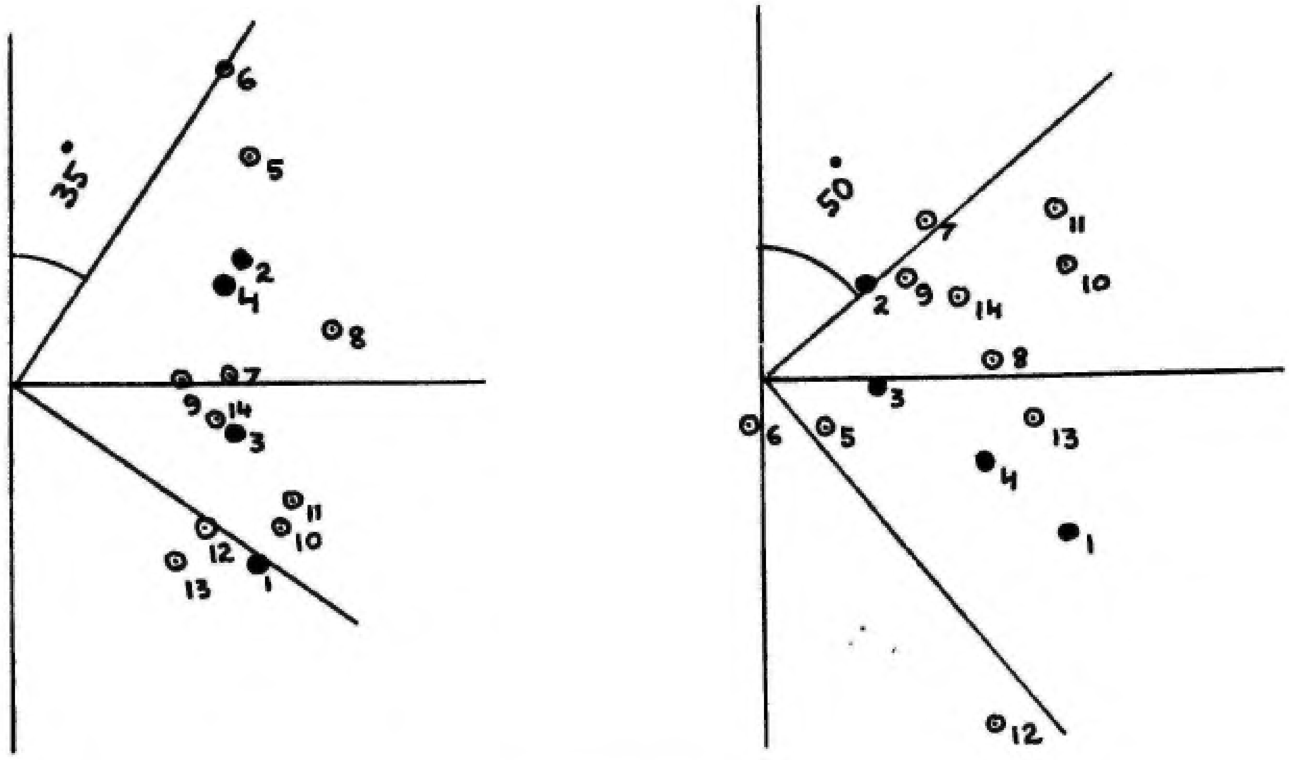
Step of Rot.	Initial Factors.	Factors after rotation	Angle of rotation
1	I & II	I' & II'	35° clockwise
2	I'& III	II''& III'	50° clockwise

Table 22.

Steps of Graphical Rotation.

(Technical Institute)

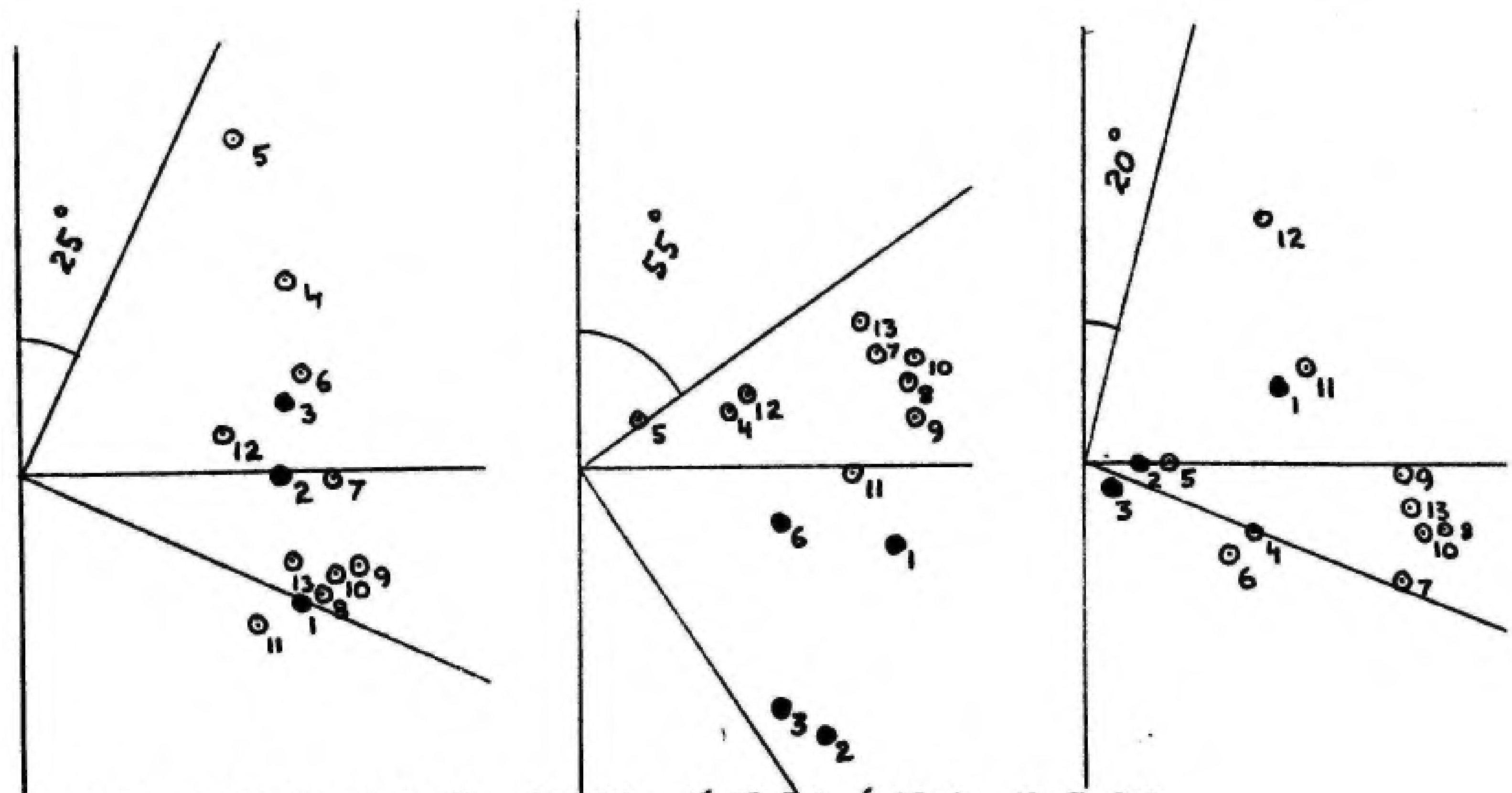
Step of Rot	Initial Factors.	Factors after rotation	Angle of rotation
1	I & II	I' & II'	25° clockwise
2	I'& III	I''& III'	55° clockwise
3	III'& IV	III''& IV'	20° clockwise



1. A.D., 2:S.S., 3:B.C., 4:B.S., 5:Otis, 6:V-14, 7:Mat.,
8: S-14, 9:F.R., 10:P&E., 11:3D.S, 12:Draw, 13:M.AJ, 14:Blck

Figs 68 & 69

Graphic Rotation (School of Architecture)



1:E.D., 2:Math, 3:G.S., 4:Otis, 5:V-14, 6:Mat., 7:S-14
8:F.R., 9:P&E., 10:3D.S, 11:Draw, 12:M.AJ, 13:Blck

Figs 70,71 & 72

Graphic Rotation (Technical Institute)

Table 23.

Rotated Factor Matrix.

(School of Architecture)

Variable	Factor Loading I	II	III	h^2
Arch. Design	.6471	-.0088 ✓	.2657	.4894
Struct. Sci.	.0044 ✓	.4800	.3069	.3246
Build. Const.	.4240	.1768	.0181 ✓	.2114
Build. Science	.1744	.4389	.1662	.2506
Otis Int.	.1469 ✓	.6447	.0346 ✓	.4378
V.S.14 I	.0612 ✓	.7746	-.0814 ✓	.6100
Matrices	-.0379 ✓	.2874	.4727	.3074
V.S.14 II	.2730	.4842	.3848	.4570
Form Relation	.0182 ✓	.2126	.3739	.1853
Plan & Elev.	.2217	.0642 ✓	.6236	.4422
3.D.S	.1427 ✓	.1250 ✓	.6819	.5010
Drawing Test	.8377	-.0189 ✓	-.0938 ✓	.4190
Meier's A.J.	.2905	-.0857 ✓	.4801	.3222
Block Test	.1460 ✓	.1740	.4298	.2363
Variance per cent	11.48	13.50	14.21	39.19

< .15

Table 24

Rotated Factor Matrix.

(Technical Institute)

Variable	Factor Loading I	II	III	IV	h^2
Tech. Drawing	.6028	.3960	.3172	.2862	.6118
Mathematics	.7807	.2194	.1003	.0031	.6676
General Sci.	.6766	.3749	.0950	-.1032	.6180
Otis Int.	.0938	.6168	.3719	-.0197	.5313
V.S.14 I	-.0151	.8416	.1504	.0814	.7377
Matrices	.3388	.4435	.3382	-.0818	.4325
V.S.14 II	.2115	.3302	.6970	.0028	.6395
Form Relation	.2136	.0205	.6982	.0858	.5408
Plan & Elev.	.4059	.1251	.6296	.2169	.6247
3.D.S.	.2021	.0274	.7001	.1185	.5456
Drawing Test	.3616	-.0688	.3606	.3595	.3950
Meier's A.J.	.0769	.2641	.1741	.6023	.4684
Block Test	.0969	.0717	.6600	.1286	.4665
Variance per cent	15.36	13.43	21.94	5.27	56.00

3. Group Factor Analysis.

In order to obtain further evidence about the variables, it was decided to re-analyse the correlation matrices of the School of Architecture and the Technical Institute by a group factor method. In this analysis Burt's (1948) Addition Group Factor method was used. The first problem in this kind of analysis is to decide how the original matrix of correlation is to be positioned or grouped. Burt suggested starting with the classification indicated by the bipolar factors as the basis for the group factor analysis. He claimed that this procedure was entirely automatic and objective.

Following Burt's suggestion the correlation matrix was partitioned into three sub-matrices suggested by the bipolar analysis given in Tables 25-26. After grouping the variables, the totals for the sub-matrices were found out. They may be represented symbolically as:

$$R = \begin{bmatrix} (R_{11}) & R_{12} & R_{13} \\ R_{21} & (R_{22}) & R_{23} \\ R_{31} & R_{32} & R_{33} \end{bmatrix}$$

The square blocks lying along the diagonal (R_{11}, R_{aa} and R_{33}) were omitted in the basic factor calculations. Instead of using one division to obtain the basic factor loadings from the column total, as in a normal bipolar analysis, as many different divisions were required in this case as there were omitted sub-matrices - in this case, three. They were calculated from this formula:

$$\sqrt{R_{23}\left(\sqrt{\frac{R_{12}}{R_{13}}}+\sqrt{\frac{R_{13}}{R_{12}}}\right)}$$

which was appropriately arranged for each block. The figures for the terms inside the brackets were the sums of those sub-matrices, whose column totals were to be divided. After the first factor residuals were calculated, the three diggonal matrices were analysed separately by the summation method, using reduced self correlations, obtained by iteration. The residual matrix after extracting basic and factors showed no trace of significant overlapping. Under such circumstances, no gain would have been made by carrying the analysis further to obtain overlapping group factors.

The solution from the non-overlapping group factor analysis appeared to give a satisfactory fit to the original tables, and appeared to provide a ready psychological explanation. Tables 27-28 give the factor matrix.

Table 25.

Grouping Of Variables Suggested by Bipolar Factors.

(School of Architecture)

Variable	Bipolar Factor I	Bipolar Factor II	Group
Drawing Test	-	-	A
Architectural Design	-	-	
Meier's A.J. Test	-	(-)	
Building Const.	(-)	(-)	
V.S.14 Part I ✓	-	(-)	B
Otis Intelligence	-	(-)	
Structural Science	-	(-)	
Building Science	-	(-)	
Block Test	(-)	(-)	C
3-D.S	-	-	
Plan & Elevation	-	-	
Form Relation	(-)	-	
V.S.14 Part II	(-)	(-)	
Matrices	(-)	-	

Table 26.

Grouping of Variables as Suggested by Bipolar Factors.

(Technical Institute)

Variable	Bipolar Factor I	Bipolar Factor II	Bipolar Factor III	Group
Form Relation	-	-	(-)	A
Block Test	(-)	-	(-)	
3-D.S	-	-	(-)	
Plan & Elevation	-	(-)	(-)	
V.S.14 Part II	(-)	-	-	
Drawing Test	-	(-)	(-)	
V.S.14 Part I	-	(-)	(-)	B
Otis Intelligence	-	(-)	(-)	
Meier's A.J. Test	(-)	(-)	-	
Matrices	-	(-)	(-)	
Eng. Drawing	-	-	(-)	C
Mathematics	(-)	-	(-)	
General Science	(-)	-	(-)	

Table 27.

Group Factor Matrix.

(School of Architecture)

Variable	Factor Loading Basic	A	B	C	h^2		Page 91
Drawing Test	.1884	.6702			.4847	x	.7108
Arch. Design	.3002	.6653			.5327		.4894
Meier's A.J.	.2204	.5945			.4020		.2365
Build Const.	.3962	.3835			.3041		.2600
V.S.14 I	.2679		.6844		.5402		.6103
Otis Int.	.3479		.5166		.3879		.4385
Structural Sci	.4042		.3647		.2964		.3246
Building Sci	.3761		.3505		.2644		.2506
Block Test	.3082			.5393	.3858		.2186
3-D.S	.5689			.3807	.4785		.5010
Plan & Elev.	.5673			.2959	.4094		.4421
Form Relation	.3665			.1386	.1427		.1791
V.S.14 II	.8383			.1070	.7141	x	.4570
Matrices	.5425			.0932	.3030		.3135
Variance per cent	19.28	9.95	7.08	4.02	40.33		

The h^2s here and on page 91 correspond fairly well. The two chief discrepancies are marked x

Table 28.

Group Factor Matrix.

(Technical Inst.)

Variable	Factor Loading Basic	A	B	C	h^2
Form Relation	.4812	.6316			.6205
Block Test	.4255	.5837			.5218
3-D.S	.5796	.3943			.4914
Plan & Elev.	.6193	.3833			.5305
V.S.14 II	.6334	.3309			.5107
Drawing Test	.4766	.1973			.2661
V.S.14 I	.3325		.8461		.8264
Otis Int.	.4868		.5170		.5043
Meier's A.J.	.3982		.1632		.1852
Matrices	.6261		.1219		.4069
Tech Drawing	.5955			.2565	.4204
Mathematics	.4965			.7279	.7763
General Sci.	.4868			.5569	.5471
Variance per cent	26.897	9.156	7.882	6.967	50.903

SECTION C.

Multivariate Analysis.

The usual accounts of test validation call for a multiple correlation between the "predictors" and the external criteria. Very often, investigators in the field of prediction experiments have contented themselves with an internal criterion, as provided by factor analysis. But in almost every new sphere of enquiry both types of evidence are desirable. Also, the vast majority of investigations in this field have been confined to the prediction of a single criterion. But the aptitude to be predicted is frequently multi-dimensional, and it cannot, as a rule, be represented satisfactorily by any single criterion.

1. Teams of Tests for Predicting the Complex Criteria.

The first step in the multiple analysis was to select teams of tests for predicting the complex criteria. In compiling the teams, an attempt was made to make them well balanced as regards factor composition. The overlapping between the test battery and the criteria was carefully examined, and one or more tests were selected to represent each common factor, so that all the aspects of the criteria were adequately covered. A criterion which had high loading in a particular test factor was covered by more than one test which had similar factor loading.

It was decided not to include too many tests in each team, because it was noticed that very little improvement could be achieved in multiple prediction by compiling more than four or five tests. And since the reliability of the tests was far from perfect, the prediction by a shorter battery would not be reliable.

Several teams of tests were composed by various combinations of four or five tests to predict the same criteria. The teams finally compiled were:

School of Architecture:

1) V.S.14 I & II, 3-D.S, M.A.J., Draw.
2) Mat., S-14, P.& E., 3-D.S, Draw.
3) V.S.14 I & II, M.A.J., Draw.
4) V-14, P.&E., M.A.J., Draw.
5) V-14, Mat, P.&E., M.A.J., Draw.
6) V.S.14 I & II, P.&E., Draw.
7) V-14, Mat.,3-D.S, M.A.J.
8) S-14, P.&E., M.A.J., Draw.

Technical Institute:

1) V-14, P.& E.,3-D.S, Draw.
2) V.S.14 I & II, P.& E.,Block, Draw.
3) V-14, Mat., P.& E., Draw.
4) Mat., P.& E., 3-D.S,Draw.
5) V.S.14 I & II, P.& E., Draw.
6) V.S.14 I & II, Mat., F.R., Draw.

Technical School: Engineering Department:

1) M.H.S., F.R., T.S.8, P.& E., Draw.
2) M.H.S., F.R., P.&E., Draw, Block.
3) M.H.S., F.R., P.&E., Draw.
4) M.H.S., P.&E., Draw, Block.
5) M.H.S., F.R., P.&E., Block.
6) Mat., M.H.S., F.R., T.S.8.
7) M.H.S., F.R., P&E.

Technical School: Building Department:

1) Mat., M.H.S., F.R., P.&E., Block.
2) M.H.S., T.S.8, P.& E., M.A.J., Bloack.
3) M.H.S., F.R., P.& E., M.A.J.
4) M.H.S., F.R., P.& E., Block.
5) M.H.S., P.& E., M.A.J., Block.
6) Mat., M.H.S., F.R., P. & E.
7) Mat., M.H.S., F.R., T.S.8.
8) M.H.S., F.R., P.& E.

2. Multiple Prediction:

After compiling the teams, the multivariate analysis was carried out in order to derive the following three degrees of correlation between the test battery and the complex criteria:

1) Multiple correlation - both the teams of the predicting tests and the components of the criteria being arbitrarily weighted. Here the correlation was uniquely defined and no maximal problem existed.

2) Maximum prediction - the components of the criteria being arbitarily weighted, and the test weights obtained which gave maximum battery correlations with the complex criteria defined by the arbitarily weighted assessment.

3) Maximum prediction in the Hotelling sense - the weights being assigned to the components of both teams. The maximum prediction was computed and the weights yielded a value for prediction which could not be equalized or exceeded, not matter what other weights were chosen.

i) Multiple correlation.

By considering a set of variates for the criteria and a set of variates for the battery of tests, the matrix of correlation coefficients between the a - b variates may be symbolized as:

$$\begin{bmatrix} R_{aa} & R_{ab} \\ R_{ba} & R_{bb} \end{bmatrix}$$

Further, by assigning the vector of weights u to the a variates, and the vector w to the b variates, the following pooling square is obtained:

	u'	w'
u	R_{aa}	R_{ab}
w	R_{ba}	R_{bb}

On application of product moment correlation of coefficient, the battery correlation between a and b is given by r_m

$$r_m = \frac{u'R_{ab}w}{\sqrt{u'R_{aa}u \cdot w'R_{bb}w}}$$

The weights u and w were selected quite freely, without any intention of maximizing the prediction.

In this investigation all the componenets of the criteria and the tests were given equal weights and the multiple correlation was calculated by applying the pooling square method (Thomson 1950).

ii) Maximum prediction.

The fundamental principle which underlines the calculation of the regression coefficient required to give maximum correlation between a battery of tests and a criteria, is the principle of least squares. According to this principle $\sum(x_i - \hat{x}_i)^2$ has to be the minimum, where $\hat{x}_i$ = the criterion score as estimated by the weighted battery of tests, and x_1 = the criterion score.

Peel (1947) devised a method for obtaining test weights which give maximum prediction of complex criteria. By his method, the test weights w - which give maximum prediction of an external complex criteria, formed from a number of assessments weighted arbitarily by the vector of weights u - can be calculated by the equation:

$$w' = u'R_{ab}R_{bb}^{-1}$$

where the assessments are the a variates, and the predicting tests are the b variates. The maximum correlation is given by:

$$r_m = \sqrt{\left[\frac{u'R_{ab}R_{bb}^{-1}R_{ba}u}{u'R_{aa}u}\right]}$$

The computation was done in the following steps:

1) $R_{ab}R_{bb}^{-1}$ was calculated by Aitken's method of pivotal condensation (Thomson 1950)

2) The criteria were arbitarily weighted, firstly giving equal weights to all the components, and then different weights to different components, on educational and psychological grounds, based on experts' opinions.

3) The maximum prediction was obtained by calculating:

a. $$u'R_{ab} R_{bb}^{-1} R_{ba} u = \begin{vmatrix} w_1 w_2 \ldots w_q \end{vmatrix} \begin{vmatrix} R_{ba} u \end{vmatrix} \begin{matrix} u_1 \\ u_2 \\ \cdot \\ \cdot \\ \cdot \\ u_p \end{matrix}$$

then,

b. $$u'R_{aa} u = u_1 u_2 \ldots u_p \begin{vmatrix} R_{aa} \end{vmatrix} \begin{matrix} u_1 \\ u_2 \\ \cdot \\ \cdot \\ \cdot \\ u_p \end{matrix}$$

and finally,

c. $$r_m = \sqrt{\frac{\text{the value obtained in step a}}{\text{the value obtained in step b}}}$$

iii) Maximum Prediction in the Hotelling Sense.

Hotelling's idea about maximum prediction was to give weights to the components of the criteria, as well as to the parts of the battery of tests, which would cause the combined sum of the one to correlate as highly as possible with the combined sum of the other (Hotelling 1935,'36, Thomson 1947). The maximum prediction was obtained by making the best of the correlation coefficients represented by the matrix:

$$\begin{array}{c|c} R_{aa} & R_{ab} \\ \hline R_{ba} & R_{bb} \end{array}$$

Hotelling's method also involves the solving of the equation for:

$$\left| R_{ab} R_{bb}^{-1} R_{ba} - \lambda R_{aa} \right| = 0$$

Since $\lambda = r_m^2$, which is to be maximized, it is the largest root wanted. This root can be found by the trial and error method. The criterion weights u which give this maximum prediction are in the ratio of the elements of any row of the matrix.

$$\operatorname{adj} \left(R_{ab} R_{bb}^{-1} R_{ba} - \lambda R_{aa} \right)$$

The weights w are found by condensing R_{bb}, standardizing it, and performing the usual regression calculation.

In the actual calculation, the steps involved were as follows:

1) The value of $\left| R_{ab} R_{bb}^{-1} R_{ba} \right|$ was taken from the maximum prediction analysis calculated by Peel's method, which was previously described.

2) The equation $\left| R_{ab} R_{bb}^{-1} R_{ba} - \lambda R_{bb} \right| = 0$, was solved by trial and error, calculating the above determinant for the λ = square of the largest correlation among the cross correlations in R_{ab} and working upwards till the sign changed, then interpolating. Thus

the maximum correlation $r^2 = \lambda$ was obtained.

3) The weights u were found by calculating the co-factors of any row of $\left| R_{ab} R_{bb}^{-1} R_{ba} - R_{bb} \right| = 0$
The weights were found in the ratios $u_1 : u_2 : u_3 \ldots : u_p$

4) R_{bb} was then standardized after being condensed.

5) Finally, the weights were found out by a regression calculation by pivotal condensation, giving the regression coefficients in the ratios $w_1 : w_2 : w_3 \ldots : w_q$

The results were checked by a "pooling square" and the figures agreed, closely enough, with the value of r as found before.

The standard errors of the multiple corrleation may be determined by the approximate formula given by Kelley (1923) or Hotelling (1936). In this research the number of degrees of freedom was taken as the denominator, instead of the total number of cases in the sample. The formula used was:

$$S.E.r_m = \frac{1 - r_m^2}{\sqrt{(N - n - 1)}}$$

Results of the multiple prediction analysis is given in Tables 29-57.

TABLE 29

Battery No. 1.

Prediction for VS-14 Parts I & II, 3D.S, Meier A.J. and Drawing Tests.

(School of Architecture)

Relative weights assigned to:							r_m	S.E.r_m	Battery Reliability r_b
CRITERION		TEST							
A.D.	S.S.	V-14	S-14	3D.S	M.AJ	Draw			
1	1	1	1	1	1	1	.5828	.0794	.8407
Arbitrary weights		Calculated weights					Best r_m		
1	1	.561	.588	.745	1.000	.894	.5922	.0781	.8451
3	1	.151	.435	.341	1.000	.995	.6938	.0747	.8250
Calculated weights							Max. r_m		
1.000	-.002	-.243	.319	-.230	.922	1.000	.7176	.0683	.7847

TABLE 30

Battery No. 2.

Prediction for Matrices, VS-14 Part II, Plan and Elevation, 3D.S and Draw Tests.

(School of Architecture)

Relative weights assigned to:							r_m	S.E.r_m	r_b
CRITERION		TEST							
A.D.	S.S.	Mat.	S-14	P&E.	3D.S	Draw			
1	1	1	1	1	1	1	.5600	.0827	.8908
Arbitrary weights		Calculated weights					Best r_n		
1	1	.580	.814	.795	.344	1.000	.5717	.0812	.8888
3	1	.126	.457	.482	.196	1.000	.6100	.0756	.9145
Calculated weights							Max. r_m		
1.000	-.286	-.190	.206	.262	.096	1.000	.6104	.0755	.8635

TABLE 31

Battery No.3

Prediction for VS-14 Parts I & II, Meier Art Judgement and Drawing Tests.

(School of Architecture)

Relative weights assigned to: CRITERION		TEST				r_m	S.E.r_m	r_b
A.D.	S.S.	V-14	S-14	M.AJ	Draw			
1	1	1	1	1	1	.5058	.0889	.8664
Arbitrary weights		Calculated weights				Best r_m		
1	1	.188	1.000	.906	.831	.5373	.0856	.8329
3	1	-.189	.681	1.000	.987	.6863	.0632	.8010

TABLE 32

Battery No. 4.

Prediction for VS-14 Part I, Plan and Elevation, Meier A.J. and Draw Tests.

(School of Architecture)

Relative weights assigned to: CRITERION		TEST				r_m	S.E.r_m	r_b
A.D.	S.S.	V-14	P&E.	M.AJ	Draw			
1	1	1	1	1	1	.5820	.0792	.8283
Arbitrary weights		Calculated weights				Best r_m		
1	1	.635	.747	.685	1.000	.6151	.0743	.8387
3	1	.313	.439	.851	1.000	.6867	.0631	.8230

TABLE 33

Battery No. 5.

Prediction for VS-14 Part I, Matrices, Plan & Elevation, M.AJ and Drawing Tests.

(School of Architecture)

Relative weights assigned to: CRITERION		TEST					r_m	S.E.r_m	r_b
A.D.	S.S.	V-14	Mat.	P&E.	M.AJ	Draw			
1	1	1	1	1	1	1	.5917	.0783	.8534
Arbitrary weights		Calculated weights					Best r_m		
1	1	.831	.551	1.000	.940	.989	.5980	.0773	.8086
3	1	.332	.075	.485	.963	1.000	.6822	.0644	.8047

TABLE 34

Battery No. 6.

Prediction for VS-14 Parts I & II, Plan and Elevation and Drawing Tests.

(School of Architecture)

Relative weights assigned to: CRITERION		TEST				r_m	S.E.r_m	r_b
A.D.	S.S.	V-14	S-14	Draw	P&E.			
1	1	1	1	1	1	.5379	.0848	.8824
Arbitrary		Calculated weights				Best r_m		
1	1	.393	.685	.915	1.000	.5549	.0827	.8560
3	1	-.010	.529	1.000	.581	.6035	.0759	.8556

TABLE 35

Battery No. 7.

Prediction for VS-14 Part I, Matrices, 3D.S and Meier's A.J. Tests.

(School of Architecture)

Relative weights assigned to: CRITERION		TEST				r_m	S.E.r_m	r_b
A.D.	S.S.	V-14	Mat.	3D.S	M.AJ			
1	1	1	1	1	1	.5374	.0824	.8246
Arbitrary weights		Calculated weights				Best r_m		
1	1	.857	.530	.824	1.000	.5460	.0838	.8018
3	1	.407	.071	.467	1.000	.5601	.0820	.7277

TABLE 36

Battery No. 8.

Prediction for VS-14 PartII, Plan and Elevation, Meier A.J. and Drawing Tests.

(School of Architecture)

Relative weights assigned to: CRITERION		TEST				r_m	S.E.r_m	r_b
A.D.	S.S.	S-14	P&E.	M.AJ	Draw			
1	1	1	1	1	1	.5843	.0889	.8516
Arbitrary weights		Calculated weights				Best r_m		
1	1	.992	.827	.992	1.000		.0856	.8509
3	1	.520	.353	.926	1.000	.6932	.0632	.8359

TABLE 37

Battery No. 1.

Prediction for VS-14 Part I, Matrices, Plan and Elevation, 3D.S and Draw Tests.

(Technical Institute)

Relative weights assigned to: CRITERION			TEST					r_m	S.E.r_m	r_b
T.D.	Math	G.S.	V-14	Mat.	P&E.	3D.S	Draw			
1	1	1	1	1	1	1	1	.5748	.0453	.9267
Arbitrary weights			Calculated weights					Best r_m		
1	1	1	.417	.801	1.000	.084	.587	.5961	.0436	.8956
4	2	1	.243	.505	1.000	.165	.536	.6088	.0425	.8785
Calculated weights								Max. r_m		
1.000	.270	.450	.378	-.007	1.000	.141	.462	.6163	.0420	.8524

TABLE 38

Battery No. 2.

Prediction for VS-14 Parts I & II, Plan and Elevation, Block and Drawing Tests.

(Technical Institute)

Relative weights assigned to CRITERION			TEST					r_m	S.E.r_m	r_b
T.D.	Math	G.S.	V-14	S-14	P&E.	Blck	Draw			
1	1	1	1	1	1	1	1	.4853	.0516	.9171
Arbitrary weights			Calculated weights					Best r_m	.0463	
1	1	1	.492	.108	1.000	-.274	.570	.5605	.0463	.8201
4	2	1	.293	.175	1.000	-.250	.559	.5887	.0442	.8269
Calculated weights								Max r_m		
1.000	.269	.215	.377	.348	1.000	-.550	245	.5913	.0440	

TABLE 39

Battery No. 3

Prediction for VS-14 Part I, Matrices, Plan and Elevation and Drawing Tests.

(Technical Insitute)

Relative weights assigned to: CRITERION			TEST				r_m	S.E.r_m	r_b
T.D.	Math	G.S.	V-14	Mat.	P&E.	Draw			
1	1	1	1	1	1	1	.5775	.0447	.9074
Arbitrary			Calculated weights				Best r_m		
1	1	1	.421	.743	1.000	.580	.5915	.0443	.8900
4	2	1	.248	.431	1.000	.527	.6004	.0431	.8315

TABLE 40

Battery No. 4.

Prediction for Matrices, Plan and Elevation, 3D.S and Drawing Tests.

(Technical Institute)

Relative weights assigned to: CRITERION			TEST				r_m	S.E.r_m	r_b
T.D.	Math	G.S.	Mat.	P&E	3D.S	Draw			
1	1	1	1	1	1	1	.5633	.0460	.9195
Arbitrary weights			Calculated weights				Best r_m		
1	1	1	.973	1.000	.199	.616	.5803	.0447	.8960
4	2	1	.553	1.000	.239	.551	.5975	.0434	.8783

TABLE 41

Battery No. 5.

Prediction for VS-14 Parts I & II, Plan and Elevation and Drawing Tests.

(Technical Institute)

Relative weights assigned to: CRITERION			TEST				r_m	S.E.r_m	r_b
T.D.	Math	G.S.	V-14	S-14	P&E.	Draw			
1	1	1	1	1	1	1	.5184	.0483	.9103
Arbitrary weights			Calculated weights				Best r_m		
1	1	1	.532	.009	1.000	.531	.5545	.0467	.8473
4	2	1	.327	.089	1.000	.523	.5855	.0444	.8497

TABLE 42

Battery No. 6.

Prediction for VS-14 Parts I & II, Matrices, Form Relation and Draw Tests.

(Technical Institute)

Relative weights assigned to: CRITERION			TEST					r_m	S.E.r_m	r_b
T.D.	Math	G.S.	V-14	Mat.	S-14	F.R.	Draw			
1	1	1	1	1	1	1	1	.5001		.9246
Arbitrary weights			Calculated weights					Best r_m		
1	1	1	.281	1.000	.354	.138	.857	.5308		.9190
4	2	1	.089	.786	.573	.188	1.000	.5162		.9325

TABLE 43

Battery No. 1.

Prediction for MH.S, Form Relation, TS.8, Plan and Elevation and Drawing Tests.

(Technical School:Engineering Dept.)

Relative weights assigned to: CRITERION				TEST					r_m	S.D.r_m	r_b
T.D.	Geom	M.W.	W.W.	MH.S	F.R.	TS.8	P&E.	Draw			
1	1	1	1	1	1	1	1	1	.6114		.9335
Arbitrary weights				Calculated weights					Best r_m		
1	1	1	1	.372	.223	-.003	.750	1.000	.6559		.8857
4	2	1	1	.312	.268	-.032	.786	1.000	.6633		.8473
Calculated weights											
.750	1.000	.688	-.013	.462	.063	.003	.658	1.000	.6736	.0407	.8790

TABLE 44

Battery No. 2.

Prediction for MH.S, Form Relation, Plan and Elevation, Drawing and Block Tests.

(Technical School:Engineering Dept.)

Relative weights assigned to: CRITERION				TEST					r_m	S.D.r_m	r_b
T.D.	Geom	M.W.	W.W.	MH.S	F.R.	P&E.	Draw	Blck			
1	1	1	1	1	1	1	1	1	.6322		.9250
Arbitrary weights				Calculated weights					Best r_m		
1	1	1	1	.351	.207	.727	1.000	.191	.6569		.8796
4	2	1	1	.283	.259	.776	1.000	.116	.6628		.8686
Calculated weights									Max. r_m		
1.000	.900	.750	.100	.439	-.179	.649	1.000	.099	.6696	.0411	.8492

TABLE 45

Battery No. 3.

Prediction for MH.S, Form Relation, Plan and Elevation and Drawing Tests.

(Technical School:Engineering Dept.)

Relative weights assigned to: CRITERION				TEST				r_m	$S.D.r_m$	r_b
T.D.	Geom	M.W.	W.W.	MH.S	F.R.	P&E.	Draw			
1	1	1	1	1	1	1	1	.6342	.0452	.9173
Arbitrary weights				Calculated weights				Best r_m		
1	1	1	1	.367	.260	.755	1.000	.6564	.0432	.8881
4	2	1	1	.303	.331	.791	1.000	.6686	.0418	.8858

TABLE 46

Battery No. 4.

Prediction for MH.S, Plan and Elevation, Drawing and Block Tests.

(Technical School:Engineering Dept.)

Relative weights assigned to: CRITERION				TEST				r_m	$S.D.r_m$	r_b
T.D.	Geom	M.W.	W.W.	MH.S	P&E.	Draw	Blck			
1	1	1	1	1	1	1	1	.6267	.0459	.9022
Arbitrary weights				Calculated weights				Best r_m		
1	1	1	1	.709	.887	1.000	.694	.6560	.0433	.8997
4	2	1	1	.680	.897	1.000	.659	.6604	.0421	.8994

TABLE 47

Battery No. 5.

Prediction for MH.S, Form Relation, Plan and Elevation and Block Tests.

(Technical School:Engineering Dept.)

Relative weights assigned to: CRITERION				TEST				r_m	S.D.r_m	r_b
T.D.	Geom	M.W.	W.W.	MH.S	F.R.	P&E.	Blck			
1	1	1	1	1	1	1	1	.5801	.0502	.9111
Arbitrary weights				Calculated weights				Best r_m		
1	1	1	1	.478	.737	1.000	.424	.5855	.0497	.9102
4	2	1	1	.388	.743	1.000	.319	.5947	.0489	.9071

TABLE 48

Battery No. 6.

Prediction for Matrices, MH.S, Form Relation and TS.8 Tests.

(Technical School:Engineering Dept.)

Relative weights assigned to: CRITERION				TEST				r_m	S.D.r_m	r_b
T.D.	Geom	M.W.	W.W.	MH.S	F.R.	TS.8	Mat.			
1	1	1	1	1	1	1	1	.4874	.0577	.9284
Arbitrary weights				Calculated weights				Best r_m		
1	1	1	1	.779	1.000	.234	.337	.5079	.9094	.9094
4	2	1	1	.859	1.000	.141	.454	.5084	.0560	.9080

Table 49

Prediction for MH.S, Form Relation and Plan & Elev. Tests.

(Technical School: Engineering Dept.)

Relative weights assigned to: CRITERION				TEST				
T.D.	Geom	M.W.	W.W.	MH.S	F.R.	P&E.	r_m	r_b
1	1	1	1	1	1	1	.5706	.9090
Arbitrary Weights				Calculated weights			Max r_m	
1	1	1	1	.497	.708	1.000	.5795	.8981

TABLE 50

Battery No.1.

Prediction for MH.S, Form Relation, Plan and Elevation, Block and Matrices Tests.

(Technical School:Building Dept.)

Relative weights assigned to: CRITERION			TEST					r_m	S.D.r_m	r_b
B.C.	C.J.	Geom	MH.S	F.R.	P&E.	Blck	Mat.			
1	1	1	1	1	1	1	1	.5999	.0485	.9025
Arbitrary weights			Calculated weights					Best r_m		
1	1	1	.818	1.000	.962	.232	.329	.6160	.0472	.8969
Calculated weights								Max r_m		
.503	1.000	.404	.931	1.000	.689	.357	.009	.6235	.0454	.8949

TABLE 51

Battery No.2.

Prediction for MH.S, TS.8, Plan and Elevation, Meier A.J. and Block Tests.

(Technical School:Building Dept.)

Relative weights assigned to: CRITERION			TEST					r_m	S.D.r_m	r_b
B.C.	C.J.	Geom	MH.S	TS.8	P&E.	M.AJ	Blck			
1	1	1	1	1	1	1	1	.5628	.0582	.8864
Arbitrary weights			Calculated weights					Best r_m		
1	1	1	1.000	-.086	.771	.559	.275	.5738	.0508	.8665
Calculated weights								Max r_m		
.366	1.000	.535	1.000	.181	.572	.533	.346	.6064	.0479	.8817

TABLE 52

Battery No.3.

Prediction for MH.S, Form Relation, Plan and Elevation and Meier A.J. Tests.

(Technical School:Building Dept.)

Relative weights assigned to: CRITERION			TEST				r_m	S.D.r_m	r_b
B.C.	C.J.	Geom	MH.S	F.R.	P&E.	M.AJ			
1	1	1	1	1	1	1	.6111	.8621	.8621
Arbitrary weights			Calculated weights				Best r_m		
1	1	1	.997	1.000	.831	.464	.6291	.0457	.8834

TABLE 53

Battery No.4.

Prediction for MH.S, Form Relation, Plan and Elevation and Blocks Tests.

(Technical School:Building Dept.)

Relative weights assigned to: CRITERION			TEST				r_m	S.D.r_m	r_b
B.C.	C.J.	Geom	MH.S	F.R.	P&E.	Blck			
1	1	1	1	1	1	1	.5963	.0487	.8967
Arbitrary weights			Calculated weights				Best r_m		
1	1	1	.866	1.000	.900	.189	.6114	.0474	.8720

TABLE 54

Battery No.5.

Prediction for MH.S, Plan and Elevation, Meier and Block Tests.

(Technical School:Building Dept.)

Relative weights assigned to: CRITERION			TEST						
B.C.	C.J.	Geom	MH.S	P&E.	M.AJ	Blck	r_m	S.D.r_m	r_b
1	1	1	1	1	1	1	.5965	.0487	.8345
Arbitrary weights			Calculated weights				Best r_m		
1	1	1	1.000	.991	.428	.480	.5988	.0485	.8536

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TABLE 55

Battery No.6.

Prediction for Matrices, MH.S, Form Relation and Plan and Elevation Tests.

(Technical School : Building Dept.)

Relative weights assigned to: CRITERION			TEST				r_m	S.D.r_m	r_b
B.C.	C.J.	Geom	Mat.	MH.S	F.R.	P&E.			
1	1	1	1	1	1	1	.5884	.0494	.8912
Arbitrary weights			Calculated weights				Best r_m		
1	1	1	.322	.893	1.000	.978	.6146	.0471	

TABLE 56

Battery No.7.

Prediction for Matrices, MH.S, Form Relation and TS.8 Tests.

(Technical School : Building Dept.)

Relative weights assigned to: CRITERION			TEST				r_m	S.D.r_m	r_b
B.C.	C.J.	Geom	Mat.	MH.S	F.R.	TS.8			
1	1	1	1	1	1	1	.5488	.0529	.8941
Arbitrary weights			Calculated weights				Max. r_m		
1	1	1	.223	1.000	.859	.146	.5839	.0496	.8684

TABLE 57

Battery No. 8.

Prediction for MH.S, Form Relation and Plan and Elevation Tests.

(Technical School:Build. Dept.)

CRITERION		TEST				r_m	S.D.r_m	r_b
B.C.	C.J.	Geom	MH.S	F.R.	P&E.			
1	1	1	1	1	1	.6096	.0450	.8827
Arbitrary weights		Calculated weights				Best r_m		
1	1	1	.924	.927	1.000	.6160	.0473	.8820

3. Battery Reliability.

It is useful to know the reliability of a battery of tests i.e. the correlation between two successive applications of the same battery. This can be done by the pooling square method. The matrix of correlation may be symbolized as:

$$\begin{bmatrix} R_{bb} & R_{b\beta} \\ R_{\beta b} & R_{\beta\beta} \end{bmatrix} \text{giving a pooling square} \quad \begin{array}{c|cc} & u' & w' \\ \hline u & R_{bb} & R_{b\beta} \\ w & R_{\beta b} & R_{\beta\beta} \end{array}$$

where

b and β are the tests of their first and second applications respectively, and u and w are the weights assigned to them.

On application of the product moment correlation coefficient, the battery correlation between the two successive applications is given by r_b which is equal to:

$$\frac{u'R_{b\beta}w}{\sqrt{u'R_{bb}u \cdot w'R_{\beta\beta}w}}$$

In this investigation the reliability of each battery of tests was calculated and given in the last column of Tables 29-57.

Thomson (1940) observed that the weights which give maximum prediction are usually different from the weights giving maximum reliability. And he developed a method of calculating maximum battery reliability by assigning appropriate weights to the tests.

Peel (1947) devised a simpler method than Thomson's - one in which the maximum battery reliability of a battery of tests is found by obtaining the maximum value of ρ where

$$\rho = \frac{u'R_b u}{u'R_{bb} u}$$

This involves solving the equation:

$$\left| R_{b\beta} - R_{bb} \right| = 0 \text{ for its largest root}$$

The root λ_1 is equal to ρ, the maximum reliability and the weights w which give maximum reliability, are in the ratio of the elements of any row of the matrix $\left| \mathrm{adj}(R_{ba} - \lambda_1 R_{bb}) \right|$

In this research the maximum battery reliability of two teams of tests from each sample was calculated by Peel's method. The calculation was carried out in three steps:

1) The reliability of each test was inserted in the diagonal cells of the correlation matrix to form $R_{b\beta}$ (R_{bb} was obtained by inserting unity in the diagonal cells of the correlation matrix).

2) The equation $\left| R_{b\beta} - \lambda R_{bb} \right| = 0$ was solved for its largest root by the trial and error method. The root was equal to ρ, the maximum reliability.

3) The weights of the tests were obtained by suppressing any row of the matrix $\left| R_b - \lambda_1 R_{bb} \right|$

The weights were checked by substituting them in Peel's equation for obtaining maximum prediction.

Table 58 shows the conflict between the weights assigned to tests giving the maximum battery reliability and the maximum prediction.

Table 58.

Maximum Battery Reliability and Maximum Prediction.

A. School of Architecture.					
Weights assigned to tests to obtain the maximum battery reliability.				Maximum Battery Reliability.	Prediction with equally weighted assessments.
V-14	P&E.	M.AJ	Draw		
.636	.133	.070	1.000	.8698	.4445
Weights assigned to tests to obtain the maximum prediction				Battery Reliability	Maximum prediction with equally weighted assts.
.635	.747	.685	1.000	.8387	.6151
B. Technical Institute					
Weights assigned to tests to obtain the maximum battery reliability.				Maximum Battery Reliability.	Prediction with equally weighted assessments.
V-14	S-14	P&E.	Draw		
.373	.843	.510	1.000	.9078	.5125
Weights assigned to tests to obtain the maximum prediction				Battery Reliability	Maximum prediction with equally weighted assts.
.532	.009	1.000	.531	.8473	.5545

Table 58.
(cont)

C. Technical School: Engineering Dept.					
Weights assigned to tests to obtain the maximum battery reliability.				Maximum Battery Reliability.	Prediction with equally weighted assessments.
Draw	P&E.	F.R.	MH.S		
.221	.732	.792	1.000	.9195	.5861
Weights assigned to tests to obtain the maximum prediction.				Battery Reliability.	Maximum prediction with equally weighted assts.
.367	.260	.755	1.000	.8881	.6564

D. Technical School: Building Dept.					
Weights assigned to tests to obtain the maximum battery reliability.				Maximum Battery Reliability.	Prediction with equally weighted assessments.
MH.S	F.R.	P&E.	M.AJ		
1.000	.571	.664	.168	.8907	.6115
Weights assigned to tests to obtain the maximum prediction.				Battery Reliability.	Maximum prediction with equally weighted assts.
.997	1.000	.831	.464	.8834	.6291

ABBREVIATIONS.

Tests

Blck: Block Test (Performance) Experimental

Draw: Drawing Test, Experimental

F.R.: N.I.I.P. Form Relation Test

M.AJ: Meier Art Judgement Test

Mat.: Progressive Matrices, 1938

MH.S: Moray House Space Test

Otis: Otis Group Intelligence Scale, Advanced Exam

P&E.: Plan and Elevation Test

S-14: V.S.14 Part II (Spatial)

TS.8: The Peel Group Test of Practical Ability

V-14: V.S.14 Part I (Verbal)

3D.S: 3 Dimensional Space Test, Experimental

Further details of tests in Table 2. Page 54

Criteria

A.D.: Architectural Design

B.C.: Building Construction

B.S.: Building Science

C.J.: Carpentry Joinery

Geom: Geometry

G.S.: General Science

Math: Mathematics

M.W.: Metalwork

S.S: Structural Science

T.D.: Technical Drawing

W.W.: Woodwork

CHAPTER V

INTERPRETATION OF RESULTS

A. Preliminary Analysis

1. Distribution of Raw Scores.

The distribution of the raw scores reveals the level of difficulty of the tests for the subjects, and makes it possible to ascertain the suitability of the tests and the nature of the population.

Score distribution in most of the tests applied to Group A (School of Architecture) is not normal (P .05) - it is skewed negatively, the scores being massed at the high end of the scale and spread out gradually at the low end. The narrow spread of the distribution as suggested by the low standard deviation, indicates that the sample concerned is highly selected, and that the tests are too easy for the subjects. It will be noted, however, that the distribution of the assessments is quite satisfactory.

In Group B (Technical Institute), the distribution of the assessments and the tests, except the Progressive Matrices and Form Relation tests, is not normal, but the skewness is not very large. The range of scores in most of the tests is satisfactory.

The score distribution of almost all the tests given to Groups C and D (Technical School) is skewed negatively and standard deviation is low. This suggests that the samples are very homogeneous, and that some of the tests are too easy for the testees. The assessments, on the other hand, are positively skewed - the marks are massed at the low end of the scale and spread out gradually towards the high end. This indicates that although the teachers make full use of the scale, they fail to discriminate pupils at the middle range, and have a tendency to give them low marks. The standard deviation of the assessments varies from 3 to 3.5, which may be regarded as satisfactory. Age distribution in both samples is positively skewed as would be expected in a school where all students are admitted at a fixed age level.

On the whole the students from both the School of Architecture and the Technical School are highly superior and homogeneous groups. The apprentices from the Technical Institute, however, have low mental ability and are unselected.

The selective nature of a sample should always be bourne in mind while interpreting the results. The homogenity of a samples shrinks the range - the standard deviation - and hence the correlation; ultimately, the multiple prediction is under-estimated, and the results of the factor analysis are liable to differ, though the configuration may remain the same.

It has been seen that most of the tests and criteria in this investigation are not distributed normally. Facing a similar problem, Thurstone and his collaborators found that while it was desriable to normalize the raw score distribution, failure to do so did not seriously affect the results of the subsequent analysis. In the present enquiry, when dealing with results of the Technical School pupils (Engineering Department), the score distributions of Engineering Drawing (positively skewed), and three tests - Moray House Space test, Plan and Elevation test and the Otis test - (all negatively skewed), were normalized and the intercorrelations computed. The correlations between Engineering Drawing and the Moray House test before and after normalizing are .3732 and .3907 respectively. The difference, .0175, is negligible in comparison to the standard error, .0745, of the zero order correlation of 180 cases. The other differences as shown in Table 7 are also insignificant. In view of this it was decided to correlate the raw scores and assessments in all tests directly.

2. Reliability of the Tests.

The reliability of each test is computed separately as it varies from sample to sample. The coefficient is higher in a heterogeneous sample, whereas in a sample with a narrow range of ability it tends to be smaller. Reliability as computed by the split half method, strictly speaking indicates the internal consistency of the test, but nevertheless it is a legitimate estimate, for it is expected that the test which is consistent withing itself will also give consistent results when administered on different occasions. But results obtained by the split half method should be interpreted with some statistical caution, however, because it gives a slight over-estimation or reliability, on account of the fact that chance fluctuations of test performances in different sittings do not affect the scores, and that the errors in odd and even halves of the tests are correlated positively. Table 15 gives the reliability of all the tests. Considering the homogenity of the samples, the coefficients - which are in the range of .8 to .9 - may be regarded as satisfactory.

The Meier Art Judgement test is very disappointing - it yields consistently low coefficients: .6678, .6870, .5375 and .5348. The verbal tests give somewhat higher coefficients than the practical ability tests, but this result should be interpreted cautiously, because the length of the tests is not the same. After correcting for a length of 40 minutes, it is noted that most of the non-verbal tests are superior to the Otis Verbal Intelligence test. Peel's V.S.14 and T.S.8 tests are outstanding. The results of the Block Test cannot be directly compared with other coefficients given in the table, because the coefficients given are based on a different sample.

3. Matrix of Correlation.

The intercorrelations of ten tests and four assessments in the School of Architecture Sample are given in Table 8, which shows that all the correlation coefficients are either positive or near zero. The least values of r which exceed t at the 5 per cent level and the 1 per cent level are .227 and .296 respectively. In the matrix, 42.86 per cent of the coefficients exceed the 5 per cent level.

The correlations in the matrix between the tests and assessments (R_{ab}) suggest that the 3 Dimensional Space test, the V.S.14 test Part II, the Plan and Elevation test and the Drawing test, have greatest overall correlations with the criteria. The Form Relation and Block tests show no significant correlation. Ability in Architectural Design is best predicted by the Drawing and Art Judgement tests. The V.S.14 test Part II, Plan and Elevation and 3 Dimensional Space tests give appreciable correlation with the criterion, but the verbal intelligence tests, V.S.14 Part II and Otis Intelligence do not. Building Construction ability is predicted by the Drawing, 3 Dimensional Space and Plan and Elevation tests. All other tests have no significant correlation with this assessment. Structural Science is best predicted by the Progressive Matrices and V.S.14 Part I tests - the V.S.14 Part II, Plan and Elevation and 3 Dimensional Space tests are not very inferior, but the Drawing and Art Judgement tests have near zero correlation. Building Science seems to be predicted by the same type of tests - V.S.14 Part I, Progressive Matrices, Otis Intelligence, 3 Dimensional Space and Plan and Elevation in that order.

An inspection of the submatrix R_{aa} - the intercorrelations between the assessments - shows that only Building Construction has appreciable correlation with all the other criteria. Structural Science has high correlation with Building Science, and Architectural Design gives correlation only with Building Construction.

In the Submatrix R_{bb} - the intercorrelation of the tests - the two verbal intelligence tests have the highest coefficients, as would be expected. The spatial tests, Plan and Elevation, 3 Dimensional Space, V.S.14 Part II and Form Relation, yield high intercorrelation - this implies that they are measuring the same ability. With one exception, the Drawing and Meier Art Judgement tests have no significant correlation with any tests. The exception is that between the Meier Art Judgement and the Plan and Elevation test. The high correlation between the V.S.14 Part I and V.S.14 Part II tests calls for an explanation, and it may be suggested that this is due to the fact that both tests are combined in the same book, and are administered at the same sitting, without sufficient interval.

The matrix of correlation of the Technical Institute sample given in Table 9 reveals that all the tests are positively correlated. The least values of r which exceed t at the 5 per cent and 1 per cent levels are .125 and .172 respectively. 91.03 per cent of the correlation exceeds the 5 per cent level.

Perusal of the correlations in the submatrix R_{ab} reveals that the Plan and Elevation, Progressive Matrices and Drawing tests have greatest over all correlations with the complex criteria. The 3 Dimensional Space and V.S.14 Parts I and II are not too far behind. Engineering Drawing ability is best predicted by the Plan and Elevation test. Practical ability tests and the Drawing test give appreciable correlation with this criterion, while the verbal intelligence tests V.S.14 Part I and Otis, have least correlation. Mathematical ability is best predicted by the Progressive Matrices test, though the Plan and Elevation and Drawing tests are not too inferior. Aptitude for General Science is best predicted by intelligence tests - Progressive Matrices, Otis and V.S.14 Part I. The Art Judgement test yields significant coefficients only with Engineering Drawing.

The intercorrelations of the three assessments are very high - in the range of .5 to .6. This suggests that either they all involve the same mental ability, or that there are some other external factors such as interest, industriousness and the "halo" effect in assessing, influencing the ability index. A scrutiny of the submatrix R_{ab} however, reveals that this high intercorrelation cannot be accounted for by the first hypothesis alone, and in view of this it may be said that external factors, other than abilities, do influence the assessments.

The submatrix R_{bb} shows that the two verbal tests - V.S.14 Part I and the Otis Intelligence tests - are very highly correlated. Space tests - V.S.14 Part II, Form Relation, 3 Dimensional Space, Plan and Elevation and Block tests - also yield high inter-correlations. The Drawing test gives appreciable correlation with the space tests and with the Meier Art Judgement test, but with the verbal tests it does not give any significant correlation.

Almost all the assessments for both samples from the Technical School yield highly significant correlations with age, but the correlations between age and tests are low, and some of them are not statistically significant. (See Tables 10-11). This indicates that the teachers have a tendency to give higher marks to older boys, i.e. pupils in the upper forms. Due to the presence of older boys in the same form as younger ones, i.e. those who gained admission at the first attempt and are brighter than their older fellow pupils, the correlation between age and tests is not appreciable.

In the matrix of the Engineering Department sample, (See Table 12), all the correlations are positive, but 64.45 per cent of the coefficients are above .148, which is the least value of t expected at the 5 per cent level. Sub-matrix R_{ab} shows that the Drawing test, as a single predictor, has the best over all correlation with the criteria, closely followed by the Plan and Elevation, Moray House Space, and Form Relation tests, in that order. The Otis test does not yield any significant correlation with any of the assessments. The inter-correlations of the four components of the criteria are very high: .539 to .682.

The matrix of the Building Department sample (see Table 13) contains 87.88 per cent significant correlation coefficients, and all are positive. Perusal of the matrix reveals that the Moray House Space, Plan and Elevation, and Form Relation tests yield highest over all correlation with the

Relation tests yield highest over all correlation with the complex criteria. Ability in Building Construction is best predicted by the Form Relation and Plan and Elevation tests, and in Carpentry and Joinery by the Moray House Space, Form Relation and Block tests. Geometrical ability is best predicted by the Plan and Elevation and Progressive Matrices tests. The Otis test has a significant correlation with Geometry, but not with Building Construction and Carpentry and Joinery.

In both samples from the Technical School the Meier Art Judgement test yields maximum correlation with the T.S.8 test. This supports the claim of the test constructor that T.S.8 is a measure of artistic ability, over and above gk.

B. Factor Analysis.

Discussion of the factor analysis results will centre around the four aims of such analysis as set out in the last chapter. The factor matrix of each sample will be treated separately, and later, an attempt will be made to co-ordinate the results of the different factor matrices as far as the statistics permit.

The interpretation of factors should be based on the internal evidence provided by the test saturations themselves, and by introspective analysis of the processes demanded by those tests which have high loadings, and by information obtained from previous enquiries. In naminga factor tests in which the factor appears prominently should be contrasted with those in which it plays only a small part or none at all.

1. Group A, School of Architecture.

i) Centroid analysis:

Three factors are extracted from the matrix of correlations - two of them significant (See Table 17). The total per cent of the variance is 38.80 per cent, of which the first centroid factor contributes 22.29 per cent. Using Burt and Banks' formula for the standard error of single loadings, it was found that all the loadings in this factor are significant. The variables yielding the best estimates for this factor are the V.S.14 Part II (.6629), 3 Dimensional Space (.5747), and Plan and Elevation (.5448), tests, followed by Architectural Design (.5024), the Otis Intelligence test (.4889), Structural Science (.4702) and Building Construction (.4636). The Block, Drawing, Form Relation and Meier Art Judgement tests have the least loadings.

The first factor in centroid analysis is essentially an average of all the variables in the battery - it is most heavily weighted by the type of variables which are most predominant in the battery. In the School of Architecture battery, a large number of practical ability tests are included, so it is not surprising to find that the general factor is biased by the various spatial tests. This factor may be interpreted as a gk one.

The second factor extracted is bipolar, and contributes 9.027 per cent of the variance. Using the Burt and Banks' formula, the variables which have loading for more than three times their standard error are given below:

Positive Pole		Negative Pole	
Variable	Loading	Variables	Loading
V-14	.6477	A.D.	.3625
Otis	.4587	M.AJ	.3043
S.S.	.2567	Draw	.2831
B.S.	.2222	P&E.	.3031
		3D.S	.2498

These variables reveal that the contrast is between verbal-educational and artistic-spatial characteristics.

The second bipolar factor contributes 7.48 per cent of the variance and the residual matrix from which this factor has been extracted contains only 3.30 per cent of the significant coefficients.

By applying Burt and Banks' formula, only the Drawing, Progressive Matrices and Plan and Elevation tests, and

Architectural Design, were found to be significant. Variables which have highest loadings on the two poles are given below:

Negative Pole		Positive Pole	
Variable	Loading	Variable	Loading
Draw	.7020	Mat.	.3329
A.D.	.3249	3D.S	.3291
B.C.	.1825	P&E.	.2310
		F.R.	.2264

It will be noted that the spatial tests contrast with the Drawing test and assessments.(A.D., B.C.)

ii) Rotated Centroid Factor Analysis:

It should be recalled that the axes of the centroid factors have been rotated blindly as far as psychological meaning is concerned, when attaining simple structure. Three factors are extracted and inspection reveals that the rotated factor matrix conforms to the requirements of the simple structure (See Table 23). In the factor matrix there is no general factor running through all the variables. This of course, is due to the method of analysis employed. The general factor obtained in bipolar analysis is distributed among the three rotated factors.

The first factor contributes 11.48 per cent of the variance, and the major part of this percentage is contributed by:

Variable	Loading
Draw	.8377
A.D.	.6471
B.C.	.4240
A.J.	.2905

The variables which have something to do with artistic ability have appreciable loadings and the first factor may be denoted as artistic ability. An important check on the artistic character of this factor is to inspect the tests in which it is absent. It will be seen that all the intelligence tests, scholastic subjects and practical ability tests have zero or near zero loadings.

The second column of the matrix has six entries less than .2. The variables which have highest loadings are:

Variable	Loading
V-14	.7746
Otis	.6447
S-14	.4842
S.S.	.4800
B.S.	.4389

The common element of most of these variables is verbal in character. This factor may be denoted by v. VS.14 Part I has the highest loading, which represents more than half of the variance of the test. It is somewhat puzzling to find the V.S.14 Part II in the above list, but it may be recalled that the correlation between Parts I and II of the V.S.14 test is spuriously high, and since the battery of tests is not large, this effect appears in the result of the factor analysis. It may also be partly attributed to the redistribution of the general factor.

The third column represents the factor contributing 14.21 per cent of the variance. This column contains only four tests which have projection less than .2 - this is considered negligible. The tests which have loadings about .4 or above, in these factors are as follows:

Variable	Loading	Variable	Loading
3D.S	.6819	Mat.	.4727
P&E.	.6236	S-14	.3848
M.AJ	.4801	F.R.	.3739
Blck	.4298		

The common characteristic of these tests is spatial. This factor is frequently identified as the factor k or S. It appears prominently in tests requiring a comprehension of relations and movements in space. The same factor seems to be involved when dealing in two and three dimensional space, but the three dimensional tests -

the 3 Dimensional Space and Plan and Elevation - have highest loading in this factor.

iii) Group Factor Analysis:

Since the intercorrelations of mental measures of all types are positive, it seems that at least a portion of this intercorrelation is due to some common factor. In view of this, and in order to obtain an analysis in terms of the positive correlations alone, the correlation matrix is refactorized by Burt's Group Factor method. In this analysis the group factors are extracted over and above the factor which is common to all the variables (See Table 27). The first factor extracted with positive loadings for every trait accounts for 19.28 per cent of the variance. Burt prefers to call this common factor a "basic" factor, since it is not primarily the same as the general factor reached by the ordinary simple summation method.

An inspection of the factor loadings of the different types of tests suggests that the basic factor is weighted by spatial tests, but the effect is not so marked as it is in the case of the general factor of the centroid analysis. In this factor the V.S.14 part II test has the highest loading and it represents about two thirds of the variance of the test. It will be seen that the Progressive Matrices test, which is regarded as a test of pure g, has a loading of .3479.

The group factors are necessarily less reliable than the basic factor, for they are defined by but a few variables, and they are computed from residual correlations with the basic factor removed.

Group factor A, which contributes 9.95 per cent of the variance consists of these variables:

Variables	Loading
V-14	.6844
Otis	.5166
S.S.	.3647
B.S.	.3505

The common characteristic of these variables is verbal and is denoted by v - verbal or linguistic factor, involved primarily in the meanings of words and the ideas associated with them.

The significance of Group Factor C is doubtful - it contributes only 4.02 per cent of the variables. This group consists of:

Variable	Loading	Variable	Loading
B.C.	.5493	F.R.	.1386
3D.S	.3807	S-14	.1070
P&E.	.2959	Mat.	.0932

The common characteristic of all these tests is spatial .

It will be noticed that the three dimensional tests have higher loadings than the two dimensional ones. This suggests that the nature of this factor involves manipulation of visual imagery in three dimensions.

After extracting the basic and the three group factors, the residuals are examined to find if there are any significant coefficients, but an inspection reveals that there is no trace of this (See Appendix IV). In view of this fact, it is not necessary to rotate the axes to obtain overlapping group factors.

One of the aims of factor analysis is to combine a small number of tests to predict the criteria. This can be achieved by studying the the overlapping of the assessments with the tests. All four components of the criteria have loadings in the general factor and in the basic factor. The tests which have highest common factor loadings are the V.S.14 Part II, Plan and Elevation, 3 Dimensional Space and Progressive Matrices tests.

Variable	Gen. Fact.	Basic Fact.	Tests	Gen. Fact.	Basic Factor
A.D.	.5024	.3002	S-14	.6629	.8383
S.S.	.4702	.4042	P&E.	.5448	.5673
B.C.	.4636	.3962	3D.S	.5747	.5689
B.S.	.4478	.3761	Mat.	.4488	.5425

Beyond the first factor, the assessments seem to be divided into two groups - Structural Science and Building Science, the intellectual-scholastic group, and Architectural Design and Building Construction, the artistic-practical group.

Variable	Bipolar Factor I	II	Group Factor Art	v	Rot. Cent. Factor Art	v
A.D.	-.3625	-.3249	.6653		.6471	
B.C.	-.1088	-.1825	.3835		.4240	
Draw	-.2831	-.7020	.6702		.8377	
A.J.	-.3043		.5945		.2905	
P&E.	-.3031	.2310			.2214	
3D.S	-.2448	.3291				
S.S.	.2567	.1939		.3647		.4800
B.S.	.2222			.3505		.4389
V-14	.6477			.6844		.7746
Otis	.4587			.5166		.6477

Structural Science and Building Science have highest common factor loading with the V.S.14 Part I and Otis Intelligence tests. The common element is verbal or linguistic ability. The tests which have common factor loadings with Architectural Design and Building Construction, beyond the general factor are the Drawing and Meier Art Judgement tests.

From the evidence obtained by factor analysis it may be said that Architectural Design and Building Construction call for artistic ability, practical ability and general intelligence, in that order. Structural Science and Building Science are chiefly scholastic or intellectual subjects, calling for verbal ability and general intelligence. Thus the nature of Architectural ability is not unitary. It cannot be assessed by any single criterion, neither can it be predicted by a single test or a battery of the same type of tests.

In the actual prediction analysis only one assessment from each group is considered - Architectural Design and Structural Science. These two criteria have higher factor loadings than Building Construction and Building Science respectively. Moreover, Architectural Design and Structural Science are the two subjects rated highest by the experts.

2. Group B, Technical Institute.

i) Centroid analysis:

Four factors are extracted from the correlation matrix, out of which three are statistically significant (See Table 18). The first factor contributes 33.89 per cent of the variance - that is roughly the proportion usually obtained when factorizing tests of mental ability, given to school populations. All the variables have general factor loadings higher than .4 and according to Burtand Banks' formula, all of them are significant. The minimum loading is that of the Meier Art Judgement test (.4260) which is four times higher than the standard error. The variables yielding the best estimates for this factor are the Plan and Elevation, V.S.14 Part II, 3 Dimensional Space, Form Relation tests, closely followed by Technical Drawing, the Progressive Matrices test, Mathematics, the Block and Otis Intelligence tests, and General Science, in that order. A glance at the variables shows that they are diverse in nature, yet each has a high common factor loading. The general factor is most heavily weighted by the various spatial tests in the battery. This factor may be identified as a general mental ability factor, remembering that some portion of the variance is due to spatial ability and may be denoted as gk.

The next factor extracted is bipolar, and contributes 8.88 per cent of the variance. It is usually found in a bipolar analysis of a battery of cognitive tests, after extracting the general factor, that a bipolar factor which distinguishes between verbal and non-verbal tests appears. In the present case the dichotomy is of a similar type - the intellectual or scholastic versus the non-intellectual or practical. The variables found to be significant by using the Burt and Banks' formula are:

Positive Pole		Negative Pole	
Variable	Loading	Variable	Loading
G.S.	.1571	T.D.	.2809
V-14	.7079	Draw	.3098
Otis	.4176	F.R.	.2704
Mat.	.2195	3D.S	.2692
		P&E.	.1957

The second bipolar factor contributes 7.83 per cent of the variance. In this factor all the assessments contrast with the tests. This indicates that the assessmnets are influenced by some other extraneous factors like studiousness, will to work, or the subjective influence in assessment.

The third bipolar factor is not significant - it contributes only 3.92 per cent of the variance. The contrast seems to be between the two artistic ability tests and the non-artistic tests.

ii) Rotated Centroid Analysis:

The axes of the centroid analysis are rotated blindly and the rotated factor matrix (See Table 24) shows that tolerable simple structure has been achieved. Four factors are extracted, out of which the fourth is not significant. In the first column the variables which have highest loadings are the three assessments viz:

Assessment	Loading
T.D.	.6028
Math	.7807
G.S.	.6776

These measures of school attainments show a separate group factor of their own, which may be denoted by X. It is a complex combination of interest, industriousness and the "halo" effect in ranking etc.

The second dolumn represents a factor which accounts for 13.43 per cent of the variance. The variables which have projection of about .40 or higher are given below:

Variable	Loading
V-14	.8416
Otis	.6168
Mat.	.4435
T.D.	.3960
G.S.	.3749

In this factor V-14 has the highest loading of .8416, whcih represents more than two thirds of the variance of the test. The Otis Intelligence test loading accounts for more than a third of its variance. The common element in these two tests is verbal or linguistic in character. It may be identified as the v factor, which involves the manipulation of verbal ideas. The tests which have near zero loading are the performance and non-verbal ones.

2rgl

The third factor contributes 23.39 per cent of the variance - this is easily identified in the tests in the present battery. The column contains six entries about .60 or above and only three near zero. The variables which have projection above .40 are:

Variable	Loading	Variable	Loading
T.D.	.3172	Blck	.6600
3D.S	.7001	P&E.	.6296
S-14	.6970	Draw	.3606
F.R.	.6982		

It is clear that the common element in these variables is visual or spatial in character. This factor may be denoted as k or S. All the variables depend on a visual ability of some kind - an ability to discriminate visually, to build up patterns or configurations, to imagine a design moved from one place to another, to manipulate spatial relationship, to read plans. The projection on this plane of the Form Relation test, which is a well established test of spatial ability, accounts for almost half the variance of the test. This spatial factor seems to be equally involved in dealing with both two and three dimensional space.

The fourth column represents a factor which is not statistically significant, accounting for only 5.27 per cent of the variance. Three variables have projection of about

.3 or more:

Variable	Loading
A.J.	.6023
Draw	.3595
T.D.	.2862

The Meier Art Judgement test is a test of art appreciation and the Drawing test is designed to measure some aspects of artistic ability. It seems that the common element in these two tests is artistic in nature, but it is not possible to name this factor with any statistical confidence.

iii) Group Factor Analysis:

In this analysis three group factors are extracted after the basic factor. The first column in Tables 28 represents the basic factor with positive loading in all the tests and assessments, and this factor accounts for 26.897 per cent of the variance. It seems to correspond with the general factor obtained in the bipolar analysis, except for the fact that the total variance is lower. The basic factor may be called the general mental ability factor, though it has been somewhat weighted by the spatial tests.

The first group factor A, contributes 9.156 per cent of the variance. This group consists of the following tests:

Test	Loading	Test	Loading
F.R.	.6316	P&E.	.3833
Bl ck	.5837	S-14	.3309
3D.S	.3943	Draw	.1917

It is clear that the common element in these tests is spatial in character. This factor has been denoted by k or S - the spatial factor.

The second group factor B, consists of four tests and contributes 7.882 per cent of the variance.

Test	Loading	Test	Loading
V-14	.8461	M.AJ	.1632
Otis	.5170	Mat.	.1219

In this factor only the V.S.14 Part I and Otis Intelligence tests have appreciable loadings. The common element in these two tests is verbal ability, and this factor may be denoted as the v-verbal factor. The presence of the Meier Art Judgement and the Progressive Matrices tests in this group, is due to the fact that in grouping the variables, the partition suggested by the bipolar analysis is strictly adhered to, to make the analysis unique. The loadings of these two tests in the verbal factor, however, are below .2, which may be regarded as negligible.

The third group factor, C, contains the three assessments and accounts for 6.967 per cent of the variance.

Assessment	Loading
T.D.	.5955
Math	.7279
G.S.	.5569

This factor is the same as the factor X identified in the rotated centroid analysis.

One of the objects of factor analysis is to chose tests for predicting the complex criteria, and this is achieved by studying the overlapping of the assessments with the tests.

The evidence of the bipolar and group factor analysis supports the view that there is a broad factor common to all the technical subjects and tests. The major part of the common variance between the tests and the assessments is mainly attributed to the general factor or basic factor. The tests which have highest loadings are given along with the assessments:

Assessment	Gen. Fact.	Basic Fact.	Tests	Gen. Fact.	Basic Fact
T.D.	.6084	.5955	Mat.	.5788	.6261
Math	.5762	.4965	S-14	.6645	.6334
G.S.	.5503	.4868	F.R.	.6285	.4812
			P&E.	.7185	.6193
			3D.S	.6427	.5796

Beyond the general or basic factor, group factors appear to be of minor importance as predictors of success in any of the subjects. A large percentage of the variance of the assessments is due to the factor denoted by X, which does not overlap with the test battery. Beyond the general or basic factor and the X factor, Mathematics has no loading in any other factor. The other two assessments, Technical Drawing and Gэneral Science seem to have different factorial structure, which is demonstrated below:

Variable	Bipolar Fact. I	Rot. Cent. Fact. v	k	a_{rt}
T.D.	-.2809	.3960	.3172	.2862
F.R.	-.2704		.6982	
3D.S	-.2692		.7001	
Blck	-.1884		.6600	
P&E.	-.1957		.6296	.2169
Draw	-.3098		.3606	.3595
A.J.	-.1884	.2641	.1741	.6023
G.S.	.1571	.3749		
Otis	.4176	.6168	.3719	
V-14	.7079	.8416		

It seems that Technical Drawing has something in common with the spatial tests and artistic tests, and General Science with the verbal tests, beyond the broad general factor of gk, although the overlapping is very low.

3. Group C, Technical School, Engineering Dept.

In analysing the matrices of the two samples from the Technical School, only the bipolar analysis is carried out.

Three factors are extracted from the correlation matrix of the Engineering Department, and of these, two are statistically significant (See Table 19). The first factor accounts for 33.40 per cent of the variance. Using the Burt and Banks formula, all the loadings of the variables are found to be significant. The general factor is heavily weighted by the tests of practical ability. This general factor may be tentatively called the "technical" factor, which is a complex combination of the spatial factor, commonly known as k or S, and general intelligence, g.

The second factor is bipolar, and accounts for 6.89 per cent of the variance. In this factor all four components of the criteria contrast all the tests. The factor may be identified as X. The large percentage of the assessments is attributed to this factor.

The second bipolar factor is not statistically significant and accounts for only 3.7 per cent of the variance.

The overlapping between the test battery and the assessments is solely determined by the first factor. All four components of the criteria have high loadings in this general factor. The four assessments and the tests which have highest loadings in this factor are given below:

Assessment	Loading	Test	Loading
T.D.	.6982	TS.8	.5829
Geom	.7260	MH.S	.5687
M.W.	.7013	F.R.	.6198
W.W.	.6232	P&E.	.6355
		Draw	.6575
		Blck	.5502

4. Group D, Technical School, Building Dept.

Three factor are extracted, out of which the third is not statistically significant.

The first factor accounts for 31.37 per cent of the variance and is common to all the assessments and all the tests. All the figures are found to be significant by the Burt and Banks criterion.

An inspection of the tests in Table 20 shows that the general factor is weighted by the various tests of practical ability. The loadings of the intelligence and artistic ability tests - Otis Intelligence, Progressive Matrices, Drawing and Meier Art Judgement - are low in comparison to those of the practical ability tests. The general factor may be defined as a "technical" factor or gk - the emphasis on k rather than g.

The second factor is bipolar and accounts for 5.42 per cent of the variance. The variable loadings are given below.

Positive Pole		Negative Pole	
Variable	Loading	Variable	Loading
C.J.	.1713	B.C.	.2509
MH.S	.2442	Geom	.2639
Blck	.4784	Otis	.3064
		M.AJ	.2173

It seems the practical items contrast the non-practical characteristics. The Otis test has highest negative loading and the Block test has highest positive loading.

The second bipolar factor contributes 5.24 per cent of the total variance and is not significant.

All three assessments have high general factor loading and the major portion of the overlapping with the test battery may be accounted for by this factor. The three assessments and the tests which have highest loadings are given below:

Assessment	Loading	Test	Loading
B.C.	.6015	Mat.	.5226
Geom	.6019	TS.8	.5879
C.J.	.5586	MH.S	.7125
		F.R.	.6063
		P&E.	.6989
		Blck	.5585

Beyond the general factor, the overlapping between the assessments and the test battery is very small.

5. Factorial Composition of the Experimental Tests.

One aim of factor analysis is to establish the hypothetical factors measured by the experimental tests. This can be achieved by comparing their factor loading with well established tests.

V.S.14 Part I is designed to measure intelligence through a linguistic medium. It has a similar factor composition to Otis' well known verbal intelligence test. The results of the two tests are compared below:

School of Architecture

	Centroid Factor		Rot. Cent. Factor			Group Factor	
	I	II	Art	v	k	Basic	v
Otis	.4889	.4587	.1469	.6447		.3479	.5166
S-14	.4254	.6477	.0612	.7746		.2679	.6844

Technical Institute

	Centroid Factor			Rot. Cent. Fact.			Group Factor	
	I	II	III	X	v	k	Basic	v
Otis	.5639	.4176	-.1447		.6168	.3595	.4868	.5170
V-14	.4734	.7079			.8416		.3325	.8461

These figures show that the factorial composition of the two tests is remarkably even in each analysis, and that the V.S.14 Part I test has higher loading in the verbal factor. This test can be said to be a test of verbal intelligence, superior to the Otis test as far as this experiment is concerned.

All four experimental tests of practical ability viz. V.S.14 Part II, Plan and Elevation, 3 Dimensional Space and Block, were given to two samples - the School of Architecture and the Technical Institute. Results of the factor analyses may be compared with two well known non-verbal tests - the Form Relation and Progressive Matrices tests. Form Relation has previously been found to have loadings on both the g and k factors, the size of the loading depending on the age range of the population tested. The k factor varies from .40 to .60. The Progressive Matrices test is a pure measure of g although it calls for some amount of k factor. The results of these six tests are:

School of Architecture

	Centroid Factor I	II	III	Rot. Cent. Fact. Art	v	k	Group Fact. Basic	k
Mat.	.4488		.3329		.2874	.4747	.5425	
F.R.	.3573		.2264		.2126	.3739	.3665	.1386
S-14	.6629			.2730	.4842	.3848	.8383	.1070
P&E.	.5448	-.3031	.2310	.2217		.6236	.5673	.2959
3D.S	.5747	-.2498	.3291	.1427	.1250	.6819	.5689	.3807
Blck	.4287			.1460	.1740	.4298	.3082	.5393

Technical Institute

	Centroid Factor				Rot. Cent Factor			Group Factor	
	I	II	III	IV	Art	v	k	Basic	k
Mat.	.5788	.2195	-.1112	-.1925	.3388	.4435	.3382	.6261	
F.R.	.6285	-.2704	.2181	-.1581	.2136		.6982	.4812	.6316
S-14	.6645		.2565	-.2264	.2115	.3302	.6970	.6334	.3309
P&E.	.7157	-.1957	.1165		.4059		.6296	.6193	.3833
3D.S	.6427	-.2692	.2404	-.1315	.2021		.7001	.5796	.3943
Blck	.5737	-.1884	.3016	-.1049			.6600	.4255	.5837

These two tables reveal that the factorial composition of the four experimental tests is similar basically, to the composition of the Progressive Matrices and Form Relation tests. The present investigation confirms the findings of previous researches that the Progressive Matrices test seems to be a test of g, and that a small amount of its variance is attributed to k, whereas the Form Relation test is primarily a spatial test, though it has a considerable g loading. V.S.14 Part II seems to have high general factor loading, in fact higher than the two tests mentioned above. Its spatial loading is lower than that of the Form Relation test, but higher than that of the Progressive Matrices. V.S.14 Part II may be regarded primarily as a non-verbal intelligence test. The Plan and Elevation and 3D.S tests appear to measure both factors.

Their spatial factor loading is higher than that of the Form Relation test, yet their general factor loading is higher than that of both the Progressive Matrices and Form Relation tests. So far as the evidence of this investigation goes, the Plan and Elevation and 3 Dimensional Space tests may be regarded as measures of the gk type. The Block test also has similar factorial composition, but its spatial factor is more prominent than the general factor.

Two of these tests - the Plan and Elevation and Block - were given to the younger samples, along with the Progressive Matrices and Form Relation tests. All these tests have high gk factor loading, thus confirming the findings in groups A and B.

C. Multivariate Analysis

The multiple prediction analysis provides a method of estimating the value of a battery of tests in predicting a criteria, and it furnishes a basis for determining the most appropriate weights to give each test in the battery.

The abilities under investigation call for a number of different aptitudes, which in a combination, determine how successful the testee will be. It is hardly possible to assess this complex pattern of traits with a single test or with a single type of test material.

On the basis of the factor analysis several teams of tests, each consisting of four or five are compiled, and several combinations of these variables are tried out to determine their predictive efficiency.

1. Group A, School of Architecture.

The components of the criterion for the School of Architecture are Architectural Design and Structural Science. They are weighted by experts in the ratio of 3:1 in favour of Architectural Design, as a measure of success for the architectural course.

In the first place both the criteria and all the tests in each battery are equally weighted. The multiple correlation is appreciably higher than the correlation of any test with either of the criteria. This multiple correlation, however, is not the best prediction of success - best prediction is achieved by calculating the regression weights of each test by Peel's method (See Tables 29-36).

The first team of tests consists of the V.S.14 Parts I and II, 3 Dimensional Space, Meier Art Judgement and Drawing tests. Multiple correlation between the criterion composed of the equally weighted assessments and the five tests assigned best weights is .5992. The two components of the criterion are weighted arbitrarily, according to

Best that is with these weights

experts' opinions, to give psychological meaning. Best prediction rises to .6938, which is significantly higher than the previous estimates.

A.D.	S.S.	V-14	S-14	3D.S	M.AJ	Draw	r_m
3	1	.151	.435	.341	1.000	.995	.6938 $\pm$ .0747

All the weights assigned to the five tests are positive, and the Art Judgement and Drawing tests contribute most to the prediction. The contribution of S-14 and the 3 Dimensional Space tests is appreciable, but V-14 plays very little part in prediction. This is quite feasible from a perusal of the factor matrices. It may be recalled that Architectural Design has a large common loading with the Art Judgement and Drawing tests and both the criteria have the same common factor loading as the V.S.14 Part II and the 3 Dimensional Space tests. But the V.S.14 Part I has appreciable common loading only with Structural Science. It is only to be expected that when Architectural Design is given three times more weight than Structural Science, the two artistic tests will yield highest weights.

In the criterion for prediction of success in an architectural course, it has been assumed that the two components should be weighted in favour of Architectural Design. This is a step which few would question. The weights assigned to the components of both batteries may be found in order to yield a value for the correlation between the two teams which cannot be equalized or exceeded, no matter what other weights are chosen.

The regression coefficients and the maximum correlation are calculated by the Hotelling method.

A.D.	S.S.	V-14	S-14	3D.S	M.AJ	Draw	r_m
1.000	-.002	-.243	.319	-.230	.922	1.000	.7176 ± .0583

The maximum prediction thus obtained is .7176. The maximum r of .7176, obtained from a population of 75 subjects has a standard error of .0444. The difference between maximum prediction in Hotelling's sense and the best prediction by the Peel method is not significant. The best prediction (.6938) is a little inferior to the maximum prediction (.7176). All the multiple correlations, however, are highly significant as their standard error is about .05 only.

The solution in the Hotelling sense is mathematically unique, but it is questionable whether it is the best in any real or practical sense. Calculation of maximum prediction in the Hotelling sense, however, provides valuable information as regards which assessment has been best predicted by the given set of tests. The battery under discussion is exclusively suited for predicting Architectural Design alone. This finding, however, is not very disappointing as the test battery is compiled to give effective prediction of Architectural Design, because it is by far the most important subject in the architectural course.

An inspection of the regression coefficients reveals that the Drawing and Art Judgement tests yield the major part of the multiple correlation. The coefficient of the V.S.14 Part II test is appreciable, but those of the first part of this test and the 3 Dimensional Space test are negative. This can be explained on looking back at the results of the factor analysis. The Drawing and Art Judgement tests and Architectural Design all have high artistic factor loadings and the V.S.14 Part I and Structural Science have verbal factor loadings. The presence of the negative regression in the 3 Dimensional Space test calls for an explanation, for at first it might appear that the result of the factor analysis is somewhat contradictory to the regression analysis. It appears that it is detrimental to success in an Architectural course to score high in the 3 Dimensional Space test, yet this test and the criteria have the same general or basic factor loading. Paradoxical though it may seem, reflection will make the principle clear - the 3 Dimensional test has been included in the battery because it has the same general or basic factor loading as the criteria. But the same factor has been more effectively measured by the V.S.14 Part II test, which is present in the same battery. Beyond the general factor, the 3D.S test is more similar in factor pattern to Structural Science (which has a zero coefficient in the regression equation) than Architectural Design.

The reliability coefficients of the battery are given along with the multiple prediction. The fluctuation of these coefficients is somewhat arbitrarily defined by the reliability of the tests included in the battery and by the weights assigned to the tests. It is only to be expected that the battery reliability will decrease as more weight is given to the Art Judgement and less to the V.S.14 Part I test. The question of best battery reliability and best prediction will be discussed later.

The second battery also consists of five tests - the Progressive Matrices, V.S.14 Part II, Plan and Elevation, 3 Dimensional Space and Drawing tests. The multiple correlation is not altered significantly from the previous results when both the criteria are assigned equal weights, but the best prediction drops to .6100 when the assessments are weighted 3:1 in favour of Architectural Design. This is only to be expected because the Meier Art Judgement test is not included in the battery. The only difference between the best prediction and the maximum prediction in the Hotelling sense is negligible.

A.D.	S.S.	Mat.	S-14	P&E.	3D.S	Draw	r_m
3	1	.126	.457	.482	.196	1.000	.6100 ± .0756
1.000	-.286	-.190	.206	.262	.096	1.000	.6104 ± .0756

The correlation is mainly due to the Drawing, Plan and Elevation and V.S.14 Part II tests, and the contribution of the Progressive Matrices and 3 Dimensional Space tests is not appreciable. This can readily be explained by a perusal of the factor matrices. The Progressive Matrices is a test of pure g and its factorial composition is more similar to that of Structural Science than Architectural Design, whereas the Plan and Elevation test has a similar factorial pattern to Architectural Design. On the whole, this battery is better suited to predict Architectural Design than Structural Science.

Battery No. 3 is similar to the first one, but the 3 Dimensional Space test has been dropped out. It will be noticed that the best prediction, .6863, is not inferior to that of the first battery. This fact illustrates that the inclusion of too many tests in a battery does not necessarily improve prediction.

A.D.	S.S.	V-14	S-14	M.AJ	Draw	r_m
3	1	-.189	.681	1.000	.987	.6863 ± .0632

The regression coefficients are more or less similar to those obtained in battery No. 1.

In the fourth battery the V.S.14 Part II test is replaced by the Plan and Elevation.

A.D.	S.S.	V-14	P&E.	M.AJ	Draw	r_m
3	1	.313	.439	.851	1.000	.6867 ± .0631

Now the V.S.14 Part I test contributes appreciably to the prediction and the multiple correlation is .6867. The reason why this test plays such an important part in this battery is because there is no other test in the battery which represents the verbal factor.

In battery No.5 the Progressive Matrices test is combined with the four tests in the previous battery. But the multiple correlation obtained remains virtually unaltered. Inclusion of the Progressive Matrices test, therefore, does not improve the predictive value of the test battery. This is because the factors measured by this test have been adequately measured by the V.S.14 Part I and other tests in the battery. The sole effect of the Matrices test is to introduce an irrelevant factor - specific to itself - which obscures the prediction.

Since the Meier Art Judgement test is not always practicable for large scale application, it is decided to compile a battery without it. Thus battery No. 6 is composed of the V.S.14 Parts I and II, Plan and Elevation and Drawing tests. The omission results in considerable loss in prediction - the multiple correlation being .6035.

A.D.	S.S.	V-14	S-14	M.AJ	Draw	r_m
3	1	-.010	.529	.581	1.000	.6035 ± .0759

It seems that the Art Judgement test is indispensable when predicting success in the Architectural course.

Similarly the Drawing test seems to be essential in the battery, because the multiple correlation obtained with battery No.7 - containing the V.S.14 Part I, Progressive Matrices, 3 Dimensional Space and Art Judgement tests - is .5601 which is very much inferior to the other results reported earlier.

A.D.	S.S.	V-14	Mat.	3D.S	M.AJ	r_m
3	1	.407	.071	.467	1.000	.5601 ± .0820

The low correlation may be attributed to the fact that three of the four tests have similar factor loadings to Structural Science, whereas more weight is assigned to Architectural Design.

From the results of the previous analyses it will be noticed that the tests which have best predictive value are the Drawing and Meier Art Judgement tests, followed by the Plan and Elevation and V.S.14 II tests. So it is decided to compose battery No.8 of these four tests - the best prediction obtained is as high as .6932, which is higher than any other coefficient obtained by any other combination of tests.

A.D.	S.S.	S-14	P&E.	M.AJ	Draw	r_m
3	1	.520	.353	.926	1.000	.6932 ± .0632

From the educational or psychological point of view this battery may not be acceptable because it does not contain any tests which have v factor loading.

The importance of the v factor, however small, can not be ignored. In view of this, the fourth battery, which includes the V.S.14 Part I, Plan and Elevation, Drawing and Meier Art Judgement tests, is most suitable for predicting Architectural ability, and its predictive efficiency (.6867) is not too inferior to that of battery No. 8 (.6932).

2. Group B, Technical Institute.

Multiple correlation is obtained between the test battery and the complex criteria, giving equal weights to the tests as well as the criteria (See Tables 37-42).

The value of the best prediction is obtained first by giving the three assessments equal weights i.e. 1:1:1 for Engineering Drawing, Mathematics, General Science. This may be regarded as an over all ability index for succes in the technical course. But to forecast success in Draftsmanship, the different components of the criteria are assigned arbitary weights based on experts' judgement. The weights given are in the ratio of 4:2:1 for E.D:Maths: G.S.

The first battery is composed of the V.S.14 Part I, Progressive Matrices, Plan and Elevation, 3 Dimensional Space and Drawing tests. The multiple correlation as calculated by giving equal weights to all the variables is .5748. Best prediction for Technical ability is .5961 and for Draftsmanship .6088. The difference is not significant as the standard error of r is about .042. It seems the battery is equally efficient for predicting Technical ability and Draftsmanship.

T.D.	Math	G.S.	V-14	Mat.	P&E.	3D.S	Draw	r_m
1	1	1	.417	.801	1.000	.084	.587	.5961 ± .0436
4	2	1	.243	.505	1.000	.165	.536	.6088 ± .0425

The regression coefficients of the tests are almost the same in both predictions. The reason why differential weighting of the components of the criteria has not induced any appreciable change in the regression weights of the tests may be found in the factorial analysis, which reveals that the correlation between the tests and the criteria is mainly due to the general or basic factor. Maximum weight is assigned to the Plan and Elevation test, followed by the Progressive Matrices and Drawing tests. The contribution of the V.S.14 Part I test is appreciable in predicting Technical ability, but it is less important in the case of Draftsmanship. On the other hand, the 3 Dimensional Space test yields near zero coefficients in the case of Technical ability, but it plays some part in Draftsmanship. This can be explained easily by a glance at the factor matrices. The Plan and Elevation test has maximum common factor loading with all three assessments, whereas V.S.14 Part I and Progressive Matrices have similar factor loadings to General Science and Mathematics. For this reason, when Engineering Drawing is assigned higher weights, the importance of the V.S.14 Part I and the Progressive Matrices tests is reduced.

Maximum prediction in the Hotelling sense yields a figure of .6163, which is not significantly greater than the best prediction (.6088) because its standard error is .0420.

T.D.	Math	G.S.	V-14	Mat.	P&E.	3D.S	Draw	r_m
1.000	.270	.450	.378	-.007	1.000	.141	.462	.6163 ± .0420

The coefficients thus assigned to the components of the criteria are not acceptable on education grounds. However, it is satisfying to note that the analysis furnishes valuable information that this battery of tests is well suited to predict Engineering Drawing ability. All the multiple correlation figures are highly significant - the largest standard error being .050.

Battery No.2 is composed of the V.S.14 Part I, Plan and Elevation, Block and Drawing tests. The multiple correlation between the two teams assigning equal weights to all the components is .4853. By calculating the best regression coefficients the prediction is considerably improved: .5605 for Technical ability and .5887 for Draftsmanship.

T.D.	Math	G.S.	V-14	S-14	P&E.	Blck	Draw	r_m
1	1	1	.492	.108	1.000	-.274	.570	.5605 ± .0463
4	2	1	.293	.175	1.000	-.250	.559	.5887 ± .0442

The Plan and Elevation test contributes most to the prediction, followed by the Drawing and V.S.14 Parts I and II, in that order. The most noticeable feature is the negative coefficient of the Block Test. It would appear, at first, that high scoring in the Block test is detrimental to success in the Technical course. But the test is included in the battery as a measure of practical ability, so when a more reliable and valid test of practical ability is included, the Block test adds nothing to the prediction. Its only effect, therefore, is to introduce a new factor which has no bearing on the criteria, and the inevitable effect of this is to hinder the gradings for practical ability.

Maximum prediction in the Hotelling sense is .5913 - this figure is not significantly higher than the best prediction obtained by the Peel method.

T.D.	Math	G.S.	V-14	S-14	P&E.	Blck	Draw	r_m
1.000	.269	.215	.377	.348	1.000	-.550	.245	.5913 $\pm$ .0440

Moreover, the weights assigned to the components of the criteria are not acceptable. But it is good to see that Technical Drawing ability is best predicted by the battery of tests in which this investigation is particularly interested.

Since in the first battery of predictors the 3 Dimensional Space test is assigned least weight, this test is omitted from Battery No.3.

T.D.	Math	G.S.	V-14	Mat.	P&E.	Draw	r_m
1	1	1	.421	.743	1.000	.580	.5915 ± .0443
4	2	1	.248	.431	1.000	.527	.6004 ± .0431

The multiple correlations obtained are not very inferior to those obtained previously, and the regression coefficients assigned to the tests are also in the same ratios.

The fourth battery is compiled of four tests - Progressive Matrices, Plan and Elevation, 3 Dimensional Space and Drawing. The predictive efficiency of the battery is very little affected - the best prediction for Technical ability and Draftsmanship being .5803 and .5975 respectively. The regression coefficients are almost in the same ratio as in Battery No. 1.

T.D.	Math	G.S.	Mat.	P&E.	3D.S	Draw	r_m
1	1	1	.973	1.000	.199	.616	.5803 ± .0467
4	2	1	.553	1.000	.239	.551	.5975 ± .0434

Though V.S.14 Part I contributes appreciably to the prediction in the first battery, the loss is very little when it is dropped from the battery. It seems again, that it is a waste of time to compile too many tests for predicting a criteria.

Battery No. 5 is composed of the V.S.14 Parts I and II, Plan and Elevation and Drawing tests. The multiple correlations for technical ability and Draftsmanship are .5545 and

.5855 respectively.

T.D.	Math	G.S.	V-14	S-14	P&E.	Draw	r_m
1	1	1	.532	.009	1.000	.531	.5545 ± .0467
4	2	1	.327	.089	1.000	.523	.5855 ± .0444

The correlation is due to the Plan and Elevation, Drawing and V.S.14 Part I tests. The contribution of V.S.14 Part II is negligible.

In battery No.6 the Plan and Elevation test is dropped and the Form Relation test is introduced. The battery is composed of the V.S.14 Parts I and II, Progressive Matrices, Form Relation and Drawing tests.

T.D.	Math	G.S.	V-14	Mat.	S-14	F.R.	Draw	r_m
1	1	1	.281	1.000	.354	.138	.857	.5308 ± .0493
4	2	1	.089	.786	.573	.188	1.000	.5162 ± .0475

The predictive value has been reduced considerably: .5308 for Technical ability, and .5162 for Draftsmanship. It seems that the Plan and Elevation test is indispensable for predicting success in a Technical course.

3. Group C, Technical School, Engineering Dept.

First of all the multiple correlation of each battery is calculated, assigning equal weights to all the variables. Then the regression coefficients are solved by giving equal weights to all the components of the criteria. This criteria may be regarded as the over all ability index necessary for success in the engineering course in a junior Technical School. For Draftsmanship, the components of the complex criteria are assigned differential weights in the ratio of 4:2:1:1 for Engineering Drawing: Geometry; Metalwork: Woodwork. By assigning these weights to the criteria, the regression coefficient is calculated to find the best prediction for Draftsmanship. (See Tables 43-49).

The first battery is composed of the Moray House Space, Form Relation, T.S.8, Plan and Elevation and Drawing tests. Multiple correlation between the test battery and the criterion battery is found to be .6114. The best predictions are .6559 for Engineering ability, and .6633 for Draftsmanship. It appears that the battery is equally efficient to predict success in Technical ability and Draftsmanship. The standard error of the coefficients is about .04.

T.D.	Geom	M.W.	W.W.	MH.S	F.R.	TS.8	P&E.	Draw	r_m
1	1	1	1	.372	.223	-.003	.750	1.000	.6559 ± .0439
4	2	1	1	.312	.268	-.032	.786	1.000	.6633 ± .0426

The regression coefficients reveal that the multiple correlation is mainly due to the common gk factor, and the four assessments, and the Drawing, Plan and Elevation and Form Relation tests are richest. This also explains why the regression weights of the tests in both Engineering ability and Draftsmanship remain virtually unaltered.

Next the maximum prediction in the Hotelling sense is computed. Prediction is found to be .6736 - a figure very little superior to the best prediction obtained by the Peel method.

T.D.	Geom	M.W.	W.W.	MH.S	F.R.	TS.8	P&E.	Draw	r_m
.750	1.000	.688	-.013	.462	.063	.003	.658	1.000	.6736 ± .0407

The weights assigned to the criteria are by no means acceptable on educational or psychological grounds. It seems that the battery is more suited to predict success in the intellectual aspect of the criteria, because Geometry yields maximum weight, followed by Engineering Drawing. The weight of Metalwork is low, and that of Woodwork is nil. The correlation is due to the Drawing, Plan and Elevation and Moray House Space tests.

In the next battery the Block test is introduced and the TS.8 test is taken out. The best predictions obtained are .6569 and .6628 for Engineering ability and Draftsmanship respectively, and the coefficients are mainly due to the Drawing and Plan and Elevation tests.

T.D.	Geom	M.W.	W.W.	MH.S	F.R.	P&E.	Draw	Blck	r_m
1	1	1	1	.351	.207	.727	1.000	.191	.6569 ± .0428
4	2	1	1	.283	.259	.776	1.000	.116	.6628 ± .0426
1.000	.900	.750	.100	.439	-.179	.649	1.000	.099	.6696 ± .0413

Maximum prediction in the Hotelling sense gives a figure of .6696 which is negligibly higher than the best prediction, because its standard error is .0411. The weights assigned to the assessments are again unacceptable, and it may be said that the test battery is well suited to predict Engineering Drawing and Geometry.

Battery No.3 is the same as the first one, expept that the TS.8 test has been removed. The best predictions for Engineering ability and Draftsmanship are .6564 and .6686 respectively.

T.D.	Geom	M.W.	W.W.	MH.S	F.R.	P&E.	Draw	r_m
1	1	1	1	.361	.260	.758	1.000	.6564 ± .0432
4	2	1	1	.303	.331	.791	1.000	.6686 ± .0418

The regression coefficients are almost in the same ratios as in the first battery.

In battery No.4 the Block test is included in place of the Form Relation test. I will be noticed that the predictive value of this battery is as good as that of the other batteries.

T.D.	Geom	M.W.	W.W.	MH.S	P&E.	Draw	Blck	r_m
1	1	1	1	.709	.887	1.000	.694	.6560 ± .0433
4	2	1	1	.680	.897	1.000	.659	.6604 ± .0421

The regression equations show that the Drawing test is most important in this battery, while the contribution of all the tests is appreciable.

The Drawing test is left out of the next battery, No.5, and the tests included are the Moray House Space, Form Relation, Plan and Elevation and Block tests. The best predictions for Engineering ability and Draftsmanship are .5855 and .5947 respectively. These figures are somewhat less than the previous correlation.

T.D.	Geom	M.W.	W.W.	MH.S	F.R.	P&E.	Blck	r_m
1	1	1	1	.478	.737	1.000	.424	.5855 ± .0497
4	2	1	1	.388	.743	1.000	.319	.5947 ± .0489

In battery No.6 both the Plan and Elevation and the Drawing tests are omitted. The multiple correlations computed between the criteria and the battery composed of the Moray House, TS.8, Form Relation and Progressive Matrices, are .5079 and .5084 for Engineering ability and Draftsmanship respectively. The standard error of these figures is about .056. The predictive efficiency is very much reduced when both the Plan and Elevation and Drawing tests are excluded from the battery.

T.D.	Geom	M.W.	W.W.	MH.S	F.R.	TS.8	Mat.	r_m
1	1	1	1	.779	1.000	.234	.337	.5079 ± .0561
4	2	1	1	.859	1.000	.141	.454	.5084 ± .0560

4. Group D, Technical School, Building Dept.

The three assessments of the criteria are weighted equally i.e. 1:1:1 for B.C:C.J:Geom for composing the index of the technical ability required of builders. First of all the components both of the tests and the criteria are weighted equally, and the multiple correlation is calculated. Then the regression equation is computed by the Peel method to obtain the best prediction (See Tables 50-56)

The first battery is composed of the Moray House Space, Form Relation, Plan and Elevation, Block and Progressive Matrices tests. The best prediction obtained is .6160. This figure, however, is not significantly higher than the multiple correlation obtained by assigning equal weights to all the tests because the standard errors of the coefficients are about .045.

B.C.	C.J.	Geom	MH.S	F.R.	P&E.	Blck	Mat.	r_m
1	1	1	.818	1.000	.962	.232	.329	.6160 $\pm$ .0472

The regression coefficients show that the correlation is due mainly to the Form Relation, Plan and Elevation and Moray House Space tests. The factorization has already revealed that the correlation between the test battery and the complex criteria is mainly due to the general factor and the same three tests have highest loadings in this factor. Although the Moray House Space test has higher loading than the Form Relation test, it contrasts Building Construction and Geometry appreciably in the first bipolar factor, which explains why the Moray House test yields less coefficients in the regression equation. Maximum prediction in Hotelling's sense is found to be .6235, which is not significantly higher than the best prediction already obtained.

B.C.	C.J.	Geom	MH.S	F.R.	P&E.	Blck	Mat.	r_m
.503	1.000	.404	.931	1.000	.689	.357	.009	.6235 ± .0464

The weights assigned to the components of the criteria are not acceptable, because Carpentry and Joinery yields weights about double those of Building Construction and Geometry.

Battery No.2 incorporates the Moray House Space, TS.8, Plan and Elevation, Meier Art Judgement and Block tests. Best prediction is .5738.

B.C.	C.J.	Geom	MH.S	TS.8	P&E.	M.AJ	Blck	r_m
1	1	1	1.000	-.086	.771	.559	.275	.5738 ± .0508

Correlation is mainly due to the Moray House and Plan and Elevation tests, although the contribution of the Meier Art Judgement test is appreciable. The weight of TS.8, however, is nil. The factorial analysis shows that the T.S.8 test has appreciable general factor loading, yet it fails to yield any weight in the regression coefficients. This is because the test is introduced to the battery as a test of practical ability, but this ability has been adequately covered by other tests present in the same battery, and the specific aspect of the test has nothing in common with the criteria. Maximum prediction in the Hotelling sense is found to be .6064. The difference between this and the best prediction is not statistically significant.

B.C.	C.J.	Geom	MH.S	TS.8	P&E.	M.AJ	Blck	r_m
.366	1.000	.535	1.000	.181	.572	.533	.346	.6064 ± .0479

It will be noticed that the regression coefficients of the tests are in the same ratios in both equations. This test battery seems to be best suited for predicting Carpentry and Joinery ability.

Battery No.4 is composed of four tests - the Moray House Space, Plan and Elevation, Form Relation and Meier Art Judgement tests. The best prediction obtained, .6291, is somewhat higher than the previous figures, though the difference is not statistically significant.

B.C.	C.J.	Geom	MH.S	F.R.	P&E.	M.AJ	r_m
1	1	1	.997	1.000	.831	.464	.6291 ± .0457

The weights assigned to the tests are quite satisfactory. The Form Relation and Moray House Space tests have highest coefficients, closely followed by the Plan and Elevation and Art Judgement tests.

In the fourth battery, the Art Judgement test is replaced by the Block test, but it appears that the Block test makes very little contribution to the best prediction.

B.C.	C.J.	Geom	MH.S	F.R.	P&E.	Blck	r_m
1	1	1	.866	1.000	.900	.189	.6114 ± .0474

The correlation is mainly due to the Form Relation, Plan and Elevation and Moray House Space tests, and the best prediction is almost as good as that obtained with battery No.3

In the fifth battery both the Meier Art Judgement and the Block tests are included with the Moray House Space and Plan and Elevation tests. Best prediction is .5899 and the correlation is mainly due to these last two tests, although the contributions of the others are appreciable.

B.C.	C.J.	Geom	MH.S	P&E.	M.AJ	Blck	r_m
1	1	1	1.000	.991	.428	.480	.5988 ± .0485

Battery No.6 includes the Progressive Matrices test along with the Moray House, Form Relation and Plan and Elevation tests. Best prediction obtained is .6146.

B.C.	C.J.	Geom	Mat.	MH.S	F.R.	P&E.	r_m
1	1	1	.322	.893	1.000	.978	.6146 ± .0471

The regression coefficient of the Progressive Matrices test is appreciable, but the correlation is mainly due to the Form Relation, Plan and Elevation and Moray House Space tests.

The final battery is compiled of only three tests - the Moray House Space, Form Relation and Plan and Elevation tests. The predictive efficiency of this battery is as good as that of batteries No. 1 and No. 6, which include five and four tests respectively. This illustrates, once again, that adding more and more tests to a battery does not necessarily improve prediction.

B.C.	C.J.	Geom	MH.S	F.R.	P&E.	r_m
1	1	1	.924	.927	1.000	.6101 ± .0473

The indication is that all three tests are equally important and that multiple correlation obtained by assigning equal weights to the tests is not inferior to the best prediction.

5. The reliability of a Test Battery.

The reliability of each test battery is given in the last column of each of the prediction analysis tables. The coefficients of reliability mostly vary from .85 to .90. This figure may be regarded as satisfactory, considering the homogenity of the samples.

The coefficient of the reliability depends on the tests included in the battery and the relative weights assigned to them. For example, Battery No.6 in Group A has higher reliability coefficients (.8824,.8560 and .8556) than Battery No.3 (.8664, .8329 and .8010) because the latter battery contains the Meier Art Judgement test, which has very low reliability (.6675), whereas the former battery includes the Plan and Elevation test where the reliability is higher (.7413). The other three tests in both batteries are the same. But predictive efficiency of the latter battery is superior to that of the former. This shows that the battery which gives best maximum prediction is not necessarily the most reliable. Again, when equal weights are assigned to the tests in Battery No.3 the reliability coefficient is found to be .8664, but when more weight is assigned to the Meier Art Judgement test the reliability falls to .8010, although its predictive efficiency is improved appreciably, illustrating that the weights assigned to the tests yielding best prediction, do not necessarily give the best reliability.

To illustrate the conflict between the weights assigned to tests giving the maximum battery reliability and the weights given to tests yielding maximum prediction, four batteries of tests, one from each sample are considered. The best weights which yield maximum battery reliability are calculated and compared with the weights giving maximum prediction (See Table 58).

The maximum reliability of the battery containing the V.S.14 Part I, Plan and Elevation, Meier Art Judgement and Drawing tests is .8698 and the multiple correlation is .4445. The regression coefficients are in ratios:

V-14	P&E.	M.AJ	Draw
.636	.133	.070	1.000

The reliability coefficient is mainly attributed to the Drawing and V.S.14 Part I tests whose reliabilities are high, whereas the other two which have low reliabilities, yield almost zero coefficients. The weights giving maximum prediction are in ratios:

V-14	P&E.	M.AJ	Draw
.635	.747	.685	1.000

The multiple correlation is .6151 - much higher than the multiple correlation obtained before, but the battery reliability is reduced to .8337.

Similarly, the battery composed of the V.S.14 Parts I and II, Plan and Elevation and Drawing tests, given to the Technical Institute sample, yields the maximum reliability of .9078, by assigning respective weights in the ratios .373: .843: .510: 1.000. Multiple prediction is .5125. The maximum prediction of .5545 is obtained by combining the scores of V.S.14 Parts I and II, Plan and Elevation and Drawing tests respectively in the ratios .532: .009: 1.000: .531. The corresponding reliability of the battery comes down to .8473.

In the case of the third battery in the same table, the maximum reliability is .9173, and its corresponding prediction is .5861. Maximum prediction, on the other hand, is .6564, considerably higher than the previous figure, but the corresponding reliability is somewhat lower (.8881).

The differences in the fourth battery are not so marked, but they are in the same direction.

CHAPTER VI

DISCUSSION

In the previous chapter the results of this investigation were interpreted, sample by sample. Now an attempt will be made to co-ordinate the results of the different samples, as far as statistics permit, and to compare or contrast the main findings with those of previous researches.

The statistical analysis starts with the objective performances of individuals. Reduction of scores is obtained by computing the intercorrelations of the variables. The correlation coefficient is a measure of correspondence between two traits, and a single coefficient is relatively easy to interpret. But in dealing with a large table of correlations it is almost impossible to interpret the complex relationship of all the traits. Simplification is obtained through factor analysis. Altogether 660 students produce 13,810 individual test and assessment scores. These are reduced to 338 correlations, and by factor analysis are boiled down to five factors. It may be mentioned that factor analysis does not add anything to the original data, but it is indispensable for simplification, making it easier to interpret and understand it.

Factor analysis provides the evidence of relationship of a criterion and predictors. The investigator is guided by the results of factor analysis when assembling his test battery for prediction, and when deciding which of the criteria are to be used. It is also helpful when developing tests which are independent of one another.

But when it comes to validation of the tests, the multiple correlation technique is the most powerful. Multiple prediction analysis provides a direct way of validating a criterion- that is by saying that so and so predictors, when combined in such and such a way, will be able to forecast success in certain fields with so much per cent of accuracy.

1. The Psychological Nature of Factors.

The psychological nature of factors has been a salient problem from the earliest days of factor analysis. The divergence of views is largely due to confusion between factors as mathematical explanations of correlations, and factors as concrete psychological or physiological identities. Thomson (1950) and Thurstone (1935,'38a,'47) have repeatedly criticised the supposition that every factor necessarily represents an ultimate and unitary mental ability. To Allport (1934) and Anastasi (1936), factors have no psychological meaning, and they are primarily mathematical artifacts. Most psychologists today regard factor analysis as a means to an end...the understanding of the complex structure of the mind. They do not discard factors as "mathematical artifacts", yet they are reluctant to accept any factor as a concrete psychophysiological entity. Factors are regarded as indicators of some systematically working causes, or set of causes.

Burt's view has been well summarized by Thomson:- "It would almost seem correct to describe Burt's aim as the more modest one of merely describing the actual marks - he himself uses phrases which seem to imply this - and not the more ambitious one of reaching factors which have a kind of independent existence and will be invariant in different batteries". Wolfe (1940) after discussing different authors' views concluded "Factors found, and their relative importance in a battery, are functions of a sample, of the nature of the tests, of the way in which they are scored, of the experience or age of the subjects, and of many other causes in addition to the hypothetical underlying capacity".

There are many causes of factors, beyond native ability, which may produce a factor. Since the students tested in this investigation show considerable homogenity, in education, experience, cultural background, age (difference in age has been removed statistically where necessary), and in sex, it is reasonable to assume that the factors obtained are chiefly due to difference in native abilities.

The existence of a common factor has been almost univerally accepted by the factorists of different schools of thought. Burt (1947a) writes "The difference between Thurstone's multiple factor theory and my own, has been chiefly due to the fact that I start off with the factors that account for most of the variance, that is, as a rule, with the general factor; he prefers to leave the general factor to emerge, if at all, at the very end." "With few exceptions," Holzinger and Swineford (1939) state, "the intercorrelations of mental tests of all types are positive. The simplest interpretation of at least a portion of this common intercorrelation, is that it is due to some common factor."

Spearman and Holzinger interpret the common factor as general mental ability, when the battery is composed of cognitive tests. Hotelling and Kelly and their followers, prefer to interpret it in terms of whatever tests have the largest loadings in it. Most factorists are reluctant to accept the results of the bipolar method, just as they stand, because they regard this factor as a causal entity. Burt looks on the general factor as a weighted average or highest common factor, and removes all that is common to them, regardless of the psychological implication involved. Thurstone regards the centroid analysis as a first step to his factor analysis, and he looks on this first factor as a hotchpotch of everything included in the battery of tests. The centroid factors, he maintains, have no psychological meaning until rotation. Burt advocates caution in interpreting the nature of the general factor in his summation method, but he is not willing to disregard completely, the findings of the bipolar analysis, since it seems to him that this would be a great loss of valuable information. The negative element in a bipolar factor, after the first factor has been taken out, presents considerable difficulty to most factorists. But to Burt (1939,'40,'49) it does not raise any real problem, as he has pointed out that factors are merely a convenient form of classification and so, as such, the positive and the negative dichotomy of a bipolar factor will often tell all that it is needed to know.

In this investigation the four correlation matrices are subjected to the centroid method of factor analysis. The first factor common to all the variables is interpreted as a general factor of the gk type. This is due to the fact that a large number of variables present in the battery are spatial in character. Therefore, the general factor is heavily weighted by the various tests of spatial ability.

While dealing with the Technical School samples, the effect of the spatial tests is so preponderous and the loadings of the assessments on the technical subjects are so large, that the general factor is interpreted as a "technical" factor. This factor is by no means unitary in nature - it may be regarded as an amalgamation of several psychological entities, but because they are all common to the variables in the battery, this particular mathematical technique is not able to differentiate between them. This technical factor seems to be primarily a practical ability factor (k:m) but some percentage of the variance is due to general ability (g).

Interpretation of the first factor has been attempted by many other investigators in the same line. Vernon (1950), for example, found it to be a mixture of g and k:m in a battery of mechanical tests. Howard's (1945) battery was chiefly composed of various practical ability tests, and he called the first factor an ability to "think in terms of visual imagery, associated with three dimensional bodies". McLeish (1950) analysed the Seashore battery and found the first factor to be a combination of general intelligence and musical ability. Morrow's (1931) analysis of a battery of tests of mechanical, artistic and musical ability, yielded a general factor common to all the tests of artistic and mechanical ability; he called this factor the "analysis of spatial relations".

Bradford (1948) demonstrated how the nature of the general factor may change according to the respective proportions of verbal and non-verbal tests included in the battery - the general factor leaning towards the kind of tests most generously included. When equal numbers of both types of tests are included, the general factor approaches to general mental ability, and leaves a large percentage of variance to emerge in the subsequent bipolar analysis.

Spearman (1931) wrote that the mere average of tests picked up and assembled without rhyme or reason, would present the very hub of meaninglessness, and to find the real g, one must use an absolutely random set of tests, for any deviation from randomness would bias the nature of the general factor found. To get a clear cut g, it seems it is necessary to compile a battery which incorporates various kinds of cognitive tests of different levels, and they should be equally balanced. This, however, is not the aim of this investigation - the battery is deliberately weighted heavily with practical ability tests, because the evidence of previous research and of job analysis has revealed that this ability is most relevant to the aptitudes under consideration.

The correlation matrices of groups A and B are factorized by Burt's Group Factor method. The common factor extracted accounts for the cross correlation between the different groups of variables. It seems that this common factor is also weighted by spatial ability, but it is more stable than the first factor of the bipolar analysis. Burt (1950) showed that factors obtained by this method are "virtually irrelevant when the battery is enlarged or diminished". He, however, does not look for anything psychologically meaningful in the common factor which he calls the "basic" factor, since it is not primarily the same as the general factor reached by the ordinary Simple Summation method.

The axes of the bipolar analysis of groups A and B is further rotated by Thurstone's graphic method. There is no general factor. This of course, is due to the method of analysis employed. Eysenck (1939) re-analysed Thurstone's 1938 data, and was able to find a general factor running through all the tests, and several group factors, similar to Thurstone's. The g factor was eliminated by rotating the axes to a new position defined by Thurstone's simple structure, thereby distributing much of the variance of the first dominant factor more equally among the others.

Spearman and Burt decry Thurstone's method, saying that the technique of rotating the centroid factor until the number of zero loadings is maximized, results in dividing g up among a number of small and insignificant factors. Spearman (1939) feels that Thurstone's method of rotation loses g in a maze of experimental and statistical errors. Thomson (1950) prefers a theory of a general factor, plus group factors, since this seems to him to be more in accordance with his ideas of the sampling theory. Burt (1947) wrote "As to the need for a general factor in addition we can appeal once again to the everyday experience of the teachers. The mere fact that children can be classified according to 'general intellectual' ability furnishes strong presumptive evidence against any explanation of individual difference, which does not include a wide spread general factor. Here, therefore, I would suggest, Thurstone's original mode of rotation obscured a critical fact, which is not only suggested by everyday experience, but is varified by the inevitable appearance of large positive correlations in all test data from unselected groups".

In this investigation the rotated centroid analysis finds group factors similar to those found by the group factor method, but the common factor seems to be distributed among the group factors. It seems that this lack of control of the g factor in the rotated centroid analysis, obscured the interpretation of the analysis. Thus, in dealing with group B, the Matrices test which is regarded as a test of pure g, has significant loadings on all three factors - x,v and k. Similarly the Drawing test has significant loading in X and v, which cannot be accounted for. In dealing with group A a similar problem arises: the V.S.14 Part II test yields .4842 verbal loading, so it would appear best to accept the g factor or its equivalent (the common element of the variables) and keep it out of the way before proceeding to find the group factors.

In this investigation, altogether four group factors are identified - v:verbal,k:spatial, artistic, and X: industriousness. The existence of group factors has long been accepted by all factorists. "Indeed" Burt (1949) writes, "it is not too much to say that at the moment, a far closer accord has been reached about the existence and nature of group factors, than about the existence and nature of the general factor".

One of the group factors which has been identified and accepted generally, is the v:verbal factor. It is well marked in verbal intelligence tests and moderately in science subjects. The earliest statistical evidence of a verbal factor was reported by Burt in 1915. Davey (1926) found a group factor running through most of her verbal tests, and soon after, Stephenson (1931) and Kelly (1928) established the verbal factor. This factor is denoted by v - the verbal or linguistic ability, involved primarily in the meanings of words and the ideas associated with them. The verbal factor appears to be divided into two sub-factors - the W:word factor, dealing with words in isolation, and the V-language factor, dealing with words in their context, or the manipulation of verbal ideas. (Thustone 1938, Burt 1949). The v factor in this enquiry seems to be of the second type.

Verbal ability is a functional ability, which is a compound of the general and verbal factors. The proportion of each of these factors present may well alter the nature of the verbal ability necessary in different linguistic activities. Thus, in Structural Science and General Science, the general or basic factor plays a larger part than the v factor. But in the case of the

V.S.14 Part I or the Otis Intelligence tests, the v factor is of prime importance.

Similar to verbal ability, practical ability could be said to be a combination of the general and spatial factors. In the group factor analysis the spatial factor does not emerge so prominently as the verbal factor. This is because a large portion of the variance, due to the spatial factor, has been taken out in the basic factor gk. The spatial factor appears prominently in tests requiring a comprehension of relations and movement in space. All the variables depend on some type of visual ability - an ability to discriminate visually, to retain a visual image, to move part of an object, visually, from one place to another, to visualize a configuration, to imagine a design moved from one plane to another. The spatial factor is the same as El Koussy's (1935) k factor, or Thurstone's (1938) S factor. It is prominent in all the spatial tests, the performance test, Engineering Drawing, and to some extent in the non-verbal intelligence tests. The same factor seems to be involved when dealing in two and three dimensional space.

The data of Bains, Thurstone and others, show the superiority of the three dimensional tests over the two dimensional ones.

In this research there is a slight indication in group

A that the three dimensional tests have loadings slightly higher than the two dimensional ones, but this result should be interpreted with caution, because it is known that three dimensional tests are not only different from two dimensional ones in dimension, but also in nature, and their difficulty level makes them better suited to the students tested. In group B there is no such superiority of the three dimensional tests, because the two dimensional tests are equally suitable. Unfortunately, this investigation is not designed to test any such hypothesis. For this, the test battery should be so designed that the two types of tests are equally suited to the experimental population, and also to the psychological principles called for in solving the problems, should be similar as far as possible, except in the dimensional aspect of the tests.

In this enquiry the performance test and shopwork marks have the same factor loadings as the paper and pencil spatial tests. This finding seems to support the results of Price (1940), Williams (1948), Leff (1949) and others. They found that Alexander's F factor common to performance tests and shopwork, and El Koussy's k factor, common to paper and pencil non-verbal tests are substantially the same. Drew's finding that the space factor k is distinct from the F factor has been frowned upon, because alternative analysis of his data by Vernon (1950) and Emmett (1949) failed to find any grounds to support his claims. Drew's research has been adversley criticised by Slater (1947), who doubted whether there was any scientific value in Drew's work. One of the main reasons for Drew's doubtful result, it may be said, is the subjective method of rotation of the centroid axes. Gharieb (1949) claimed that he has established two distinct factors, k and F. But closer inspection of his results reveals that the two factors are not so distinct as he suggested. Some of the paper and pencil tests in his battery have F factor loading, while some of the performance tests and the shopwork marks have appreciable k and low F loading.

The findings of this research seem to support Vernon's (1950) view that spatial, mechanical, performance, perceptual, manual, together with practical occupational abilities have something in common on and above g, which he denotes by k:m. It appears that the k:m factor could be sub-divided more easily on priori than statistical grounds.

Another group factor is identified as the artistic factor. This factor is present in group A and it appears to be of prime importance for success in an Architectural course, and especially in Architectural Design. In group B the existence of this factor is detected, but it is not significant. The artistic factor is common to the Meier

Art Judgement and Drawing tests, and to Architectural Design. It is also detected, to some extent, in Building Construction and Engineering Drawing.

The components of Artistic ability are the artistic factor and the gk factor, but the v factor does not play any part in it. The artistic factor, as found in this investigation, cannot be identified with aesthetic appreciation, because the art judgement test, which is supposed to be a test of art appreciation, has lower loading than Architectural Design and the Drawing test, which are measures of artistic-creative ability. Artistic ability is not only a matter of passive appreciation, but also of creative imagination and artistic creation.

Burt, Dewar, Stephenson, Eysenck and Peel, all have established a general factor of artistic ability, but these researches are mainly confined to the appreciation of pictures, rather than actual art work.

It seems that gk plays some part in artistic ability. From the evidence furnished by this investigation, it is not possible to judge the relative importance of g and k, but the variance contributed by gk is much lower than that contributed by the artistic factor. Burt and his collaborators have long established that the artistic factor is independent of intelligence and that it represents a separate ability. Dewar (1937) established that artistic ability cannot be identified with general intelligence. Morrow's (1938) "general factor analysis of spatial relations" is common to tests of art and mechanical ability. Barrell (1945), Borg (1950) and others, have all suggested a relationship of artistic ability and spatial ability. Meier thinks that art judgement is the most important single factor in artistic ability, but he considers it as only one of the six factors which go to make up this ability. Two of Meier's other factors - "aesthetic intelligence" and "perceptual judgement" - may together be the same as the gk factor found in this investigation.

The Iowa School has done considerable work in the field of artistic ability. Meier's six factors of artistic ability are not the factors of the mind, derived from the factor analysis of mental traits. Although much work of an exploratory nature has been done by the Iowa School, the results require the support of further work, based on modern statistical technique.

It will be noted that in groups C and D, the artistic factor does not appear. This is because there are not enough art tests in the battery. The Drawing test has high general factor loadings in both samples - this suggests that the Drawing test, which is chiefly a measure of the art factor, measures the gk factor in the younger population. This illustrates that the same test may have different factorial composition in different age levels. The situations presented by the practical ability tests and shopwork in groups C and D, have been familiarized by schooling, but art work is novel to the students, so they utilize the gk factor in solving the problem of the Drawing test, instead of the art factor. In the case of group A, the students are so superior in gk ability, that all of them have the minimum level necessary for the Drawing test, and consequently any difference in performance in this test is determined by the art factor.

One group factor common to all the assessments is found in groups B and C. This is designated as the X factor. It does not play any part in the tests, but without exception, all the achievement measures of the two groups, have considerable loading in it. It is important in school success, and it is not g or any other group factor. This implies that success in the Engineering course in the Technical School and the Technical Institute, is largely determined by a factor which the test battery is unable to measure. The X factor cannot be dispensed with by identifying it with the "halo" effect in assessment, because various other investigators reported the presence of this factor in examination marks, where different subjects have been marked by different examiners, and it is very unlikely that all the examiners have been affected by personal bias in the same direction.

The explanation of this factor has to be found in the domain of personality or temperament, rather in that of abilities. Alexander (1935), Bradford (1946), Holzinger and Swineford (1939) and many others, have interpreted the X factor as a scholastic factor, influenced by the personality, interest and industriousness of the pupils. Alexander (1935) described this factor as X, and he is inclined to think it is "persistence or determination". It appears to him that in testing, the time is so short, and stimulation so great, that persistence plays no part, but in school achievement, however, where success depends on persistent effort over a period of years, it is likely to play an important role. Vernon (1939,'50) explains this factor as one of studiousness or willingness to work. Eysenck (1947) seems to be in agreement with these views. It appears that a student's success in school (or college) involves his persistence, studiousness, interest, application and so forth, over and above abilities.

Because of this, selection for secondary or higher education, which acknowledges the importance of previous school work, in addition to psychological tests, is usually more successful than selection by tests alone. Unfortunately it is difficult to compare applicants from different schools, because of the wide differences in teaching, and the varying standards of examination. Moreover, success in an examination is determined by ability and industriousness, so examination results cannot be accepted as a measure of the X factor. It seems that prediction would be improved considerably if it were possible to measure the X factor objectively. It may be suggested that teachers' ratings of their pupils' "industriousness" or "application" will help to improve prediction. This rating, however, is open to criticism, because the applicants would come from different schools, but owing to the inability to measure X objectively, it seems that this is the only substitute.

Knowledge of the nature of the X factor is very little, and further research would certainly be profitable. To confirm that the X factor is really due to industriousness, an experiment could be designed taking into account teachers' ratings on industriousness and other personality traits, examination results, and achievement tests in the same subjects, together with different tests of ability.

2. The Importance of Factors in School Success.

The existence and nature of the factors is of special interest from the point of psychological theory, but the relevance of the factors for success in various school subjects is the prime consideration in this research. The results provide adequate evidence of the existence of g,v,k,art and X factors, and these factors enter into different subjects in varying amounts, although none calls for each and every factor.

In the first place, the general factor or basic factor seems to be important for every subject in all four courses. But the amount of this factor needed for success in different subjects varies. Also, it will be noticed that the general factor plays the predominant part in the Junior Technical school subjects, but in the School of Architecture, the special factors are more important.

In group A there are four components in the criteria, of which Architectural Design is to be considered first, because it is the basic subject in the curriculum of the architectural course. Success in Architectural Design depends on two factors - the gk and art factors. The relative importance of the two factors is interesting. In the group factor analysis the ratio is 2gk:5art, and in the rotated centroid analysis the ratio is 2k:5art. This suggests that a student with high general and spatial factors, but poor art factor, has little chance for success in Architectural Design.

Success in Structural Science is determined by two factors gk or k, and v, each as important as the other, and Building Science has similar factor composition.

Building Construction consists of the same two factors as Architectural Design, but in different amounts. The group factor analysis shows that the two factors are equally important, but the rotated centroid analysis is only significant in art factor loading.

It will be noticed that prediction of Architectural Design will be successful, since 50 per cent of its total variance is covered by two factors. Prediction of Structural Science will be partly successful, but that of Building Construction and Building Science will not be successful, because the major part of the variance has not been accounted for.

In group B, the criteria incorporates three subjects - Technical Drawing, Mathematics and Science. Success in all three depends, as shown by the bipolar and group factor analyses, chiefly on two factors - gk and X. The importance of the X factor is also shown by the rotated centroid analysis.

Reference to the factor matrix of the rotated centroid method, shows that success in Technical Drawing is dependent on four factors - X,v,k and art. The factor X is most important, and it accounts for 36 per cent of the variance. The verbal loading in Technical Drawing cannot be accounted for. The appearance of the v factor in Technical Drawing may be due to distribution of the general factor over the group factor. Too much importance must not be given to the figures obtained by graphic rotation, because the solution obtained cannot be regarded as unique.

In the group factor analysis the variables have been classified and the axes are not rotated. Under such circumstances the total variance of Technical Drawing is accounted for by two major factors, gk and X, the former being less important that the latter. (gk=36%, X=7%)

Success in Mathematics at the Technical Institute appears to depend on three factors viz X, v and k, as shown in the rotated centroid factor matrix. Importance of the X factor is most prominent. In the group factor analysis, success in Mathematics may be accounted for by two factors, gk and X, accounting for 25 and 53 per cent of the loadings respectively. To use only the g, k and v tests for predicting success in Mathematics, would not be very successful without taking X into account.

General Science, in the rotated centroid analysis, appears to depend on the v and X factors. In the group factor analysis the two factors are gk and X, accounting for 24 and 31 per cent of the variance. The verbal factor, however, does not appear in the group factor analysis, because the axes have not been rotated.

Success in the Engineering course in the Junior Technical school is solely determined by two factors, gk and X. All four school subjects, Technical Drawing, Geometery, Metalwork and Woodwork, have substantial loadings in both factors. Since in this research, no attempt has been made to isolate g from k, it is not possible to say their relative importance. It may be that both are involved in the four different subjects in varying proportions, according to the complexity of the subjects. Prediction of success in the Engineering course will be fairly successful, because the variance contributed by the gk factor, ranges from 37 to 53 per cent. Here again, it seems that prediction could be greatly improved if there were any measure of the X factor.

Success in the Building course in the Junior Technical school, too, depends chiefly upon the gk factor. Building Construction and Geometry seem to have some amount of verbal factor loading above gk, though it is relatively low. As in Engineering, the relative importance of the g and k factors in the three different subjects cannot be determined. Prediction will be less successful than in the Engineering course.

It may be noticed that in both groups from the Technical school there is no sign of a separate art factor. This is, of course, due to the lack of sufficient variables rich in this factor. Had there been more art tests in the battery, it would be expected that a separate art factor would emerge, but it is very unlikely that success in school subjects would depend upon this factor, because the low correlation between the Meier Art Judgement test and the subjects, can be attributed solely to the gk factors.

It is interesting to note how well these findings fit the expectation, i.e. the results of the job analysis. The results of this and the factor analysis seem to be almost identical. In the job analysis, artistic ability, spatial ability, and general intelligence, are reported to be relevant to architectural ability. The results of the factor analysis show almost the same types of abilities necessary for success in an architectural course - the $g_{k,v}$ and art factors. The job analysis reveals that success in Engineering Drawing depends chiefly on k and g. Factorial analysis seems to yield similar results, but the X factor emerges to be very important, and this has been completely ignored in the job analysis. The art factor shows some importance in Technical Drawing in the Technical Institute, but not in the Technical School. This is, however, according to expectation. The art factor may be expected to play a larger part while dealing with design draftsmanship.

3. Three Degrees of Multiple Correlation.

The correlation of a predictor with the criterion, merely expresses the value of each test in isolation. But a problem arises when the criterion battery is complex and there are a large number of predictors. In this case, several tests are combined in a battery, and appropriate weights are assigned to obtain best prediction. Each test could be weighted according to its correlation with the criteria, without computing the regression equation, when the inverse of the correlation matrix is approximately equivalent to a unit matrix. But when the criteria is complex, calling for more than one factor, and the components of the criteria are assigned differential weights, it is unavoidable to compute multiple regression coefficients to obtain best prediction.

In this investigation multivariate analysis is carried out in order to derive three degrees of correlation between the test battery and the complex criteria. First of all, both the teams are equally weighted. The multiple correlation thus obtained provides a much better prediction than any single correlation coefficient. Thus the Plan and Elevation test, when applied to Engineering pupils from the

Technical School give a maximum overall correlation with the complex criteria (.40). But when three other tests are combined with it, the multiple correlation rises to .66. By assigning equal weights to the variables, arbitary and uncontrolable multiples are introduced, depending on the unintentional weighting caused by the difference in the standard deviation of the several variables.

Burt (1943) suggested "For practical purposes it is often unnecessary to use expressly calculated weights, such as those based on the partial regressions: it may be sufficient merely to eliminate the unintentional weighting entailed by the differing standard deviations of the several tests, and then take a straight sum or simple unweighted average of the marks." The results obtained in this research seem to support this view. The improvement obtained by the Peel method is most cases is not statistically significant. But when the criteria call for more than one factor and the components of the criteria are assigned differential weights, much improvement is obtained by assigning appropriate regression weights to the tests. The prediction of Architectural ability is .5828 (Battery No.1), which is very little inferior to the best prediction obtained by assigning appropriate weights to the tests (.5922); but best prediction rises to .6938 when the two criteria are assigned differential weights on educational grounds.

The weights assigned to the components of the complex criteria are selected on grounds other than the mathematical principle of least squares - educational or psychological grounds. Thus the two components of the Architectural criteria are weighted in the ratio of 3:1 for A.D: S.S. The three assessments of the Technical Institute course are given equal weights i.e. 1:1:1 for T.D:Maths:G.S. This may be regarded as an over all ability index for succes in a technical course. But to forecast success in Draftsmanship, the different components of the criteria are assigned arbitrary weights based on experts' opinions. The weights given are in the ratio of 4:2:1 for T.D:Maths: G.S. Similarly in the Junior Technical school level for Draftsmanship, the components of the four criteria are assigned weights in the ratio of 4:2:1:1 for T.D:Geom: M.W: W.W. But all the assessments are given equal weights to compose the over all ability index. Similarly, the three assessments of the Building department are equally weighted to constitute the over all ability index, 1:1:1 for B.C:Geom:C.J.

The same set of tests differently weighted, might conceivably be made to predict efficiency in several directions. For example, in predicting success in a Technical course, the tests are assigned weights roughly in the ratio of 4:8:10:1:6 for V-14:Mat:P&E.:3D.S:Draw, while in predicting Draftsmanship more weights are assigned to the spatial tests. The weights are in the ratio of 2:5:10:2:5 for V-14:Mat:P&E:3D.S:Draw. In a junior Technical school success in the Engineering course may be predicted by assigning weights in the ratio of 5:7:10:4 for MH.S:F.R.:P&E:Blck. The same battery of tests may be used to forecast success in a Building course, but the weights of the tests must be assigned in a different way i.e. 9:10:9:2 for MH.S:F.R:P&E.:Blck. Similarly, a test battery is composed of V-14,Mat, P&E, M.AJ and Draw tests for prediction of Architectural ability and Draftsmanship at Technical Institute level. The weights assigned in the case of Architectural ability are in the ratio of 3:1:5:10:10 for V-14:Mat:P&E:M.AJ:Draw. But in the case of Draftsmanship the weights are in the ratio of 2:4:10:1:5 for the same set of tests in the same order.

The arbitrary weights assigned to the criteria as in the Peel method are sound from the psychological and educational points of view. This is a criterion which few would question.

The weights assigned to the components of both batteries are found by the Hotelling method, in order to yield the maximum possible correlation between the two teams. The maximum prediction thus obtained is very little superior to the figure obtained by the Peel method. The maximum predictions of .7176,.6104,.6163,.5887,.6736, .6696,.6235,.6064, are very little higher than the best predictions of .6938,.6100,.6088,.5913,.6559,.6569,.6160 and .5738 respectively. The difference between the two predictions varies from .0004 to .0326 - this difference may be regarded as negligible, as the standard error of the coefficients ranges from .04 to .07.

The solution in the Hotelling sense is mathematically unique, but as has been pointed out in the previous chapter, it is questionable whether it is best in any practical sense. Burt, Emmett, Thorndike and Peel, have pointed out that the weights assigned to the components of the assessments by the Hotelling method might not remotely resemble any weight which one is prepared to accept on educational or psychological grounds. The results of this investigation point in the same direction. The weights assigned to the two criteria of Architectural ability are 10:0 in battery No.1 and 10:-3 in battery No.2, in favour of Architectural Design, whereas the weights assigned by the experts are 3:1 for A.D:S.S. Similarly the regression weights of the three assessments in the Technical Institute (Battery No.1) are assigned in the ratio of 10:3:5 by the Hotelling method, but the three assessments are weighted equally by the experts as an index of over all success in a Technical course. These and other statistics in this thesis illustrate that the assessment that receives heavy weights in the composite, because it can be readily predicted by a battery of tests, is not necessarily the best available professional judgement.

Calculation of maximum prediction in the Hotelling sense, however, is useful to know the maximum predictive efficiency of the battery, and it provides valuable information as regards which assessment has been best predicted by the given set of tests. The batteries used for predicting Architectural ability, have been found to be exclusively suited for predicting Architectural Design. Similarly, the batteries compiled to predict success in Draftsmanship predict Engineering Drawing most efficiently of all the assessments. These findings are satisfactory, however, as those two sets of batteries are compiled to yield effective prediction of Architectural Design and of Engineering Drawing, which are by far the most important subjects for the Architectural course and Draftsmanship respectively.

4. The Number of Tests in a Battery and Negative Weights in the Regression Coefficients.

Predictive efficiency of a battery cannot be increased indefinitely by adding more and more tests to it. In this investigation, it is found that four tests in each battery is adequate to predict success in any of the abilities concerned. For example, in dealing with Engineering pupils in the Technical School, the Plan and Elevation test gives maximum over all correlation with the criteria, .42. When two other tests, the Moray House Space and the Form Relation tests are combined with it, the multiple correlation yields a figure of .5795. The Drawing test is added and the multiple correlation is found to be .6564. This figure seems to be the maximum, because any further addition of T.S.8 test does not increase the coefficient. This, at first sight, seems to be contradictory to the results of the factor analysis, because the T.S.8 test has given positive correlation with the criteria, and it has the same gk factor loading as the criteria. Though this may appear a paradox, very little thought will make the principle understandable - the T.S.8 has been introduced to the battery because it has the same gk factor loading as the criteria. But the same factor has been more thoroughly measured by the other four tests present in the same battery, which are richer in gk. The sole effect of the T.S.8. test here, is to introduce some irrelevant factor, specific to itself, which contributes nothing to success in the Technical course. It may be expected that the T.S.8 test will show its usefulness when compiled with other tests which have less gk loading. This is done in battery No.6 where the T.S.8. test is combined with the Form Relation, Moray House Space and Progressive Matrices tests, and it is found that the T.S.8 contributes appreciably to the prediction.

Appearance of the negative coefficients in the V.S.14 Part I test in Battery No.3 of the School of Architecture, and in the Block test in Battery No.2 of the Technical School, may be explained in the same way. Factor analysis has revealed that V.S.14 Part I is chiefly a v test, and that Structural Science also has v factor loading, beyond the general basic factor. But the other criterion - Architectural Design - has no v factor loading. When the two criteria are assigned equal weights and V.S.14 Part I is used for prediction it yields positive coefficients, as expected, because of its common general or basic factor and v factor. But when V.S.14 Part II is introduced to the same battery of tests, due to its high gk factor loading, the importance of V.S.14 Part I is considerably reduced. When Architectural Design is assigned three times more weight than Structural Science, and the V.S.14 Part II test is used in the same battery, V.S.14 Part I actually yields a negative coefficient, because its sole effect is to introduce the v factor, which is by no means helpful for success in Architectural Design. It is to be expected that the student who is good in the verbal factor is likely to be a bookish type with no time and interest for non-academic subjects like Architectural Design.

It would appear at first that high scoring in the Block test is detrimental to success in the Technical course. The test is included in the battery as a measure of practical ability (gk factor), so when more reliable and valid tests of practical ability are included, the Block test adds nothing to the prediction. Its only effect, therefore, is to add a new factor which has no bearing on the criteria, and the inevitable effect of this is to hinder prediction. The new irrelevant factor may be manual dexterity.

5. Prediction of School Success with Tests.

Success in the Architectural course is best predicted by the Drawing, Meier Art Judgement, Plan and Elevation, and V.S.14 Part I tests, giving weights roughly in the ratio of 10:9:4:3 respectively. The multiple correlation obtained is .6867 and this may be regarded as the best over all prediction from the statistical, psychological as well as the practical point of view. Slightly higher prediction may be achieved by replacing the V.S.14 Part I test by the V.S.14 Part II in the above battery, but a battery without a test of the verbal factor cannot be accepted on psychological grounds, because the importance of the v factor, however small, can not be overlooked in predicting Architectural ability.

Success in a Technical course at the Technical Institute level is best predicted by a battery of four tests - Plan and Elevation, Progressive Matrices, Drawing, and V.S.14 I, with weights assigned roughly in the proportion of 10:7:6:4 respectively. The multiple prediction obtained is .5915.

The same battery of tests may be used to predict success in Draftsmanship, but the weights assigned are somewhat different - 10:5:4:2 for P&E.:Draw:Mat:V-14. The multiple prediction obtained is .6004. At the Junior Technical School level, the best forecast in Draftsmanship is obtained by the Drawing, Plan and Elevation, Form Relation, and Moray House Space tests, giving relative weights roughly in the ratio of 10:8:3:3 respectively, and the prediction obtained is .6686.

The same battery may be used for predicting success in an Engineering course at the Technical School, and the weights assigned to the tests and the multiple correlation (.6564) are almost the same as before.

The best battery for predicting success in the Building course in the Technical school is composed of the Form Relation, Moray House Space, Plan and Elevation and Meier Art Judgement tests. The prediction obtained is .6291, by assigning weights in the ratio of 10:10:8:5 for the Form Relation, Moray House Space, Plan and Elevation and Meier Art Judgement tests respectively.

It will be noticed in predicting success in the two different courses, Engineering and Building, that three tests - Form Relation, Moray House Space and Plan and Elevation - are common to both batteries. The predictive efficiency by assigning equal weights to these three tests is .5706 and .5989 for the Engineering and Building courses respectively.

The Drawing test is most important for forecasting Engineering success, but it has no predictive value for the Building course. Similarly, the Meier Art Judgement test plays some part in predicting success in the Building course, but not in the Engineering course.

Selection for the Junior Technical School may be carried out in two stages. First of all, the test battery of the Form Relation, Moray House Space and Plan and Elevation tests, may be applied to all the applicants and the appropriate number of pupils may be selected according to the availability of seats. After that, the pupils may be alloted to the two different departments (Engineering and Building) of the school, according to their performances in the other two tests - the Drawing and the Meier Art Judgement tests.

6. Regression Weights.

The coefficients of the regression equation obtained are valid only in the case of a population similar to the sample tested. They depend on the correlation coefficients which in turn depend on the arbitrary standard deviations of the predicting tests for the students forming the sample. Thus Emmett (1952) warns "...regression coefficients based on the statistics of the sample are occasionaly put forward as the ultimate estimates of the relative predictive value of the tests."

When the sample is very homogeneous, in reference to any particular ability, the regression weight of the tests of that ability is liable to be very small. For example, the students of the School of Architecture are very highly selected and superior in mental ability, as measured by the Progressive Matrices test. The job analysis reveals that success in an architectural course depends largely upon general intelligence, yet the Progressive Matrices test, which is supposed to be a pure g test, failed to yield appreciable regression coefficients. This is because the sample tested is very superior in intelligence - all the subjects have the level of intelligence necessary to be successful in the course. Had the whole population from which the sample is drawn been tested, the Progressive Matrices test would have yielded appreciable correlation with the criteria, and hence would play a prominent part in the prediction. In predicting success in the Junior Technical school course, the Matrices test also failed to yield any appreciable coefficient for similar reasons. But in the case of the Technical Institute sample, which is less selected and less able, the test plays a very prominent part in prediction.

Thus the weights of the regression equation can not be accepted as they stand - they are not only the property of the tests, but also of the sample tested. This points to the aution that it is necessary to take while using the set of tests for selecting candidates from the population. Unless the applicant group is similar to the experimental group, the regression coefficients cannot be relied upon as they stand.

The correlations derived from the sample may be corrected to population values by Aitken's adaptation of

Karl Pearson's selection equation of multivariate selection. From the corrected correlations, partial regression coefficients and multiple correlations may be found.

The effect of selectivity of the sample on the regression coefficient and the multiple correlation has been studied by Burt (1943) and Thomson (1950). Emmett and Wilmut (1952) compared the scores of two batteries of tests given to 281 Grammar school children aged 11 plus, with marks in the School Certificate examination five years later. The resulting multiple correlations were .517 and .578. These correlations when correlated for selection rose to .849 and .830. Burt (1943) reported similar results with technical students.

The multiple correlation obtained in this investigation mostly varies from .6 to .7. Since the samples tested here are highly selected, the prediction coefficient of .85 to .90 in the population might well be yielded by the figures obtained in this research after correction for selection. The square of these multiple correlations is the proportion of the qualities making for success measured by the predictors. It is roughly 75 per cent, which leaves only 25 per cent to be ascribed to the interest, industriousness, home and social environment and subjectiveness in assessment. By taking into consideration the X factor and other personality factors, the prediction could be improved still further.

7. Multiple Prediction and Battery Reliability.

In this enquiry, the battery reliability of several sets of tests is computed by Peel's method and it is found that the best weights for prediction differ from the weights which will give maximum battery reliability. The problem of finding a set of weights which will "make battery reliability equal to prediction, and both as large as possible, under this condition" has been posed by Thomson (1940) but is not yet solved. If and when a solution is reached, it will make prediction more reliable and efficient at the same time.

Validity of a test depends upon its reliability. One way of improving test reliability is to increase the length. In this investigation it has been noticed that the Plan and Elevation test has high validity, yet it takes only 20 minutes to administer. Its reliability varies from .74 to .82. It could be lengthened to 40 minutes without making it too monotonous or strenuous, and the reliability of the test would be much higher (.86 to .92).

One of the tests in this investigation which proves to be very useful, yet has too low a reliability coefficient, is the Meier Art Judgement test. Low reliability of this test may be attributed test may be attributed to the chance element in recording preference of one of two pictures. This could be avoided by making it the multiple choice type - instead of asking the subject to chose one out of two, he could be presented with several pictures of different artistic merit, and asked to identify the best one. In this way the chance element in judgement would be eliminated. Karweski and Christenson (1925) devised their tests of art judgement along similar lines - they asked the subject to state the reason of his preference in order to avoid random choice. But this method is open to criticism, because knowledge of the aesthetic is likely to affect the score. A child may not be able to say why he prefers one picture to another, yet by virtue of his higher aesthetic ability, he may be able to appreciate an object of high artistic merit.

The Meier Art Judgement test could be further improved by introducing colour, which forms an integral part of art appreciation.

An inspection of Table 15 reveals that the tests which are most reliable after correcting for length are those which are of the creative response type, because the chance factor in solving the problems is greatly reduced. All three of the Peel tests i.e. V.S.14 Parts

I and II and the T.S.8 test are of this type, and they yield maximum reliability coefficients. The only difficulty is that the creative-response type of problem sometimes introduces the subjective element into the scoring. Thus, although the N.I.I.P. Memory for Design test has been found to be a very successful test of spatial ability, it is not very often used, due to the subjectivity of scoring. But objective scoring may be achieved as shown by Peel's tests.

It may be suggested, therefore, that further investigation in this field should attempt to adapt tests to meet the demands of creative response.

CHAPTER VII.

CONCLUSION.

1. Summary and Conclusions.

Technical Drawing is an extremely important component of modern technology - it controls our architecture, our industrial and machine design, our every modern convenience.

An attempt has been made in this thesis to bridge the gap between the designer and the psychologist, and to make a psychometric study of architectural and engineering drawing. It is hoped that such a study will be useful for an understanding of the abilities required of the architect and draftsman, and eventually play a part in vocational and educational guidance and selection. This investigation was carried out with special emphasis on the selection of students for an Architectural course, and for courses in a Junior Technical school and a Technical Institute.

The population tested consisted of : Group A, 75 male adult students from a School of Architecture, Group B, 225 apprentices at 15 plus from a Technical Institute, Group C 180 pupils at 12 plus from the Engineering Department of a

Junior Technical school, and Group D, 180 pupils at 12 plus from the Building Department of the same school.

The whole processes of the job activities under investigation were analysed, and the basic abilities underlined in such activities were listed. On the basis of this analysis a battery of predictors was compiled, and the key subjects of each course were chosen to compose the criteria. The test battery consisted of intelligence tests - verbal and non-verbal; practical ability tests - paper and pencil and a performance test; and artistic ability tests - an art judgement test and a drawing test. Teachers' assessments on a 15 point scale were taken as the measure of success. All the variables of the four samples were inter-correlated separately, and the matrices were factorized by the centroid method of analysis. The bipolar factor matrices of Groups A and B were rotated graphically and Burt's group factor analysis method was also applied to these groups.

The factor analysis yielded five factors all together - gk the general or basic factor, and four group factors v,k,art and X.

The general or basic factor was a composite of g and k - the relative importance of each component varying from sample to sample. This gk factor was common to all the tests and assessments in all four groups. The general factor in groups C and D was so heavily weighted by the spatial practical ability tests, and the assessments had such high loadings that it was named a "technical" factor - a broad practical ability factor.

The verbal factor v, common to the verbal intelligence tests and science subjects, was identified in groups A and B. Its existence was also detected in the bipolar analysis of Group D.

The spatial factor k, common to the spatial tests, the performance test and the Shopwork and Technical Drawing assessments, was identified in groups A and B. It seems that the performance test and the Shopwork marks measure the same factor as the paper and pencil tests, and that the space factor is equally involved in two and three dimensional tests.

The art factor, common to the Drawing and Art Judgement tests, the Architectural Design assessment, and to some extent the Building Construction and Technical Drawing assessments, was also found in these groups. It was concluded that the art factor was more a matter of artistic creation, than mere passive appreciation of beauty, and that art judgement, which is often identified with artistic ability, was only a part of the factor.

The X factor appeared in groups B and C, and it was tentatively identified as a scholastic factor, depending on the industriousness of the students. The influence of this factor in school work was larger than that of any other factor.

As far as the method of analysis was concerned, the bipolar analysis alone provided a useful means of classification. The group factor analysis was found to be most suited for providing a ready psychological explanation, and the analysis was also unique. The graphic rotation of the simple structure analysis was found to be somewhat weak, due to the arbitrariness in rotation, and the distribution of g among the group factors. It was found that the existence of g could not be overlooked, and that in factorizing mental traits, it was advisable to extract the common element of all the variables before proceeding to locate the group factors.

Factors should be regarded as causal entities, and as such, the factors obtained are the functions of the nature of the tests as well as the samples. Factor analysis is useful when choosing a few tests for predicting a criteria, and when deciding which criteria are to be used. It is also helpful when developing new tests, to varify the hypothetical traits they are supposed to measure.

On the basis of the factor analysis, sets of tests were selected for predicting different criteria. Multivariate analysis was carried out in order to derive three degrees of correlation between the test battery and the complex criteria.

By assigning equal weights to the variables, arbitrary and uncontrolable multiples were introduced, depending on the unintentional weighting caused by the differing standard deviation of the several variables. By calculating the regression equation, this difficulty was overcome, but the gain in prediction did not justify the labour involved in computation. Almost the same prediction could be achieved, merely by eliminating the unintentional weighting entailed, and then by taking a straight sum or unweighted average of the marks. But when the criterion was complex, depending on several factors, and the components of the criteria were differentially weighted, much improvement in prediction was obtained by assigning appropriate regression weights to the tests by the Peel method.

The best prediction by the Peel method was very little inferior to the maximum prediction obtained by the Hotelling method. Although Hotelling's best prediction is mathematically unique, it cannot be accepted for any practical purposes.

Where the object was to allocate students to two or more different types of education, the use of two or more sets of differential weights enables the same battery of tests to be used for several kinds of selection.

The prediction could not be increased beyond a certain limit by adding more and more tests. Sets of four tests were found to be adequate for predicting the different aptitudes under investigation.

Success in an Architectural course was best predicted by combining the scores of the Drawing, Meier Art Judgement, Plan and Elevation, and V.S.14 Part I tests, respectively, in the ratios 10:9:4:3, giving a prediction of .6867. Success in a Technical Institute course was best predicted by the Plan and Elevation, Progressive Matrices, Drawing and V.S.14 Part I tests, assigning regression weights in the ratios 10:7:6:4, giving a prediction of .5915. For predicting ability in Draftsmanship in a Technical Institute, the same four tests provided best prediction of .6004 with weights in the ratios 10:4:5:2. Success in Draftsmanship in a Junior Technical school was best predicted by combining the scores of the Drawing, Plan and Elevation, Form Relation and Moray House Space tests, respectively, in the ratios 10:8:3:3, and the prediction was .6686. Success in the Engineering Department in the same school was best predicted by the same set of tests, assigned the same weights. In the Building Department, success was best predicted by combining the scores of the Form Relation, Moray House Space, Plan and Elevation and Meier Art Judgement tests, respectively, in the ratios 10:10:8:5 - prediction was .6291.

Selection of pupils for a Junior Technical School, it was concluded, could be carried out in two stages. First of all, the Moray House Space, Plan and Elevation and Form Relation tests could be applied to all the applicants, and previous teachers' systematic ratings of the applicants' industriousness could also be taken into consideration. On the basis of this, an appropriate number of pupils could be selected according to the number of seats available, and then the pupils could be divided between the two departments of the school (Engineering and Building) according to their performances in the Drawing and the Meier Art Judgement tests.

The samples tested were highly selective - this gave an under-estimation of the validity of the test battery, and the regression coefficients were liable to be distorted. The coefficients of the regression equation were not only the property of the tests, but also of the sample tested. It was concluded that unless the applicant group was similar to the experimental group, the regression coefficients could not be used as they stood.

Considering the homogeneity of the samples tested, the regression coefficients obtained were considered satisfactory, and if a suitable measure of the X factor were available, the prediction would have been improved still further.

From the evidence of this investigation, the nature of ability of technical drawing can be summed up as follows:

Architectural drawing ability appears to depend on several more or less independent factors. It is an integration of artistic and intellectual ability. The successful architect needs the ability to reason and to analyse and synthesize items through the medium of space relations. He should have sensitive artistic judgement, in order to create objects of artistic merit, which are, at the same time, technically proficient.

Draftsmanship calls for practical intelligence. The draftsman needs, above all, the ability to think in terms of space. He must be able to think in solid and to transfer an object from three to two dimensions and vice versa. Artistic ability does not play an important part in Draftsmanship at the early stage of training.

2. Suggestions for Future Work.

This enquiry has provided sufficient evidence to justify the use of psychological tests for educational selection, but the relative importance of skills, ingenuity, insight and principles demanded by the schools, may differ from those demanded by actual occupation. It has been assumed, however, that if a satisfactory selection procedure can be devised for schools, it could be adapted for predicting success in occupation. Further research, therefore, is necessary to establish the validity of the psychological method of prediction for occupational success.

This research was confined to a limited number of measures operating in a limited field, but there is more room for future research in order to increase the number of variables, so that the whole of the abilities, temperament and interest may be taken into consideration.

One of the vital factors which needs immediate attention is the X factor. The supplementary component, which no doubt is composite and which was provisionally designated the X factor, indicates the probable influence of a number of subsidiary factors - such as home background, application, personality, interest, etc. These require more intensive study, and there seems no reason why it should not be possible to measure some of them objectively.

Since spatial ability is so important in the sphere of practical occupation, it is desirable to know much more about its psychological nature.

Another factor which is calling for futher investigation is the art factor. It is vital that the nature of this factor should be established, because art is at the very heart of human nature, yet in the clamour of the mechanical age, its significance is often forgotten.

If the results found in this experiment can be taken as pointers, the art factor may be of great value in predicting aptitudes which call for artistic ability. The importance of artistic ability was found to be most significant in Architectural Design. More research is needed to find out the part it plays in industrial design, in design draftsmanship, and in craftsmanship etc.

Research into the nature of the six Meier art factors or traits should be carried out by controlled experimental studies and factor analysis. A test similar to the Meier Art Judgement test should be devised to include the colour aspect of art appreciation.

An attempt should be made to devise tests of special ability, with the minimum g content, and future test constructors should make their tests the creative response type.

Genetic studies of the v,k, and art factors are needed to determine at what age they appear, and this knowledge would have direct influence on the whole system of education.

3. Technical Education in India.

India is the newest democracy in the world. And like all other modern societies, she is dependent for success on the intelligent participation of the masses of the people in her affairs, and on the development of progressive industries with happily placed individuals in occupations according to their individual differences in ability.

With the advent of freedom, the Indian Government has faced the gigantic problem of re-organizing the entire educational system of the country, according to her needs. The importance of Technical Education for the rapid economic and industrial development of India, has been fully recognized by the Central and State Governments. Several Technical Institutes have already been established, to provide proper educational facilities to the future technicians, architects and engineers. The India Institute of Technology at Kharagpur, established in 1951, has already 600 students. The India Institute of Science at Bangalore has been expanded, and the India School of Mining and Applied Geology at Dhunbad has increased facilities for training mining engineers. A directorate of the Marine Engineering College has been recently established at Calcutta. All other Engineering colleges have been given generous grants by the Government for expansion and improvement.

The All-India Council for Technical Education has made further progress in the matter of co-ordination and standardization of Technical Education in the country, and is also introducing technical education at secondary school level, according to the growing needs of the various industries of the country.

Authorities of Technical Institutes have been confronted with the same problem of selecting appropriate candidates as authorities in Great Britain. The usual practice has been to depend on the previous academic qualifications of the candidates, and on interviews. But as research in Great Britain has proved that this type of selection is not valid for Technical Education, perhaps it could be fruitfully supplemented by the methods of selection suggested in this research.

Since, however, the nature of the population in India is somewhat different to that in Great Britain, fresh research is needed in India to modify the selection methods suggested.

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APPENDIX-I

ITEM ANALYSIS

Block Test

Plan and Elevation Test

3 Dimensional Space Test

APPENDIX I

ITEM ANALYSIS

Item Analysis is an important step in Test Contruction, because validity of a test, depends to a great extent, upon the care with which the items in it have been chosen.

In this research, the item analysis of the three experimental tests - the Block, Plan and Elevation, and 3 Dimensional Space tests - was carried out by the Method of Upper and Lower Thirds*. For any practical purpose, it is generally accepted that this method is quite adequate. The main idea underlying the method is that the good item is one in which the superior testees do well, and the poor testees do badly.

The procedure of the Upper and Lower Thirds method is as follows:

1) Arrange the scripts in order of merit (criterion scores), highest scores at the top, lowest at the bottom.

2) Divide the scripts into three equal groups: upper (U), middle (M), and lower (L).

* Long and Sandiford "The Validation of Test Items" Univ. Toronto, Dept. of Educ. Res. 1935.
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3) Calculate the percentage of subjects in each group who answer a particular item successfully.

4) Find the difficulty (D) of the items by the formula:

$$D = 100 - \frac{U+M+L}{3}$$

5) Establish the validity (V) of the items by the formula: $V = U - L$

6) Plot each item on a graph paper, D on the x axis, V on the y axis.

According to this method, the greater the difference between U and L, the greater the validity of the item. The items which are answered correctly by approximately 50 per cent of the testees, are the most discriminating items. In choosing the items it should be bourne in mind that this technique of item analysis tends to favour items in the degree to which they approximate the 50 per cent difficulty level.

The Block test had 50 items in the draft stage, and was applied to a sample of 99 boys from a Modern School. The boys were 13 plus and each item was timed separately ($\frac{1}{2}$ minute). Forty items were selected for the final version.

In the Plan and Elevation test there were 81 items in the initial stage, out of which 50 were selected. The item analysis was based on the scores of 99 pupils from another Modern School. Enough time for the tests was allowed, so that nearly all the testees were able to attempt each item.

Similarly, in the 3 Dimensional Space test, there were 72 items in the original draft, and they were applied to 198 students at 17 plus, from a Technical Institute. Finally, 51 items were selected.

The results of the item analysis of the three tests are given in Tables A1, A2, A3, and in Figures A1,A2, A3.

Table A1.

Item Analysis: Block Tests.

Item	U	L	D	V	Item	U	L	D	V
1	64	39	48	25	26	88	15	53	73
2	76	18	56	58	27	88	30	38	58
3	94	41	33	53	28	38	8	79	30
4	76	25	45	41	29	50	12	73	38
5	56	18	61	38	30	83	15	55	68
6	70	47	42	23	31	12	0	95	12
7	94	65	18	29	32	30	12	83	18
8	59	30	60	29	33	47	6	78	41
9	100	62	18	38	34	82	9	63	73
10	90	75	16	25	35	75	9	59	66
11	79	44	38	35	36	70	30	61	40
12	100	79	41	21	37	59	15	66	34
13	100	71	11	29	38	88	38	35	50
14	83	21	44	63	39	30	0	85	30
15	63	21	55	42	40	75	15	53	60
16	100	83	9	17	41	30	3	87	27
17	97	82	13	15	42	50	15	72	35
18	94	56	27	38	43	83	27	47	66
19	92	41	34	51	44	82	9	59	73
20	66	44	43	22	45	47	12	70	25
21	88	56	26	32	46	29	12	84	17
22	100	63	15	37	47	29	6	84	23
23	73	40	47	33	48	9	0	93	0
24	83	47	32	36	49	9	0	93	0
25	91	59	20	32	50	47	0	80	47

Table A2

Item Analysis: Plan and Elevation Test.

	Item	U	L	D	V		Item	U	L	D	V
X1	1	100	100	0	0	X4	1	81	48	33	33
	2	96	78	10	18		2	81	24	48	57
	3	93	69	17	24		3	66	24	52	42
	4	90	45	25	45		4	90	57	31	33
	5	90	60	35	30		5	72	48	44	24
	6	81	75	24	6		6	75	27	50	48
	7	87	72	19	15		7	60	21	62	39
	8	75	60	29	15		8	54	27	63	24
	9	93	63	18	30		9	45	27	53	18
X2	1	54	6	67	48	X5	1	42	12	67	30
	2	51	0	75	51		2	54	15	64	39
	3	90	21	44	79		3	30	9	81	21
	4	66	3	70	63		4	39	6	80	33
	5	84	33	38	51		5	57	21	61	36
	6	87	42	59	45		6	63	15	58	48
	7	60	9	32	51		7	33	24	75	7
	8	87	42	31	45		8	63	30	56	33
	9	78	36	28	42		9	54	33	55	21
X3	1	87	24	37	44						
	2	78	21	50	57						
	3	75	6	62	69						
	4	84	18	40	46						
	5	81	48	35	33						
	6	60	6	68	54						
	7	57	21	68	36						
	8	90	39	30	51						
	9	57	12	66	35						

Table A2 (cont)

Item Analysis: Plan and Elevation Test.

Item		U	L	D	V	Item		U	L	D	V
Y1	1	100	100	0	0	Y3	1	76	45	34	31
	2	94	100	3	-6		2	95	76	18	18
	3	94	100	3	-6		3	82	27	46	55
	4	97	91	6	6		4	76	42	40	34
	5	69	18	60	51		5	57	3	72	54
	6	88	33	38	55		6	18	9	83	9
	7	70	27	54	43		7	73	24	57	39
	8	100	78	13	22		8	91	60	19	31
	9	79	30	44	49		9	30	12	80	18
Y2	1	91	52	32	40	Y4	1	15	15	87	0
	2	75	42	33	33		2	67	12	55	45
	3	70	24	46	46		3	42	15	75	27
	4	59	39	55	20		4	45	9	78	36
	5	88	45	41	43		5	39	12	16	27
	6	45	18	67	27		6	30	3	73	27
	7	42	12	72	30		7	27	9	83	18
	8	72	54	37	18		8	21	9	84	22
	9	6	6	94	0		9	15	6	89	9

Table A3

Item Analysis: 3 Dimensional Space Test.

Item	U	L	D	V	Item	U	L	D	V
X1 1	100	100	0	0	X4 1	47	15	63	32
2	100	100	0	0	2	30	5	75	25
3	95	96	5	-1	3	75	3	81	72
4	92	88	10	4	4	50	15	70	35
5	100	85	12	15	5	83	12	51	71
6	96	91	10	5	6	47	10	67	37
7	92	79	15	13	7	9	3	95	6
8	97	73	12	14	8	50	12	61	38
9	100	82	15	18	9	30	12	82	18
10	100	87	8	13	10	12	0	93	12
11	95	78	12	17	11	15	8	88	7
12	90	75	18	15	12	62	35	53	27
X2 1	65	78	-32	-13	X5 1	50	35	58	15
2	100	83	9	17	2	72	53	47	19
3	97	82	11	5	3	60	50	43	10
4	72	56	38	16	4	38	12	77	26
5	66	63	40	3	5	30	5	79	25
6	88	41	30	47	6	28	12	79	16
7	100	63	25	37	7	50	15	85	35
8	75	47	22	28	8	29	6	86	23
9	91	59	32	32	9	30	6	81	24
10	66	40	50	26	10	52	58	43	-6
11	94	56	36	38	11	75	15	57	50
12	97	56	27	41	12	69	24	82	45
X3 1	88	15	53	73	X6 1	13	5	88	8
2	50	18	50	32	2	29	5	62	24
3	85	8	40	77	3	42	9	73	33
4	38	10	72	28	4	50	15	72	35
5	65	20	63	45	5	38	5	80	33
6	75	25	43	50	6	10	0	95	10
7	70	60	33	10	7	10	0	94	10
8	72	58	37	14	8	45	5	78	40
9	33	0	85	33	9	30	9	82	21
10	38	6	82	32	10	6	0	97	6
11	50	12	71	38	11	6	0	97	6
12	45	18	67	27	12	0	0	100	0

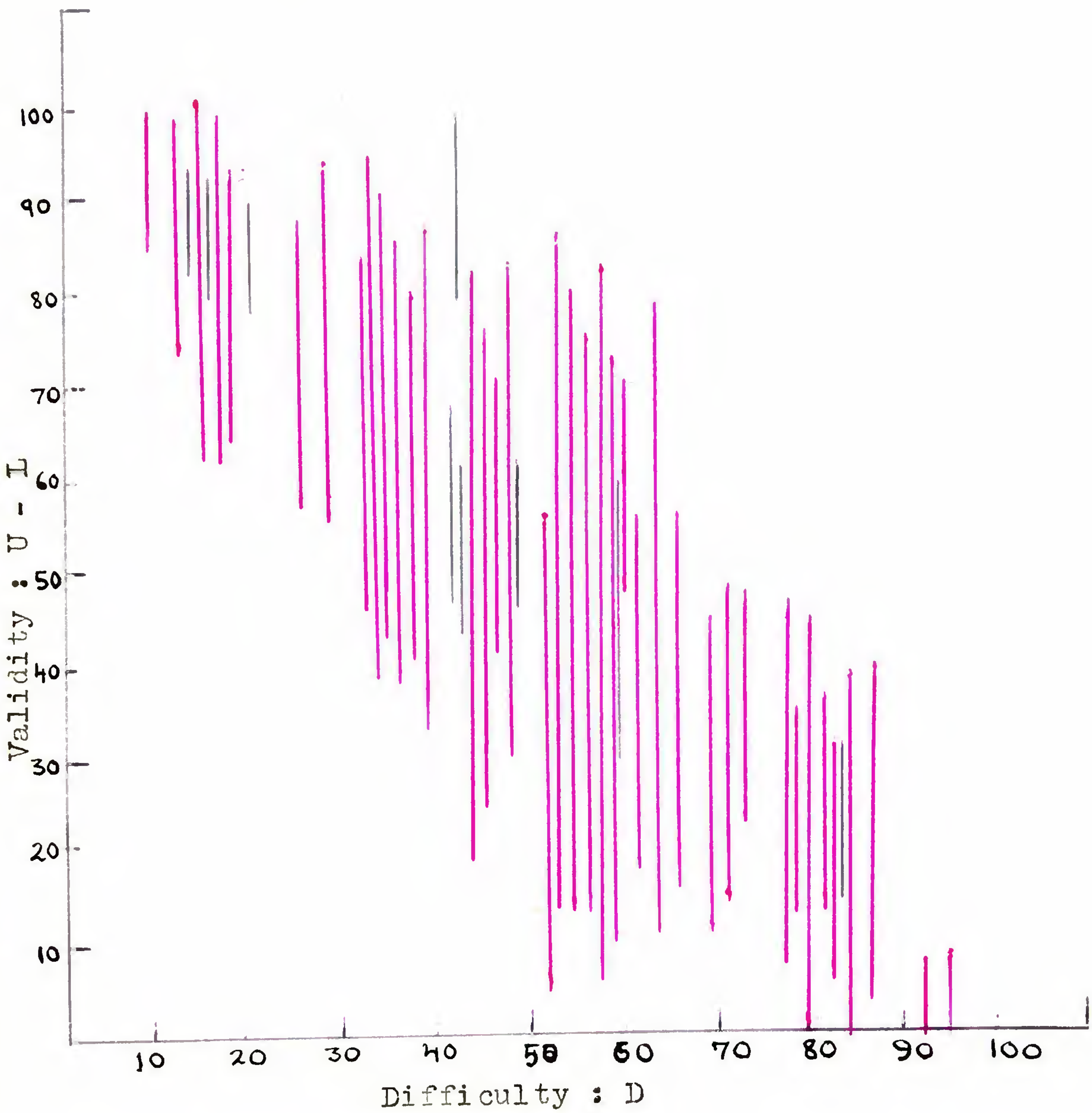


Fig A1

Item Analysis: Block Test

Items in red are selected and arranged according to difficulty.

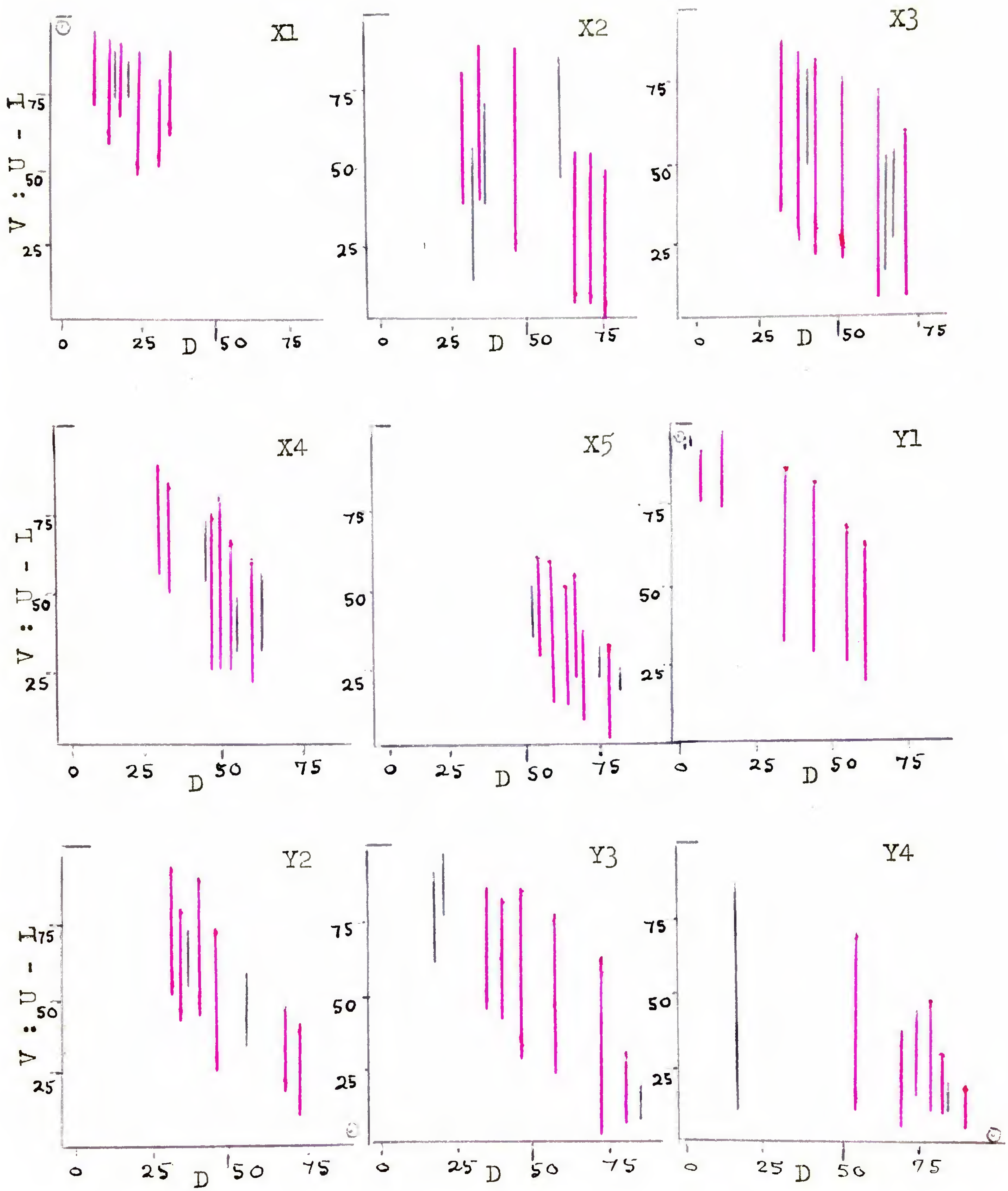


Fig A2 Item Analysis : Plan and Elevation Test

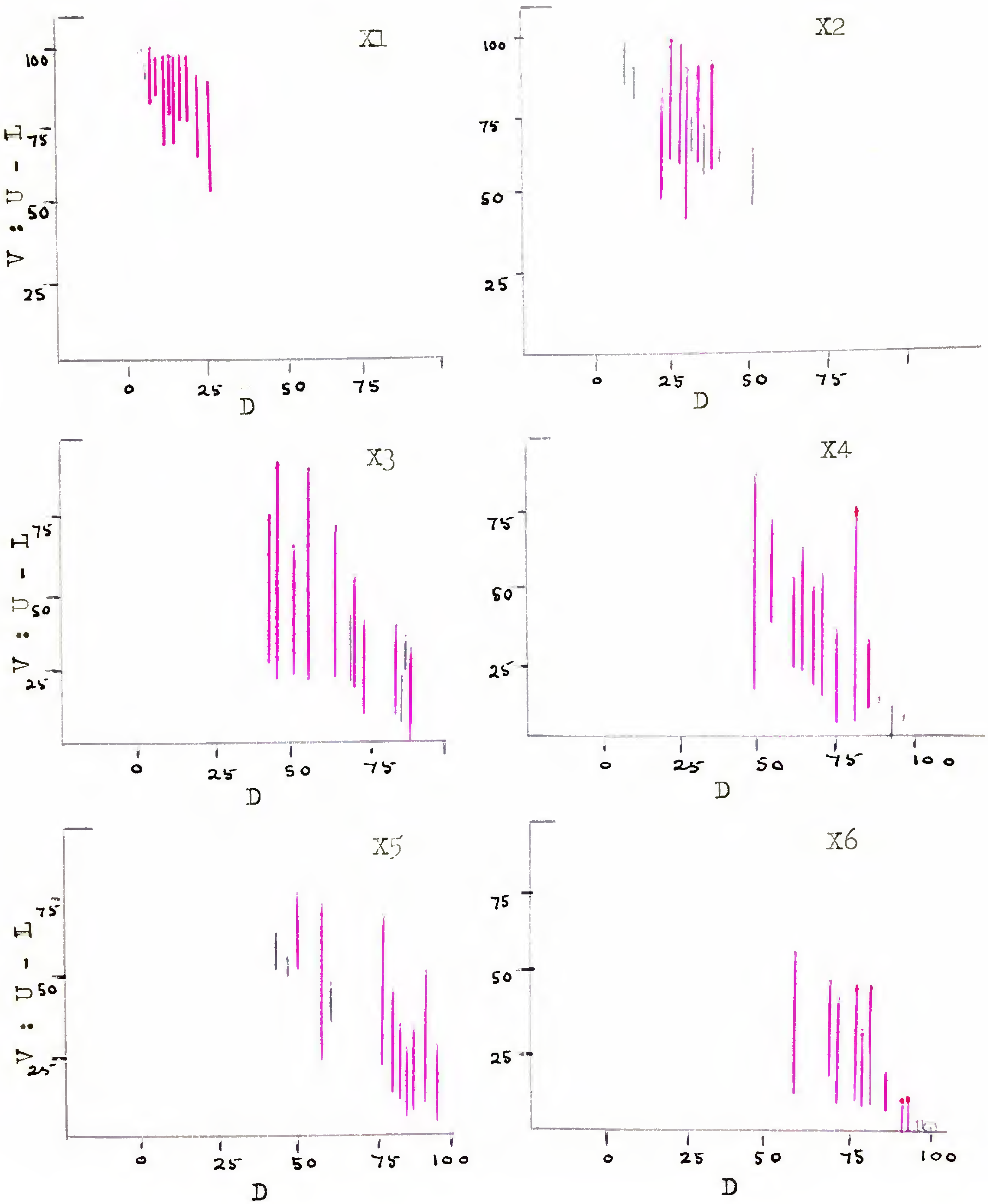


Fig A3. Item Analysis : 3 Dimensional Space Test.

APPENDIX II

SPECIMEN TEST ITEMS

V.S.14

T.S.8.

Plan and Elevation

3 Dimensional Space

Drawing Test

V.S.14

1. Items 29 - 31 of sub-test I
2. Items 15 & 16 of sub-test II
3. Example of a sub-test Y item

In each of the lines below, two of the words on the right mean the **same** as the word on the left. Find the two words and draw a line under each of them. Here is one that has been done for you:—

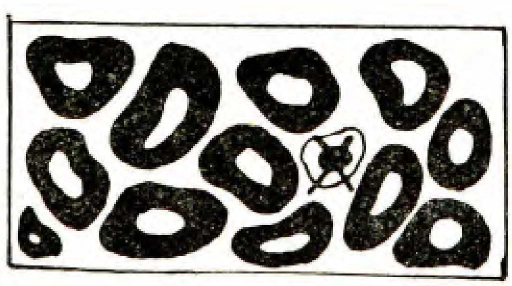
	drop	....	fall	cut	spot	water	strike
29.	**drill**	....	**exercise**	**play**	**work**	**bore**	**hole**
30.	**fine**	....	**beautiful**	**thin**	**coarse**	**silk**	**wicked**
31.	**beam**	....	**support**	**ray**	**bottom**	**lamp**	**head**

A shopkeeper has 90 customers to serve. He finds he hasn't enough bacon, cheese and eggs to give all his customers their share of each. Instead of reducing the ration, he gives some no bacon, the same number no eggs and the same number no cheese, so that everyone gets two of the three things.

15. **How many customers get no bacon?** ....

16. **How many customers get both bacon and cheese?** ....

There is a fault in each of the following patterns. You are to find this fault and mark it with a cross. Here is one which has been done for you:—



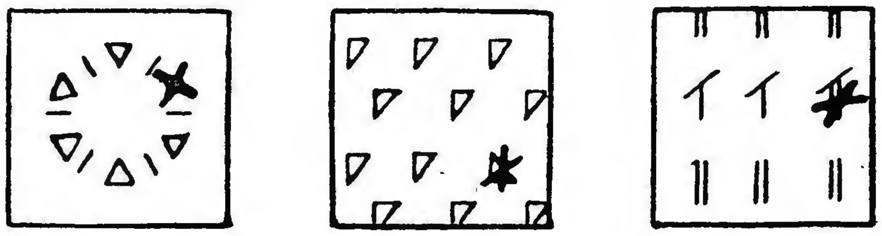
T.S.8.

(The Peel Group Test of Practical Ability)

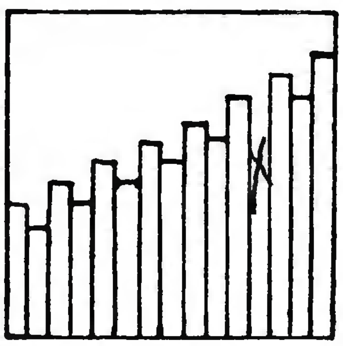
Items 1 - 7 of sub-test Y

There is a fault in each of the following patterns. You are to find this fault and mark it with a cross X. Take care to place the cross **exactly** on the wrong part. If you wish to change your X put a ring round it like this (x) It will then not be counted.

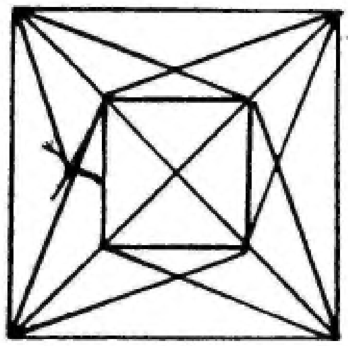
Here are three patterns which have been done for you.



NOW DO THESE :-



1



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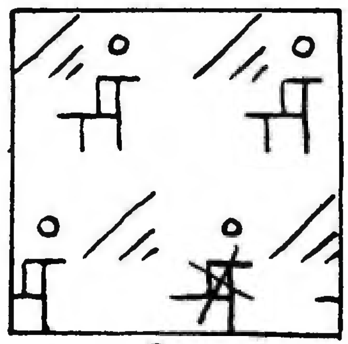

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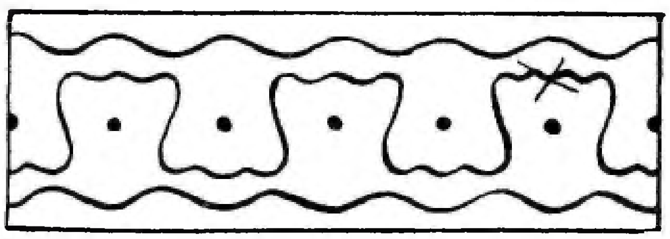
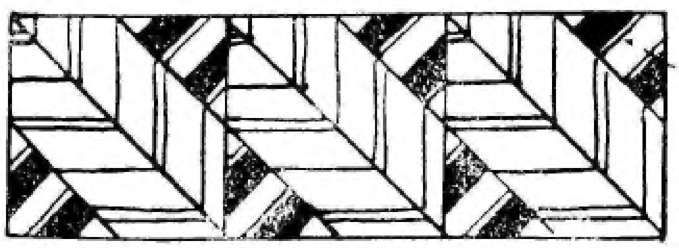
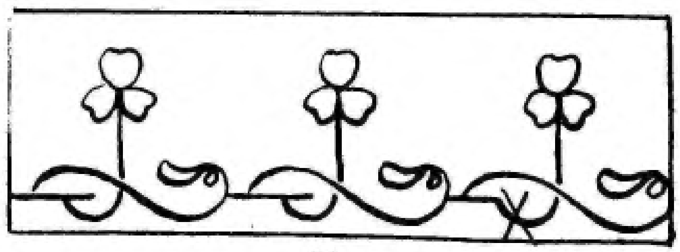


4

5



6



7

RICHARDS . Gerald John
FORM E.1.
26.5.38   13 yrs. 5 mths.

T. S. 8

(TIME : 30 MINUTES)

E. A. PEEL

University of Durham.

Answer as many as possible of the exercises in this book.

You will not have time to do them all, and every so many minutes you will be told to stop and go on to the next page

Be sure to stop whenever you are told.

You need not ask any questions because on each page you are told what do to.

Most of the exercises are easy ; but a few are quite hard.

Waste no time ; but keep on steadily until you are told to stop.

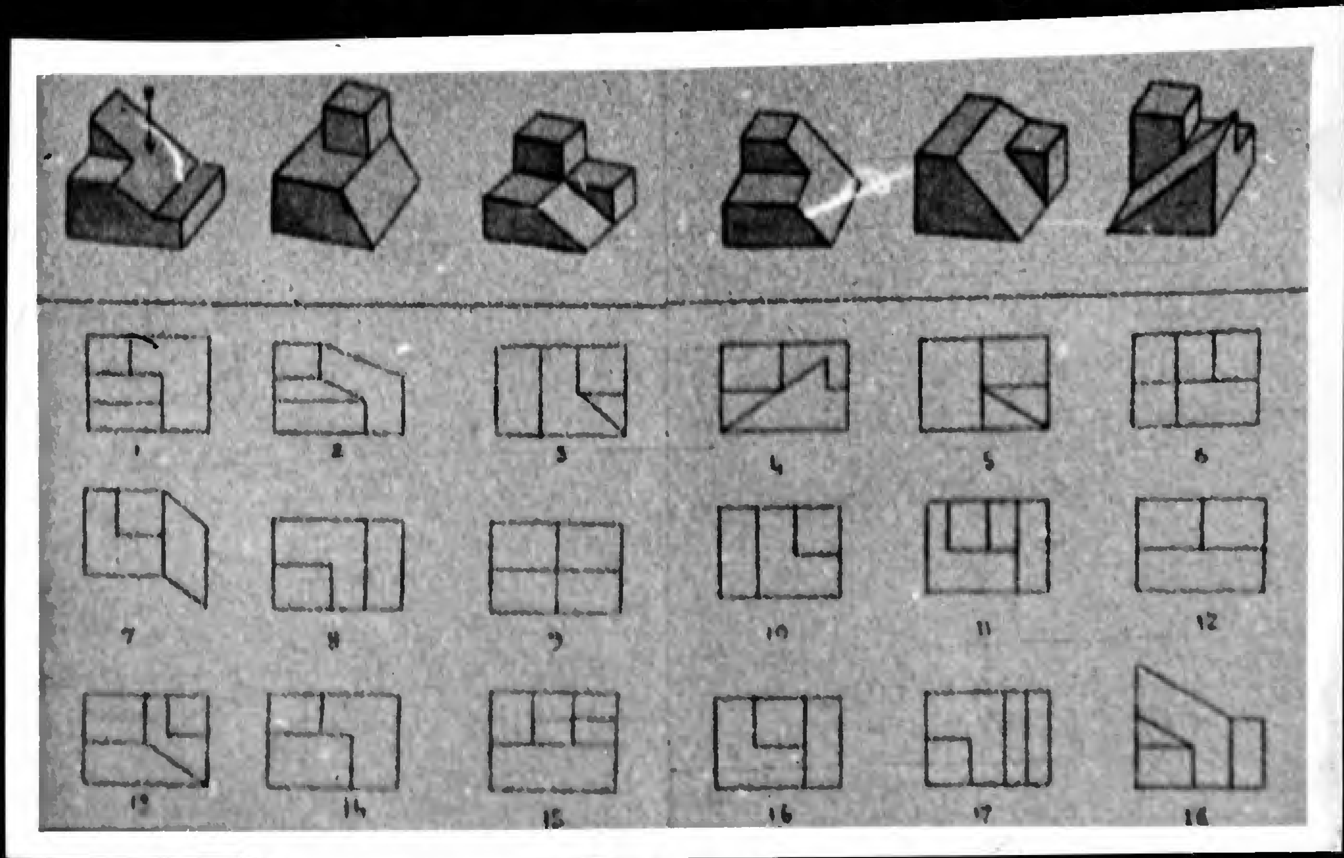
Score.	
X	15
Y	14
Z	14
TOTAL ...	43

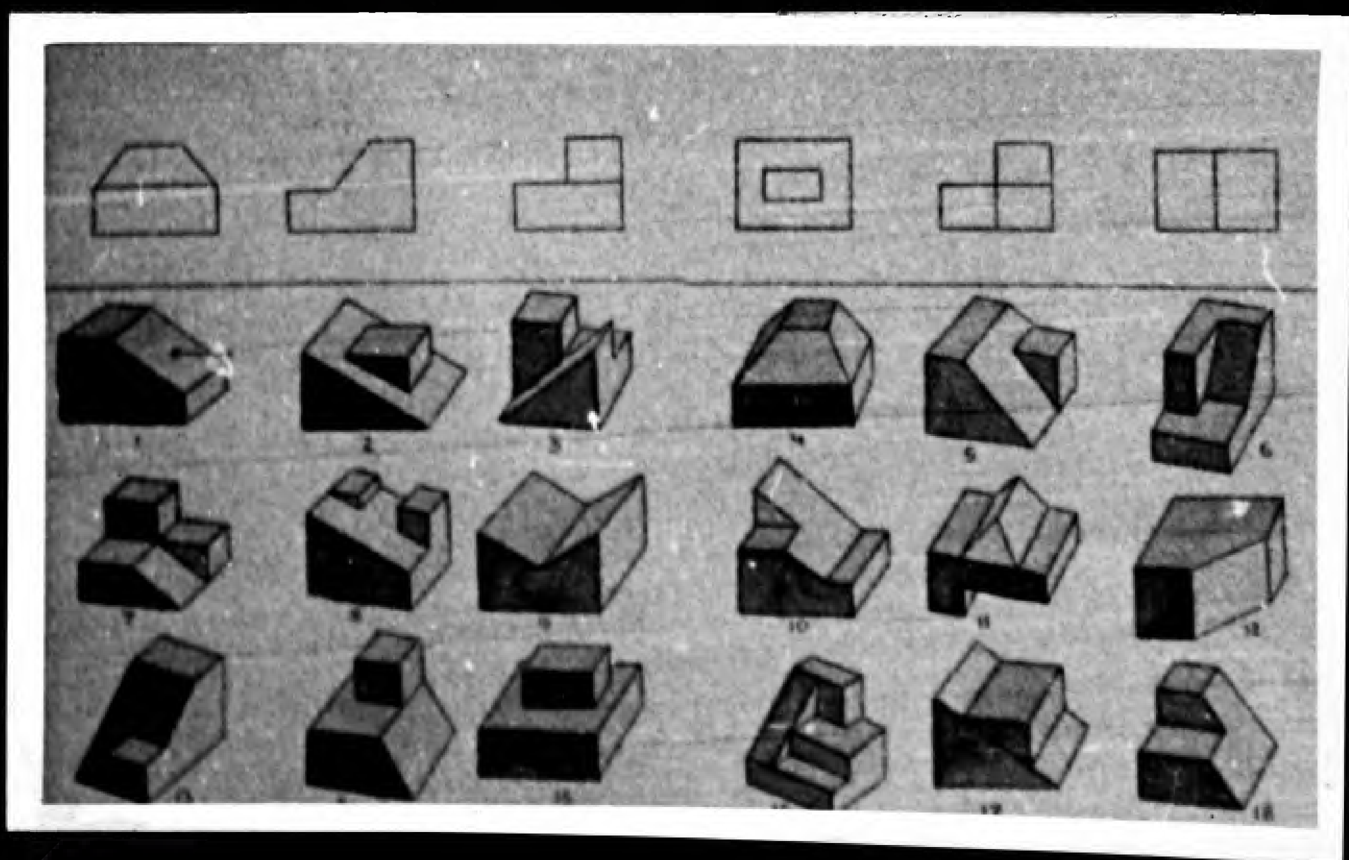
ASK NO QUESTIONS.

PLAN AND ELEVATION TEST

1. Sub-test X2 (Photo)

2. Sub-test Y2 "

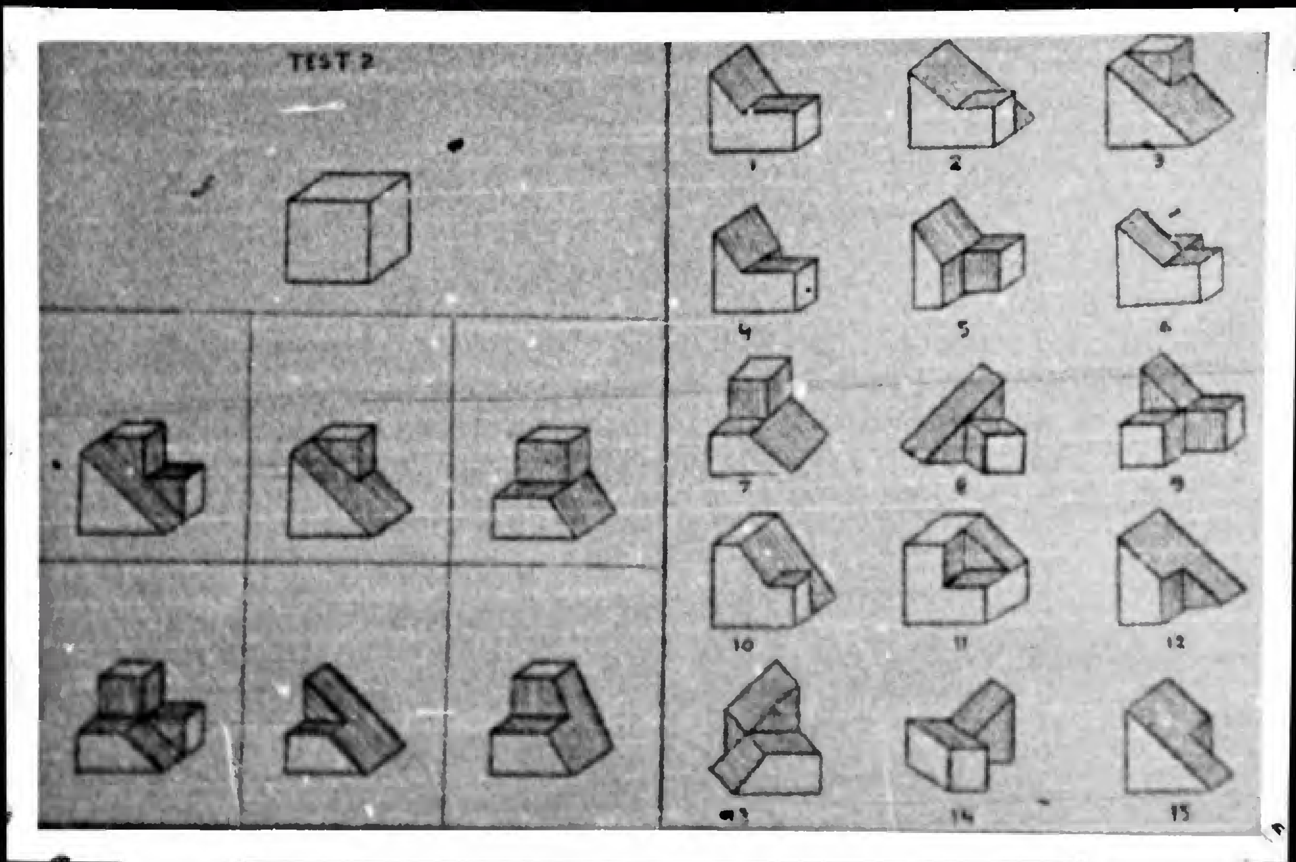




3 DIMENSIONAL SPACE TEST

Sub-test X2

(Photo)


TEST 2
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DRAWING TEST

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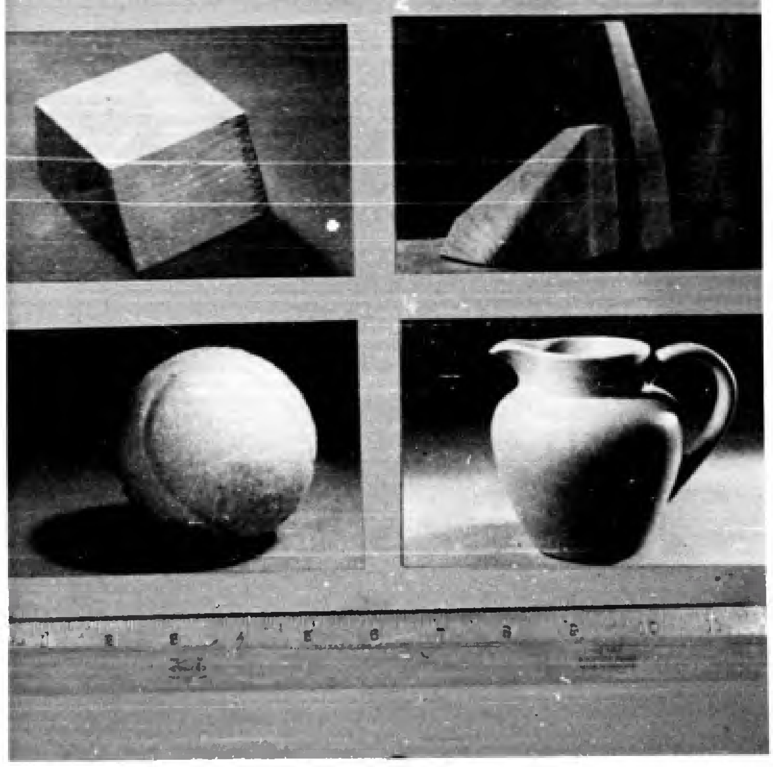
DRAWING TEST



APPENDIX III

RESIDUAL CORRELATIONS: CENTROID ANALYSIS.

School of Architecture

Technical Institute

Technical School: Engineering Dept.

Technical School: Building Dept.

APPENDIX IV

GROUP FACTOR ANALYSIS.

Basic Factor Calculation

Residual Correlations

TABLE A4

FIRST FACTOR RESIDUALS : CENTROID ANALYSIS.

Scheel ef Architecture.

	A.D.	S.S.	B.S.	B.C.	Otis	V-14	Mat.	S-14	F.R.	P&E.	3D.S	Draw	A.J.
A.D.													
S.S.	-1674												
B.S.	-0445	1996											
B.C.	1060	1204	1712										
Otis	-2326	-0215	0486	-1566									
V-14	-1372	1002	0278	-1648	3486								
Mat.	-1081	1164	0838	-1761	-0753	-0197							
S-14	-0349	-0309	-1079	-1554	0759	2180	-0424						
F.R.	-1746	-0096	0186	-0104	-0019	-0198	0163	0285					
P&E	0149	0224	-2074	0273	-1615	-1731	0011	0040	-0663				
3D.S	-0337	-0111	-0365	0155	-2004	-1985	0150	0223	0379	2355			
Draw	3306	-2160	-0908	2380	-0067	-0542	-0742	-1140	-1075	-1309	-1285		
A.J.	3478	-1586	-1518	-1201	0066	-2104	0455	-0647	-0160	1307	0125	-0183	
Blck	-1313	-1333	-1207	-0869	0479	-0841	0928	1406	1395	0550	0529	-0072	-2069

(Decimal peints emitted)

TABLE A5

SECOND FACTOR RESIDUALS : CENTROID ANALYSIS.

School of Architecture.

	A.D.	S.S.	B.S.	B.C.	Otis	V-14	Mat.	S-14	F.R.	P&E.	3D.S	Draw	A.J.
A.D.													
S.S.	0743												
B.S.	-0360	1426											
B.C.	0666	-1483	-1954										
Otis	0663	-1393	-0533	1056									
V-14	-0976	-0661	-1161	0943	0515								
Mat.	-0948	-1070	-0757	-1721	0921	0434							
S-14	-0111	-0635	-1361	1461	0177	1358	0470						
F.R.	-1712	0120	-0165	-0094	0062	0259	0160	-0273					
P&E.	-0950	-1002	1401	-0093	0225	-0232	0122	-0245	-0635				
3D.S	-1243	-0530	-0190	-0117	0858	0367	0241	-0540	0402	1598			
Draw	2280	1433	0279	2072	-1232	-1292	-0638	0781	-1048	-2167	-1991		
A.J.	2244	0712	0762	-1571	-1610	-0100	0580	0215	-0128	0276	-0725	-1146	
Blck	-1636	1108	1027	-0965	-0882	0272	0960	-1517	1403	0284	0310	-0320	-2368

(Decimal points omitted)

TABLE A6

THIRD FACTOR RESIDUALS : CENTROID ANALYSIS.

School of Architecture.

	A.D.	S.S.	B.S.	B.C.	Otis	V-14	Mat.	S-14	F.R.	P&E.	3D.S	Draw	A.J.
A.D.													
S.S.	0113												
B.S.	-0273	1478											
B.C.	0073	-1837	-1905										
Otis	-0957	1218	0577	-1221									
V-14	0645	0469	1188	-1124	0425								
Mat.	-0134	0425	0486	1113	0620	0104							
S-14	-0235	-0709	-1351	1346	-0211	-1396	-0597						
F.R.	0976	-0559	0226	-0319	-0142	0026	-0594	0187					
P&E.	0199	0554	-1339	-0329	0016	-0461	-0647	0337	-1158				
3D.S	0174	-0108	0278	-0484	0561	0041	-0855	0414	-0343	0838			
Draw	-0001	0072	0467	0791	0598	0596	-1699	0513	-0541	0545	-0319		
A.J.	-1964	-0545	-785	1728	-1532	-0015	0867	-0182	0067	0475	-0442	1750	
Blck	1097	-1427	-0983	0665	-1031	0109	0412	1454	1031	-0096	-0231	-0835	-2226

(Decimal points omitted)

Table A7

FIRST FACTOR RESIDUALS: CENTROID ANALYSIS.

Technical Institute

	E.D.	Math	G.S.	Otis	V-14	Mat.	S-14	F.R.	P&E.	3D.S	Draw	M.AJ
E.D.												
Math	2156											
G.S.	0850	3052										
Otis	-1683	-0532	0478									
V-14	-1825	-0779	0379	3863								
Mat.	-0799	0380	1142	0330	0716							
S-14	-0557	-0890	-1671	-1510	0613	0657						
F.R.	-0410	-1368	-1484	-1152	-1489	-0535	1315					
P&E.	0996	-0659	-0945	-0405	-2824	-0651	0792	0677				
3D.S	-0080	-0801	-1561	-0309	-0831	-0674	0245	1525	0630			
Draw	0545	0322	-0709	-1409	-1848	-0722	-1280	1147	-0034	0129		
M.AJ	-0311	-1641	-1103	-0081	1040	-0616	-0062	-0820	1016	-1018	1196	
Blck	-0838	-2144	-1624	-0946	-1312	-0381	1212	0984	0978	1306	0882	0148

(Decimal points omitted)

Table A 8

SECOND FACTOR RESIDUALS : CENTROID ANALYSIS.

Technical Institute

	E.D.	Math	G.S.	Otis	V-14	Mat.	S-14	F.R.	P&E.	3D.S	Draw	A.J.
E.D.												
Math	2081											
G.S.	-1291	-3093										
Otis	0510	0421	-0178									
V-14	-0143	0591	-0733	0907								
Mat.	0182	-0438	0797	-0587	-0838							
S-14	0710	0920	-1585	-1283	0999	0777						
F.R.	-1160	-1440	1059	0023	-0425	-0059	-1168					
P&E.	0446	-0711	0638	-0412	1439	0221	-0685	0148				
3D.S	-0836	-0873	1138	-0815	-1075	0083	-0098	0797	0103			
Draw	-0325	0240	0222	0115	-0345	0042	1449	0309	-0640	-0705		
A.J.	0050	1616	-1249	-0469	0383	-0820	-0011	0569	-1198	0768	-1483	
Blck	-1367	-2194	1328	0159	-0022	-0033	-1109	0475	0609	0799	-0298	-0323

(Decimal points omitted)

Table A9

THIRD FACTOR RESIDUALS: CENTROID ANALYSIS.

Technical Institute.

	E.D.	Math	G.S.	Otis	V-14	Mat.	S-14	F.R.	P&E.	3D.S	Draw	A.J.
E.D.												
Math	0536											
G.S.	-0104	0062										
Otis	0191	-0273	-0449									
V-14	-0455	-0043	0160	0776								
Mat.	0478	-0206	0215	0454	0716							
S-14	0026	-0566	0243	-1590	0718	-1062						
F.R.	0578	0176	-0083	-0284	0186	-0386	0609					
P&E.	-0757	0036	0028	0272	-1566	0091	0386	-0106				
3D.S	0195	-0520	-0120	0527	0812	-0184	-0519	0273	-0177			
Draw	-0409	0058	-0386	0077	-0379	-0077	1368	-0377	0603	0629		
A.J.	-0347	0753	0469	-0648	0220	0659	-0393	-0894	1024	-1126	-1530	
Blck	0563	0447	-0250	-0520	-0308	-0368	0335	-0183	0258	0074	-0393	-0126

(Decimal points ommited)

Table A 10

FIRST FACTOR RESIDUALS: CENTROID ANALYSIS

Technical School, Engineering Dept.

	E.D.	M.W.	W.W.	Geom	Otis	Mat.	MH.S	F.R.	TS.8	P&E.	Draw	M.AJ
E.D.												
M.W.	0864											
W.W.	1289	1989										
Geom	1751	0419	0866									
Otis	-0499	-0763	-0471	0371								
Mat.	-1073	0405	-1579	-0505	-0388							
MH.S	-0911	-0078	-1464	-0109	-0002	0160						
F.R.	0133	-0717	-0373	-1680	-0166	-0377	0485					
TS.8	-1430	-1598	-1323	-0702	0618	0248	0875	1357				
P&E.	0293	-0647	-0270	-0484	-0028	0916	0196	-0219	-0504			
Draw	0379	-0251	-0268	0517	-0980	0026	-0559	1115	0057	-0638		
M.AJ	-2020	-0199	-0867	-1279	0820	0423	-0123	-0898	1747	-0142	-0445	
Blck	-0721	-0869	-0009	-0714	0235	-0162	0571	-0020	-0917	0833	0082	0390

Table A 11

SECOND FACTOR RESIDUALS: CENTROID ANALYSIS

Technical School, Engineering Dept.

	E.D.	M.W.	W.W.	Geom	Otis	Mat.	MH.S	F.R.	TS.8	P&E	Draw	M.AJ
E.D.												
M.W.	-0482											
W.W.	-0433	0530										
Geom	0486	-0653	-0504									
Otis	0168	0483	0113	-0634								
Mat.	0374	-0997	0822	-0051	-0533							
MH.S	0151	-0566	0640	-0596	-0160	-0174						
F.R.	-0888	0077	-0445	1079	-0320	-0709	0124					
TS.8	0042	0422	-0180	-0403	0329	-0362	0212	0698				
P&E.	-0622	0368	-0086	0222	-0096	0771	-0039	-0375	-0791			
Draw	-0298	0320	0356	-0452	-0963	0062	-0520	1154	0128	-0621		
M.AJ	0919	-0734	-0326	0403	0594	-0061	-0649	-1421	0786	-0360	-0389	
Blck	0149	0384	-0611	0259	0116	-0413	0297	-0292	-1417	0715	0111	-0006

(Decimal points ommitted)

Table A 12

FIRST FACTOR RESIDUALS: CENTROID ANALYSIS

Technical School, Building Dept.

	B.C.	C.J.	Geom	Otis	Mat.	MH.S	F.R.	TS.8	P&E.	Draw	M.AJ
B.C.											
C.J.	0503										
Geom	1806	-0231									
Otis	-0692	-1275	0675								
Mat.	0116	-1885	-0023	0302							
MH.S	-0789	0793	-0854	0043	0104						
F.R.	0240	0725	-0692	-0261	0197	-0200					
TS.8	-1206	-0734	-0749	-0677	0640	-0015	0396				
P&E.	-0684	-0150	0136	-0068	-1006	0778	-0263	-0143			
Draw	0019	-0230	0104	-1281	0988	-0509	-0010	0025	-0227		
M.AJ	-0315	0138	-0452	1664	0283	-1191	-0217	0913	0371	-1013	
Blck	-0807	0690	-1523	-0360	-0814	1159	-0361	0830	0383	0570	-1785

Table A.13

SECOND FACTOR RESIDUALS: CENTROID ANALYSIS

Technical School, Building Dept.

	B.C.	C.J.	Geom	Otis	Mat.	MH.S	F.R.	TS.8	P&E.	Draw	M.AJ
B.C.											
C.J.	-0933										
Geom	1144	-0221									
Otis	-1461	0750	-0134								
Mat.	-0303	1599	-0464	-0210							
MH.S	0176	0375	0210	-0791	-0512						
F.R.	0301	-0683	-0628	-0186	0238	0260					
TS.8	1061	-0832	0597	0500	-0736	-0156	-0382				
P&E.	0362	-0369	-0474	-0325	0792	0465	0294	-0217			
Draw	-0273	-0403	-0371	0971	-1157	-0756	0035	-0033	-0357		
M.AJ	-0860	-0510	-1025	0998	-0080	0660	-0164	-1038	-0650	0793	
Blck	-0393	-0129	0261	-1106	0015	-0009	0478	0554	-0230	0086	0745

Table A.14

Basic Factor Calculation: Group Factor Analysis

School of Architecture

	Mat.	S-14	F.R.	P&E.	3D.S	Blck	Sum	S.S.	B.S.	Otis	V-14	Sum	A.D.	B.C.	M.AJ	Draw	Sum
Mat.								.327	.285	.135	.171	.918	.117	.032	.197	.093	.439
S-14								.281	.189	.387	.500	1.357	.298	.152	.158	.132	.740
F.R.								.158	.179	.166	.132	.635	.005	.155	.104	.025	.289
P&E.								.279	.037	.094	.059	.469	.289	.276	.314	.071	.950
3D.S								.259	.221	.069	.046	.595	.255	.282	.206	.085	.828
Blck								.068	.071	.249	.098	.486	.084	.112	-.063	.152	.285
Sum								1.372	.982	1.100	1.006	4.460	1.048	1.009	.916	.558	3.531
S.S.	.327	.281	.158	.279	.259	.068	1.372						.069	.338		-.041	.366
B.S.	.285	.189	.179	.037	.221	.071	.982						.181	.379	-.001	.076	.635
Otis	.135	.387	.166	.094	.069	.249	1.100						.003	.061	.164	.166	.396
V-14	.171	.500	.132	.059	.046	.098	1.006						.077	.032	-.067	.104	.146
Sum	.918	1.357	.635	.469	.595	.486	4.460						.330	.810	.096	.307	1.543
A.D.	.117	.298	.005	.289	.225	.084	1.048	.069	.181	.003	.077	.330					
B.C.	.032	.152	.155	.276	.282	.112	1.009	.338	.379	.061	.032	.810					
M.AJ	.197	.158	.104	.314	.206	-.063	.916		-.001	.164	-.067	.096					
Draw	.093	.132	.025	.071	.085	.152	.558	-.041	.076	.166	.104	.307					
Sum	.439	.740	.289	.950	.828	.285	3.531	.366	.635	.396	.146	1.543					
G.T.	1.357	2.097	.924	1.419	1.423	.771	7.991	1.738	1.617	1.496	1.152	6.503	1.378	1.819	1.012	.865	5.074
Div.	2.5014							4.2999					4.5908				
Load	.5425	.8383	.3654	.5673	.5689	.3082		.4042	.3761	.3479	.2679		.3002	.3962	.2204	.1884	

Table A15

Basic Factor Calculation: Group Factor Analysis.

Technical Institute

	S-14	F.R.	P&E.	3D.S	Blck	Draw	Sum	Otis	V-14	Mat.	M.AJ	Sum	T.D.	Math	G.S.	Sum
S-14								.224	.376	.450	.277	1.327	.349	.294	.199	.842
F.R.								.239	.149	.310	.186	.884	.341	.225	.198	.764
P&E.								.363	.056	.349	.172	.940	.535	.349	.299	1.181
3D.S								.331	.221	.304	.259	1.115	.383	.290	.197	.870
Blck								.230	.140	.294	.259	.923	.265	.116	.153	.534
Draw								.142	.053	.218	.333	.746	.360	.321	.205	.888
Sum								1.529	.995	1.925	1.486	5.935	2.233	1.593	1.251	5.077
Otis	.244	.239	.363	.331	.230	.142	1.529						.175	.272	.358	.825
V-14	.376	.149	.056	.221	.140	.053	.995						.106	.195	.298	.599
Mat.	.450	.310	.349	.304	.294	.218	1.925						.272	.372	.433	1.077
M.AJ	.277	.186	.172	.259	.259	.333	1.486						.228	.081	.124	.433
Sum	1.327	.884	.940	1.115	.923	.746	5.935						.781	.920	1.213	2.914
T.D.	.349	.341	.535	.383	.265	.360	2.233	.175	.106	.272	.228	.781				
Math	.294	.225	.347	.290	.116	.321	1.593	.272	.195	.372	.081	.920				
G.S.	.199	.198	.299	.197	.153	.205	1.251	.358	.298	.423	.124	1.213				
Sum	.842	.764	1.181	.870	.534	.886	5.077	.805	.599	1.077	.433	2.914				
G.T.	2.169	1.648	2.121	1.985	1.457	1.632	11.012	2.334	1.594	3.002	1.919	8.849	3.014	2.513	2.464	7.991
Div.	3.4246							4.7944					5.0612			
Load	.6334	.4812	.6193	.5796	.4255	.4766		.4868	.3325	.6261	.3982		.5955	.4965	.8468	

Table A.16

RESIDUAL CORRELATIONS: GROUP FACTOR ANALYSIS

School of Architecture

	Mat.	S-14	F.R.	P&E.	3D.S	Blck	S.S.	B.S.	Otis	V-14	A.D.	B.C.	A.J.	Draw
Mat.														
S-14														
F.R.														
P&E.														
3D.S			0353	2259										
Blck	1180	1664	1801	1138	1240									
S.S.	0177	-0578	0103	0497	0291	-0566								
B.S.	0810	-1263	0416	-1764	0070	-0449	2486							
Otis	-0537	0954	0389	-1034	-1289	1418	0584	1278						
V-14	0257	2754	0341	-0930	-1064	0154	1919	1175	4549					
A.D.	-0459	0464	-1047	1187	0842	-0085	-0523	0681	-1014	-0034				
B.C.	-1829	-1801	0102	0512	0566	-0100	1779	2300	-0768	-0741	2200			
A.J.	0774	-0268	0235	1890	0806	-1309	-0891	-0839	0873	-1260	4507			
Draw	-0092	0257	-0438	-0359	-0222	0939	-1172	0051	1025	0535	4606	3356	0652	

Table A.17

RESIDUAL CORRELATIONS: GROUP FACTOR ANALYSIS

Technical Institute

	S-14	F.R.	P&E.	3D.S	Blck	Draw	Otis	V-14	Mat.	A.J.	E.D.	Math	G.S.
S-14													
F.R.	2443												
P&E.	1627	2200											
3D.S	0839	2771	1641										
Blck	2325	2542	2445	2524									
Draw		2007	0265	0588	1732								
Otis	-0843	0048	0615	0489	0229	-0900							
V-14	1654	-0109	-1499	0283	-0015	-1055	1619						
Mat.	0534	0087	-0387	-0588	0276	-0804	3048	2082					
A.J.	0248	-0056	-0746	0282	0896	1432	1938	1324	2493				
E.D.	-0282	0544	1662	0378	0116	0762	-1149	-0920	-1008	-0091			
Math	-0205	-0139	0395	0022	-0953	0844	0303	0299	0611	-1167	2705		
G.S.	-1093	-0362	-0025	-0851	-0541	-0270	1210	1361	1282	-0698	1296	3806	