AN EXPLORATORY INVESTIGATION OF THE PROCESSES INVOLVED IN THE COMPLETION OF RAVEN'S PROGRESSIVE MATRICES (1938)

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by

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CHAPTER I

INTRODUCTION

The Progressive Matrices test was designed to measure intellectual functioning within the context of Spearman's concept of "g" (Burke, 1958). It purports to be a quantitative measure of eduction: the test's author, J.C. Raven, has described it has a test of "innate eductive ability" (Raven, 1940). Essentially, the test grew out of the reaction against the empirically composed heterogeneous tests as developed by Binet and his American followers (Westby, 1953).

The first intimation of the matrices test was given by Penrose and Raven (1936), and it was further described by Raven (1939, 1940). The test was finally standardized in 1941 (Raven, 1941). This standard series of the test has become known as "Progressive Matrices (1938)".

Progressive Matrices (1938) is a series of sixty visually presented "matrices" or patterns. Each matrix is a network of logical relations between simple and more complex visual forms. From each matrix, a part has been removed. The testee has to examine the matrix, and then choose from the multiple choice options (below each design) the design or design-part which best completes the matrix. The sixty matrices are grouped into five sets of twelve problems each. The aim of the test designer was to produce five sets of items progressively graded in difficulty both between and within sets (Westby, 1953). Each set has a theme to be educed by the subject. Set A requires chiefly accuracy of discrimination - all that is required is for subjects to complete a pattern. The later sets are more difficult, involving: analogies between parts of figures; progressive alterations in patterns; systematic permutations; and the systematic resolution of figures into parts.

It is clear from Raven's writings that he considered Spearman's laws of eduction or neogenesis to be of fundamental importance (Spearman, 1927). On the basis of these laws, Raven (1940) argues

> "Perceptual tests ... may appear useless artistic stunts or obscure mathematical problems, but upon investigation success in solving them is found to depend upon the ability for logical thought which is the essential factor in all intelligent conduct. Progressive Matrices is a series of such tests designed to measure the accuracy of eduction."

In the Progressive Matrices manual (Raven, 1960) the test is described as follows:

> "Progressive Matrices (1938) is a non-verbal test of a person's capacity at the time of the test to apprehend figures presented for his perception, to see relations between them, and to conceive the nature of the figure completing each system of relations presented."

Each of these ideas corresponds exactly to Spearman's principles, respectively: the principle of experience;

the eduction of relations; and the eduction of correlates.

In fact, however, what is actually measured by Progressive Matrices (1938) is not easily settled (Burke, 1958). Raven himself variously describes the test as being "a means of estimating a person's innate eductive ability" (1940), as a "test of a person's present capacity to form comparisons, reason by analogy, and to develop a logical method of thinking, regardless of previously acquired information" (1948), as designed to measure "accuracy of eduction" (1940), and as a means of assessing a "person's output of intellectual activity" (1947). Eventually, in fact, the test is offered as a test of general intelligence, which Raven defines as "the ability to reason by analogy from awareness of relations between experienced characters." (1960).

As outlined above, the strategy of the Progressive Matrices test was to measure "g" via various forms of "perceptual reasoning". Spearman (1946) considered Progressive Matrices (1938) as a test for measuring "g" or eduction, in fact, perhaps the best of all non verbal tests of "g". This has been a general English opinion e.g. Vernon (1947), Vincent (1952). Westby (1953) states that factor analysis in the services suggests that the test is an almost pure "g" test, with a small loading of some spatial perceptual factor. However, Burke (1958) after viewing many relevant investigations, states that the evidence is not convincing that Progressive Matrices (1938) has validity as a pure measure of the Spearman construct of "g".

A lot of work has been done bearing on the content validity, the construct validity and the reliability of the Progressive Matrices (1938) e.g. Barrett (1956), Burke et al. (1969), Desai (1952), Desai (1955), Eysenck (1944), M. Eysenck (1945), McLeod and Rubin (1962), Shaw (1967), Sinha (1951) and others. Comparatively, although Raven's Progressive Matrices (1938) has been an extremely widely used test, very few studies have attempted to gain knowledge of the internal dynamics of the test.

What follows is a summary of the work done by a group of researchers who have recently been investigating the reasoning errors on Raven's Progressive Matrices (1938).

Raven's Progressive Matrices (1938) was designed to measure the ability to form comparisons and reason by analogy, thereby providing an index of intellectual functioning. (Raven, 1960). It has been suggested (Fracchia, 1969) that a relationship exists between type or degree of mental illness and disturbances in abstract processes, such as concept formation, comparative reasoning, and analogic reasoning. The Progressive Matrices (1938) was not primarily designed to assess the ideational effects of mental disturbance upon complex reasoning ability, but it has been utilized in that capacity.

Kasper (1958), using Raven's suggested method of deviations from expected set scores as an index(1), reported a failure to show the efficiency of the test in discriminating the influence of neurotic or characterological pathology.

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(1) Raven (1954) suggested that two points or more deviation between expected and actual scores in any of the five sets of twelve items each possessed "psychological significance"

Jurjevich (1967) investigated what he called "avoidable errors" on Progressive Matrices (1938). No significant relationship was found between the incidence of avoidable errors and the degree of neurotic or character disturbance as measured by the M.M.P.I.

Sheppard, Fiorentino, Collins, and Merlis (1968, 1969) used a different approach in an attempt to identify performance errors on Progressive Matrices (1938). They criticize Jurjevich in that M.M.P.I. scales were used singly as measures of disturbance, and because the scoring system utilized defined all errors as avoidable, regardless of the patients' ability to solve the items.

Sheppard et al. (1968) tested the item structure of Progressive Matrices, and found that the integrity of the sets was maintained with regard to increasing difficulty. (Other studies have reported similar findings, Halstead, 1943; Rimoldi, 1947; Kier, 1949). On the basis of these findings, Sheppard et al. suggested that an error be scored as "avoidable" if the patient failed an item, and them solved other items of greater difficulty -"...thus showing that he did have the reasoning ability to solve the easier item" (1968).

In an investigation by this group (Sheppard et al. 1968) it was hypothesized that schizotypic patients would be less regular and make more avoidable errors than sociopathic patients. Patients were so classified on the basis of M.M.P.I. profiles.(1) The hypothesis was supported, the performance of schizotypic patients being found to be more erratic - they made significantly more avoidable errors - than the sociopathic patients.

In a recent study, the same authors (Sheppard et al.,1969) examined the performance of three additional groupings of patients. Again, patients were defined by M.M.P.I. patterns, and termed "secondary sociopathic", "paranoid", and "schizophrenic mixed".(2) Tests of significant t demonstrated that paranoid patients committed more avoidable errors than the secondary sociopathic and

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(1)49' MMPI pattern = sociopathic;
5 scales above T.70 = schizotypic

(2)42' MMPI pattern = secondary sociopathic;
428'MMPI pattern = paranoid;
987'MMPI pattern = schizophrenic mixed.

mixed schizophrenic patients, but there was no reliable difference between the latter two groups.

Thus, the research findings appear somewhat contradictory with respect to Progressive Matrices (1938) efficacy in distinguishing pathological indeces.

Fracchia, Fiorentino, Sheppard and Merlis (1969) investigated the extent to which the defining and scoring of avoidable errors are significant factors in determining the tests ability to detect differences in the abstract reasoning performance of M.M.P.I. diagnosed pathological groups. Using eightyeight patients, divided into four M.M.P.I. profile pattern groups,[1] Fracchia et al. (1969) found that the scoring method defining an avoidable reasoning error as "... failure to solve an item whose difficulty level was within the testee's range of ability, as determined by his performance" was sensitive to differences in pathological type. However, the scoring method using expected set scores (Raven, 1960) as the basic defining

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(1)42' MMPI pattern = secondary sociopathic;
49' MMPI pattern = primary sociopathic;
428'MMPI pattern = paranoid;
987'MMPI pattern = schizophrenic mixed.

concept for avoidable errors, when applied to the same groups, didn't show significant differences. The authors concluded that the manner of defining and that of scoring avoidable errors on Raven's Progressive Matrices (1938) were important factors in determining sensitivity to reasoning errors that are related to pathological ideation.

The present study grew out of a consideration of the fact that appropriately defined and objectively scored avoidable error indeces appear capable of assessing the impairment of intellectual functioning. In this research it was hypothesized that Progressive Matrices (1938) is not merely comprised of a process of series induction, but that embedded in this is a process of similarity perception. If this is in fact so, the similarity perception features involved in the test may act to facilitate (or conversely, to render more difficult) the task of completing the arrays for some subjects. That is, the contaminating features involved in the test, may attenuate the differences in abstract reasoning in various pathological groups that might otherwise obtain. Instead of presenting the standard test, and then using a modified scoring technique, as outlined

above, it may be more efficient to present a modified version of the test itself i.e. eliminating the similarity perception features involved in the standard form.
In this manner, it may be possible to obtain a clearer picture of the differences in abstract reasoning related to different pathological groups than is the case when "avoidable error" measures are used. Thus, the present study is an exploratory attempt to determine whether or not the standard form of Raven's Progressive Matrices (1938) is contaminated by similarity perception features.

CHAPTER II

PROBLEM AND RESEARCH HYPOTHESES

As has been outlined in detail above, Progressive Matrices (1938) comprises basically an incomplete two-dimensional array, which may be completed by the application of logical rules of some sort. The test has been described as a graded series of logically designed patterns (Wechsler, 1949). It was Raven's intention, inferable from some of the items in the test sequence, that each incomplete pattern in the series was completed by a process of induction, and it is the capacity of the subjects to perform this non-verbal induction which generates the measure of intelligence.

In fact, the process of completing the arrays may not simply be that of series induction; it may be comprised of a number of distinct sub-processes. Some possibilities are as follows

(1) Series Induction - i.e. using the operation: "given k terms, and a rule of succession

determined by inspection of the k terms in their proper order, what must the $(k + 1)^{th}$ item be ?" In some of the Raven arrays, the rule is probably better expressed along the following lines: "the possible combinations of attributes shown in the patterns presented include all except one; hence the one missing must be so-and-so."

(2) Similarity Perception. The subject may carry out (1) above, up to a point, and then get an answer which is either (a) correct by chance, or (b) slightly but not grossly wrong, because when choosing from the set of alternatives offered he does not effectively notice and distinguish between all the details of the potential answers but chooses one which is similar, as he perceives it, to what seems to be required.

(3) Guessing will be superimposed upon both these processes, which at its simplest may be expressed by saying that all the

alternatives offered have an equal choice of being chosen as the answer.

(4) Non-random Irrational Strategies (e.g. perseverative responding) may also be employed by some subjects.

The attempt was made in this investigation to test the two major subprocesses separately, using tasks of the following types -

(1) Series Induction - tasks of two sorts were used: (a) Raven arrays, presented for completion, without the alternative solution pieces. Thus, in this task, subjects could not use similarity perception cues to facilitate, or render more difficult, the task of completing the array.

(b) Series induction questions as are used extensively in reasoning tests.

(2) Similarity Perception: these tasks involved ranking of the items taken from

(a) the Raven arrays, and (b) the alternative solutions.

The general aim of this investigation was to determine if expectations regarding the processes involved in the completion of Progressive Matrices (1938) could be substantiated empirically, and if so to consider what the implications are for the standard test procedure.

The specific aims were: to undertake an exploratory factor analysis of the battery of tests as outlined above, to see if there was any evidence of a second factor; to determine if the battery of tests would be effective in discriminating between two psychiatric patient groups, and two 'normal' subject groups; and to discover where the differentiation (if found) occurred within the battery.

<u>Hypotheses</u>: (1) There is evidence that there is more than one factor involved in the five variables making up the test battery;

(2) The test battery will differentiate the

groups at a high level of significance;

(3) The research groups will separate more clearly on the series induction tasks than on the tasks involving similarity perception.

CHAPTER III

DESIGN AND PROCEDURE

A. EXPERIMENTAL SUBJECTS

Four groups of twelve subjects each were used in this design: two schizophrenic groups; and two groups of normal subjects.

1. Schizophrenic Subjects

A number of studies have shown conclusively that it is not meaningful to treat schizophrenia as though it were a single dimension. However, much less agreement prevails concerning what the basic subcategories are, except that they do not coincide with those of psychiatric nosology. The lack of cohesive unity of schizophrenia, and the unacceptable nature of the traditional subcategories (simple, hebephrenic, paranoid and catatonic types) has led to the advancement of alternative systems of subclassification.

Four dichotomous categories of importance have been proposed (Yates, 1966) distinguishing (a) process from reactive schizophrenics, (b) good premorbid from bad premorbid schizophrenics, (c) acute from chronic schizophrenics, and (d) paranoids from nonparanoid schizophrenics. The paranoid-nonparanoid dichotomy is of special interest. There has been doubt about including paranoids under the heading of schizophrenia for a very long time (Lang and Buss, 1965). Paranoid schizophrenics have been found to show less psychological deficit (e.g. Payne and Hewlitt, 1960) and clinically have been considered to show less thought disorder and deterioration over time than have the other subgroups of schizophrenia. These statements, however, do not apply to all paranoids.

In a most enlightening study, Johannsen et al. (1963) examined the correlations found between different measures used to describe schizophrenics. High correlations were found between placement on the process-reactive, acute-chronic, and good-bad premorbid scales. Only the paranoid-nonparanoid dimension appeared to be an independent dimension: testing on a double alternation learning task demonstrated differences between paranoids and non-paranoids, but not between the poles of the other dimensions.

That paranoid patients readily differentiated themselves from other subtypes regarding distractability was established by McGhie (1967). The majority of researchers who have compared experimental measures of attentive behaviour in the different subtypes of schizophrenia have agreed that patients falling into the two groups, hebephrenic and paranoid, tend to form two homogeneous groups, whose performance on tests is strikingly different (McGhie et al., 1965; Silverman, 1964a; Silverman, 1964b)

For the purposes of the present study, and in line with most recent research, it is accepted as most meaningful to subdivide schizophrenic patients into paranoid and nonparanoid categories.

(a) Paranoid Schizophrenic Patients - this group consisted of six male and six female patients, all of whom were hospitalized at Sunnyside Hospital at the time of testing. The patients were selected randomly from the total group of such patients available. The measure of exclusion was that patients must carry the primary diagnosis of Paranoid Schizophrenia, that there be no suggestion of brain damage, and that they had not received E.C.T. within the past year.

(b) Nonparanoid Schizophrenic Patients - this group consisted of six male and six female patients, selected randomly from the total group of such patients at Sunnyside Hospital. All patients selected carried the primary diagnosis of Schizophrenia of any subtype except Paranoid or Unspecified. Such patients who showed any signs or symptoms of organic brain damage, or who had received E.C.T. within the past year, were not eligible for selection.

2. Normal Subjects

The normal subjects were subdivided into two groups, "bright" normals and "dull" normals, on the basis of their performance on the WAIS Vocabulary subtest (below). All subjects were selected randomly from a number of different occupational groupings e.g. university students, teachers, nurses, police officers, factory workers, housewives, and others.

(a) "Bright" Normals: This group consisted of six male and six female adults, none of whom had ever received any of the conventional psychiatric or psychosomatic diagnoses. The criteria for inclusion in this group was a raw score of more than 50 on the WAIS Vocabulary subtest.

(b) "Dull" Normals: Six male and six female adults comprised this group. The criteria for inclusion was a raw score of less than 50 on the intelligence measure employed. None of these subjects had ever received any of the conventional psychiatric or psychosomatic diagnoses.

B. EXTRANEOUS VARIABLES

1. Age: All groups were matched on this variable. The mean age of the paranoid schizophrenic subjects was 35.5 years (their ages ranged from 22-48 years). The mean age of the nonparanoid schizophrenic subjects was 31.9 years (their ages ranged from 19-45 years). The mean age of the "bright" normals was 33.3 years (age range from 20-48 years). The mean age of the "dull" normals was 35.4 years (with the age range being from 27-48 years). An analysis of variance for a 1 factor experiment, with unrelated measures, (Winer, 1962), indicates that these differences are not significant. (See Appendix 1).

2. Sex: All groups were balanced on the sex factor.

3. Intelligence: A brief test to obtain an estimate of intelligence was included in the battery: the WAIS Vocabulary subtest. Wechsler found Vocabulary to have the highest correlation with total IQ of any of the WAIS subtests (Wechsler, 1944) and other investigators have found this also (Phelan, Levy, and Thorpe, 1967). As a

quick test of intelligence, this scale is considered one of the best available: Wechsler (1958) states that the Vocabulary subtest is "an excellent measure of ... general intelligence" and that it "holds up better with age than any other test of the scale".

It is possible to convert a subject's raw score on this subtest to an age-scaled score (Wechsler, 1955). In this manner, a subject's performance would be compared with the average for his age peers. However, in the five experimental variables used in the present study, a subject's ability was determined by his raw score - i.e. his score was not compared with that obtained by his age peers. Thus, a subject's raw score on the WAIS Vocabulary subtest was used as the measure of intelligence.

The mean scores, the standard deviation, and the ranges obtained for each group are given in Appendix 1(a). It will be noted that, as would be expected, there is a confounding of intelligence between the "bright" normals and the other groups. A t-test indicates that no reliable difference obtains between the two patient groups, or between either of these and the "dull" normal group. (See Appendix 1(c)).

4. Race: All subjects were native-born New Zealand Europeans.

5. Length of Hospitalization: It was not possible to equate the experimental groups on this variable, as it is related to the diagnostic categories used. However, Foulds et al. (1962 a,b,c) demonstrated that for schizophrenics in general, a decline in Progressive Matrices score was a function of age only; length of stay in hospital, except insofar as it was related to ageing was not associated with a decline in intellectual performance.

6. Drug Programmes: It was, of course, not possible to control this variable. All schizophrenic patients were receiving phenothiazine chemotherapy.

C. EXPERIMENTAL MEASURES

There were five subtests in the battery presented to the subjects. (For the items involved in each subtest, see Appendix 2).

(1) This task was a subtest of the total sixty items of Progressive Matrices (1938), with a bias toward the more difficult items. Two items were chosen from each of sets A and B, and four each from sets C, D, and E - i.e. sixteen items in all[(1)].

In this test, complete Progressive Matrices items were presented to the subjects in the standard fashion (Raven, 1960). The task was to choose the missing insert from the alternatives offered below each matrix.

(2) In this test, the arrays were presented without the alternatives below, the subject's task being to describe what the solution item would need to look like. Again, sixteen items were used[(1)].

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(1) Thirtytwo items in all were assigned systematically to measures (1) and (2), in such a way that avoided having each item in one measure more difficult than the corresponding item in the other measure (Appendix 2(a)).

(3) This measure, and the one following, were tests of similarity perception. For the third measure in the battery, subjects were asked to rank the alternative solution pieces taken from the Raven items. The complete set of alternative solutions was presented to the subjects, who were required to rank these in terms of their perceived similarity to the "correct" solution item. The items used in this task were selected from both Tasks 1 and 2 - eight altogether.

(4) Subjects were here required to rank the individual pieces from the array itself, in terms of their perceived similarity to the solution item. The items used in this task (ten) were selected from the first two measures, but no item was used in both measures 3 and 4.

(5) This was a test of series induction, all the items of which involved the principle of, e.g. "A, B, C, D, ... what letter comes next ?" The items for this test were drawn from four common reasoning tests, viz. AH4(1955), AH5(1956), the Canterbury Reasoning Test, (1960), and the Canterbury Junior Reasoning Test (1962). All

items involving series induction were taken from these tests, and given to ten randomly selected students and patients. From their responses, the total 120 items were ranked in order of difficulty. Every fourth item was then selected, and used in the present subtest.

D. PROCEDURE

It was explained to the subjects that the tasks they would be asked to do constituted a research investigation. Patients were informed that their performance would not in any way influence their treatment in the hospital, that the Medical Officers concerned would not have access to any test material, and that anything said would be regarded as strictly confidential.

All subjects were tested individually, in a private office. For some patients the testing took rather a long time ($1\frac{1}{2}$+ hours) but it was attempted to create and maintain motivation as far as possible: a careful watch was kept for fatigue, and there was always a break of a few moments between each subtest of the battery.

The subtests were presented in the order in which they were outlined above. The problems become progressively more difficult in each of subtests 1 and 2. It was considered that subjects should be given the opportunity in Task 1 of grasping the nature of the test. If in fact they did not do so, they would be unlikely to do so in Task 2. However, in case this occurred, subjects were always asked, at the end of Task 2, whether they would like to change any answers to former items, or go over them again.

All tests were untimed, as the Progressive Matrices test is usually administered as an untimed, "capacity" test. Also, other studies (e.g. Schnell and Dwarshuis, 1967) have found a negligible correlation between Progressive Matrices scores and the time taken to complete it.

<u>Instructions</u> For the first task (i.e. the standard Raven presentation) the standard instructions were given, viz.

> "Look at this (pointing to the upper figure). It is a pattern with a bit taken out. Each of these bits below (pointing) is the right shape to fit the space but they do not all complete the pattern." (Explained why numbers 1,2,3 are wrong and why 4 is nearly right.) Then, "Point to the piece which is quite right." (Explanation continued until the nature of the problem was clearly grasped.) Then, "All you have to do is to point each time to the bit which is the right one to complete the pattern. They are simple at the beginning and get harder as

> "you go on. If you pay attention to the way the easy ones go, you will find the later ones less difficult. Just point to the piece which completes the pattern. Now carry on at your own pace. See how many you can get right. You can have as much time as you like. There is no need to hurry. Be careful. Remember each time only one bit is quite right."

For the second task (i.e. "Raven-minus-alternatives") the instructions were

> "Now here is a pattern with a piece missing, but this time I want you to explain to me what the piece would need to look like to complete the pattern. You just tell me what would have to go in the blank space to complete the pattern." (This explanation was continued until the nature of the problem was clearly grasped.) Then, "Just explain what the piece would need to look like. There is no need to hurry. Be careful."

For both the similarity perception tasks, the items were cut into their constituent pieces, and each piece mounted on a card. The correct alternative (for Task 3), or the solution item (for Task 4), was presented first, and then the other pieces were presented in the order in which they are placed in Raven's booklet (1965 edition). The instructions were

> "I want you now to rank all these pieces (pointing) in terms of their similarity to <u>this</u> piece. That is, I want you to put all of these in order, in terms of their <u>likeness</u> to <u>this</u> one. Put the one that is <u>most</u> similar, or <u>most</u> like it, next to this one, then the next most similar one, down to the one that is <u>least</u> like it."

Task 5, the series induction measure, was administered in printed fashion, with the answers to be filled in on the question sheet. The instructions were printed at the top of the test and read as follows:

> "For each question in this test there is a line at the right hand side of the page. Wherever you see a line, there are letters, words, or numbers missing. Your task is to write the correct letters, words, or numbers on these lines, in order to answer the questions. For example:
>
> 1) A B C D E   <u>F</u> <u>G</u>
>
> In this example the ltters on the left are in alphabetical order, and so the next two letters are 'F' and 'G'.
>
> 2) 1 3 5 7   <u>9</u> <u>11</u>
>
> Here the rule is to add 2 to each number to get the next.
>
> Now try this one yourself:
>
> 3) ABC DEF GHI   ___
>
> If there is only one line on the right, only

one answer is required. If there are two lines, then two answers must be given in order to get a mark.
Work as quickly as you can.
Any questions ?"

<u>Techniques of Measurement</u> All responses to all items on all measures were marked either correct or incorrect.

For Task 1, standard marking as per the Raven manual was followed.

For Task 2, the "Raven-minus-alternatives" task, a list was compiled of the constituent aspects of each solution item. All of these aspects had to be mentioned for an answer to be marked correct. In fact, instead of answering in this fashion, a number of subjects would point to pieces in the array, and state that the solution would be "those two superimposed...." It was possible to score these responses as well.

For measures 3 and 4, the similarity perception tasks, a more complicated scoring technique was needed. Briefly, the logical structure of each item was determined by converting each piece into its axiomatic form. Thus, a logical ordering of these pieces could be obtained (Appendix 2 (b)).

For the final task, of series induction, the answers from the reasoning tests used were required[1].

Statistical Treatment of Data Both a factor analysis and a discriminant function analysis were carried out by use of the IBM 360/44 computer at the University of Canterbury.

Factor analysis was performed by means of the IBM Scientific Sub-routines Standard Factor Analysis Program.

Statistical analysis of the results was also carried out by the discriminant function analysis

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(1) It has been noted that some of the Shouksmith answers could be disputed - R.A.M. Gregson, personal communication.

IBM S.S.R. program at the University of Canterbury Computer[1].

The term discriminant function used in this program is more correctly the set of coefficients of a linear discriminant score as defined by Rao (1952)[2].

The discriminant analysis method enables differences in an a priori classification of groups to be examined in terms of the highest relative a posteriori probability of an individual being assigned to one of the a priori groupings on the basis of test scores which are common to all the individuals. In the present case, the a priori classification was in clearly defined categories : paranoid schizophrenics; nonparanoid schizophrenics; "bright" normals; and "dull" normals.

Diagramatically, the method may be illustrated

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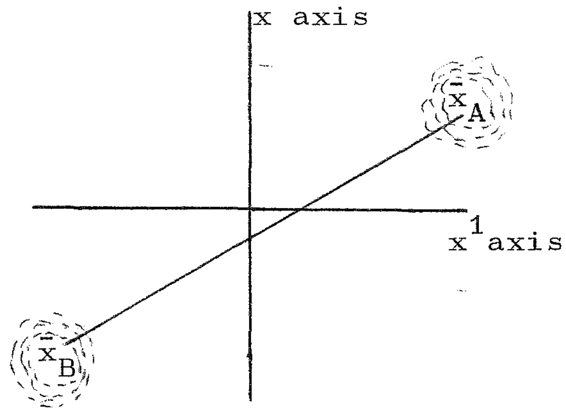
(1) This program has been modified by Professor R.A.M.Gregson of the Dept. of Psychology and Sociology, University of Canterbury.

(2) This method is also illustrated in a paper by Rao and Slater (1949)

by an example, using just two groups of scores:



$i = A, B$

The ellipses around A and B are equiprobability contours representing diverging individual subject scores about the mean values $\bar{x}_i$. Not all contours are shown, but it would be expected that the complete set of contours of A and B would intersect. The line d_{AB} represents a decision axis. Any line can be drawn at right angles to this, such that all scores to one side will be called B, all to the other side called A. This line may be drawn at any point, according to the critical value placed on it. By selecting the decision axis, and a line at right angles to it, which leads to the fewest errors of allocation to A and B, a canonical analysis of discrimination is carried out.

To distinguish between the subjects of two groups using the maximum amount of information it is necessary to find a decision axis d_{AB} which represents a line along which the distance between the two means of the groups is greatest, relative to the variation within the groups. For each group, a separate linear decision function is constructed. The degree of overlap between the clusters of scores is thereby calculated and is expressed in the form of a Generalized Mahalanobis D-Square, and the significance of this can be tested. It is distributed as a function of chi-square, giving a measure of the extent to which the groups separate out in terms of the variables used in the analysis. Having determined what linear function is most influential in partitioning the variance within and between groups, it is then possible to determine the probability by which a subject's scores apportion him to each of the groups. The revision of the original program mentioned above gives the probabilities associated with all the groups, and not just the largest probability.

The output of the program is as follows:

1) Means of variables in each group, - i.e. the centroid of each group;
2) The pooled dispersion matrix, consisting of variance and covariance scores;
3) The common means;
4) The Generalized Mahalanobis D-Square, with its associated chi-square, and degrees of freedom;
5) The discriminant function coefficients for variables in each group;
6) The classification functions for each subject.

The means of the variables, in each group, the Mahalanobis D-Square, and the classification functions are discussed in the following chapter.

CHAPTER IV

RESULTS

Hypothesis 1

The research hypothesis: there is evidence of more than one factor being involved in the test battery.

Although it was realized that the conditions of the study were such as to make the application of factor analysis not strictly appropriate (i.e. the method of subject allocation, and the use of a limited number of variables) an exploratory factor analysis was carried out. The obtained correlation matrix, the eigenvalues, the cumulative percentage of eigenvalues, and the unrotated factor matrix are outlined in Appendix 3.

With only five variables, it is not possible to define more than two factors. Both the eigenvalues obtained, and an inspection of the correlation pattern suggest that there is a very large common factor in the five research variables. However, variables 3 and 4 (i.e. the similarity perception variables) have appeared with small but respectable loadings, giving some indication of a second factor. Varimax rotation of the five factors gave no additional information, as the use of unities in the diagonal cells necessarily gave rise to specific factors, which were highlighted in the rotated matrix.

Thus, there is evidence, of a very tentative nature, of a rather small second factor being involved in the research battery (1).

Hypothesis 2

Research hypothesis: the test battery will discriminate between the research groups at a significant level.

All five variables studied in this research were used in the discriminant function analysis.

Table 1 shows that the battery of tests given to the subjects differentiates between the four groups

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(1) Generous acknowledgement is due to Professor C.J. Adcock of Victoria University of Wellington, for his comments on the results of the factor analysis.

at a significant level. Thus, there is a high degree of separation obtained between the mean values of the four groups; that is, the "generalized distance of Mahalanobis" between the groups is significant.

TABLE 1

DISCRIMINANT FUNCTION COEFFICIENTS FOR THE 4 RESEARCH GROUPS

Response Variable	Coefficients of Measurements			
	Group 1 Paranoid Schizophrenics	Group 2 "Bright" Normals	Group 3 Nonparanoid Schizophrenics	Group 4 "Dull" Normals
1	0.243	-0.243	-0.032	0.018
2	0.410	1.097	0.925	0.657
3	0.652	-0.053	0.939	0.516
4	1.373	1.726	1.611	1.279
5	-0.355	0.284	-0.412	-0.261
Constant Term	1 -5.608 2 -13.318 3 -9.695 4 -5.361			
Generalized Mahalanobis D-Square = 71.031 Degrees of Freedom as for Chi-Square = 15 $p < .001$				

Tables 2 (i) - (iv) give the Bayesian a posteriori probabilities of each of the subjects belonging to each of the research groups, and the largest function number associated with these probabilities.

The base rates are a priori set equal (i.e. effectively 0.25 each) because they were not obtainable.

TABLE 2(i)

GROUP 1, PARANOID SCHIZOPHRENICS

Subjects	Group 1 Paranoid Schizophrenics	Group 2 "Bright" Normals	Group 3 Nonparanoid Schizophrenics	Group 4 "Dull" Normals	Largest Function Number
1	0.214	0.007	0.615	0.164	3
2	0.672	0.002	0.058	0.268	1
3	0.577	0.000	0.081	0.342	1
4	0.442	0.010	0.311	0.238	1
5	0.284	0.006	0.363	0.348	3
6	0.519	0.007	0.197	0.278	1
7	0.010	0.868	0.064	0.058	2
8	0.274	0.01	0.444	0.272	3
9	0.416	0.002	0.265	0.317	1
10	0.533	0.001	0.033	0.432	1
11	0.44	0.004	0.02	0.537	4
12	0.556	0.002	0.152	0.29	1

Referring to Table 2(i), it may be seen that seven paranoid schizophrenics have a largest function number corresponding to the group to which they do in fact belong; that is, 7/12 subjects were correctly identified as being paranoid schizophrenics. A further three were identified as being nonparanoid schizophrenics. Thus, most were broadly identified as being psychiatric patients. Two subjects were misclassified as "normals". One paranoid schizophrenic subject was classified as belonging to the "bright" normal group, and had in fact a raw score on the WAIS Vocabulary subtest of 72, easily the highest in her group. The remaining subject was classified as "dull" normal, having a raw score of 14, the lowest in the group. Thus, in this group of paranoid schizophrenics there was indeed a separation occurring, but the "dull" normals and the paranoid schizophrenics did overlap to some extent due seemingly to the intelligence factor.

TABLE 2(ii)

GROUP 2, "BRIGHT" NORMALS

Subjects	Group 1 Paranoid Schizophrenics	Group 2 "Bright" Normals	Group 3 Nonparanoid Schizophrenics	Group 4 "Dull" Normals	Largest Function Number
1	0.007	0.995	0.03	0.008	2
2	0.000	0.999	0.000	0.000	2
3	0.02	0.862	0.018	0.101	2
4	0.051	0.777	0.033	0.139	2
5	0.000	0.989	0.009	0.002	2
6	0.003	0.963	0.031	0.003	2
7	0.065	0.271	0.511	0.153	3
8	0.003	0.978	0.013	0.006	2
9	0.003	0.943	0.041	0.013	2
10	0.16	0.063	0.371	0.406	4
11	0.187	0.086	0.311	0.416	4
12	0.022	0.893	0.055	0.030	2

In Table 2(ii) it can be seen that nine out of twelve of the "bright" normal subjects were correctly identified. Two subjects were misclassified as "dull" normals. Broadly, then, eleven of twelve subjects were correctly classified as being "normals". The two subjects misclassified as being "dull" normals obtained extremely low scores (for their group) on one variable in the battery (variable 5), which appears to be responsible for this misclassification.

TABLE 2(iii)

GROUP 3, NONPARANOID SCHIZOPHRENICS

Subjects	Group 1 Paranoid Schizophrenics	Group 2 "Bright" Normals	Group 3 Nonparanoid Schizophrenics	Group 4 "Dull" Normals	Largest Function Number
1	0.341	0.014	0.387	0.258	3
2	0.359	0.016	0.114	0.511	4
3	0.014	0.829	0.14	0.018	2
4	0.505	0.003	0.208	0.283	1
5	0.153	0.374	0.095	0.379	4
6	0.282	0.010	0.308	0.402	4
7	0.317	0.003	0.501	0.179	3
8	0.349	0.004	0.410	0.238	3
9	0.072	0.004	0.845	0.079	3
10	0.032	0.102	0.803	0.063	3
11	0.253	0.002	0.618	0.128	3
12	0.045	0.281	0.516	0.158	3

The nonparanoid schizophrenics were identified correctly for seven out of twelve subjects, with a further one subject misclassified as belonging to the paranoid schizophrenic group. Broadly, then 2/3 of the group were correctly identified as being patients. One subject in this group, misidentified as "bright" normal, had a raw score on the WAIS Vocabulary scale of 53 - the second highest in this group. The three misidentified as "dull" normal had raw scores of 52, 30, and 32 - the last two being the lowest in the group.

TABLE 2(iv)

GROUP 4, "DULL" NORMALS

Subjects	Group 1 Paranoid Schizophrenics	Group 2 "Bright" Normals	Group 3 Nonparanoid Schizophrenics	Group 4 "Dull" Normals	Largest Function Number
1	0.398	0.002	0.149	0.451	4
2	0.184	0.019	0.536	0.261	3
3	0.282	0.168	0.136	0.414	4
4	0.213	0.246	0.139	0.402	4
5	0.439	0.035	0.155	0.370	1
6	0.343	0.027	0.176	0.454	4
7	0.620	0.001	0.06	0.318	1
8	0.456	0.001	0.204	0.338	1
9	0.289	0.004	0.241	0.426	4
10	0.240	0.008	0.321	0.431	4
11	0.305	0.033	0.310	0.352	4
12	0.365	0.005	0.208	0.422	4

Referring to Table 2(iv), in the "dull" normal group eight subjects have a largest function number corresponding to the group to which they do belong. That is 2/3 were correctly indentified, while three subjects were misidentified as being paranoid schizophrenics, and one as belonging to the nonparanoid schizophrenic group. None of this group were classified as being "bright" normals. Again, a separation of the "dull" normals from the other groups has occurred, but a decided overlap with the paranoid schizophrenic subjects is apparent. Two of the three subjects misclassified as being paranoid schizophrenic received the lowest scores for their group on variables 1 and 2.

In Table 3, a simple diagram sets out the classification given by the discriminant function analysis, and the actual a priori groupings of the subjects.

TABLE 3

DISCRIMINANT FUNCTION

c.f. ACTUAL CLASSIFICATION OF SUBJECTS

Actual Classifications		Discriminant Function Maximum Likelihood Classifications			
		Paranoid Schizophrenics	"Bright" Normals	Nonparanoid Schizophrenics	"Dull" Normals
	12 Paranoid Schizophrenics	7	1	3	1
	12 "Bright" Normals	0	9	1	2
	12 Nonparanoid Schizophrenics	1	1	7	3
	12 "Dull" Normals	3	0	1	8

Thus, seventeen out of fortyeight are wrongly classified - 2/3 are correctly identified.

The results of the discriminant function analysis thus demonstrate that the battery of tests administered to the research subjects differentiated between the groups at a high level of significance.

As was noted above, however, although the "dull" normal group and the paranoid schizophrenic group were differentiated from each other, there was a definite overlap occurring.

Throughout the discriminant analysis, a failure to correctly identify the group membership of various individuals has been found. It is important to note that the research groups themselves are rather imprecisely and inadequately defined, and the discriminant analysis (a very sensitive procedure) is picking this up.

A discriminant function analysis is capable of finding differences, if this is at all possible. In this respect it is a misleadingly sensitive form of analysis when thinking in terms of practical clinical decisions; it gives a best course of action even when this is a useless best course. Thus, although the discriminant function analysis outlined above does demonstrate that the battery of tests administered differentiates between the research groups at a high level of significance, it will be instructive to examine the individual variables within the battery to determine on which variables the obtained differentiation occurs.

Hypothesis 3

The hypothesis: the research groups will separate more clearly on the series induction tasks than on the tasks involving similarity perception.

The mean scores of the four research groups, using first the variables tapping series induction, and then those of similarity perception are outlined below.

Firstly, the mean scores (expressed in terms of the per cent correct for each task) of the four research groups, using three variables are shown in Table 4. The variables are the standard Raven items, the "Raven-minus-alternatives" test, and the test of series induction. Following this the two similarity perception variables are discussed in the same manner.

Obviously, a more detailed statistical analysis is needed, involving the variances of the scores, and this would be incorporated in any study on a larger sample. Following the analysis of mean scores, three of the five variables are discussed individually, i.e. raw scores for all subjects on these variables are examined.

TABLE 4

GROUP MEANS FOR VARIABLES 1, 2, & 5 *

Research Groups	Variables 1	2	5
Paranoid Schizophrenics - 1	40.10	38.04	18.05
"Bright" Normals - 2	70.32	77.10	52.45
Nonparanoid Schizophrenics - 3	49.97	56.25	25.83
"Dull" Normals - 4	39.60	42.72	20.84

Regarding variable 1, the most conspicuous difference is obviously that between Group 2 and all other groups. Regarding groups 1, 3, and 4, the largest difference is 10. This stands in contrast to the much larger difference between any of these scores and that of Group 2: the difference between the group of "bright" normals and the closest of the other groups (Group 3) is

* Also see Graph 1

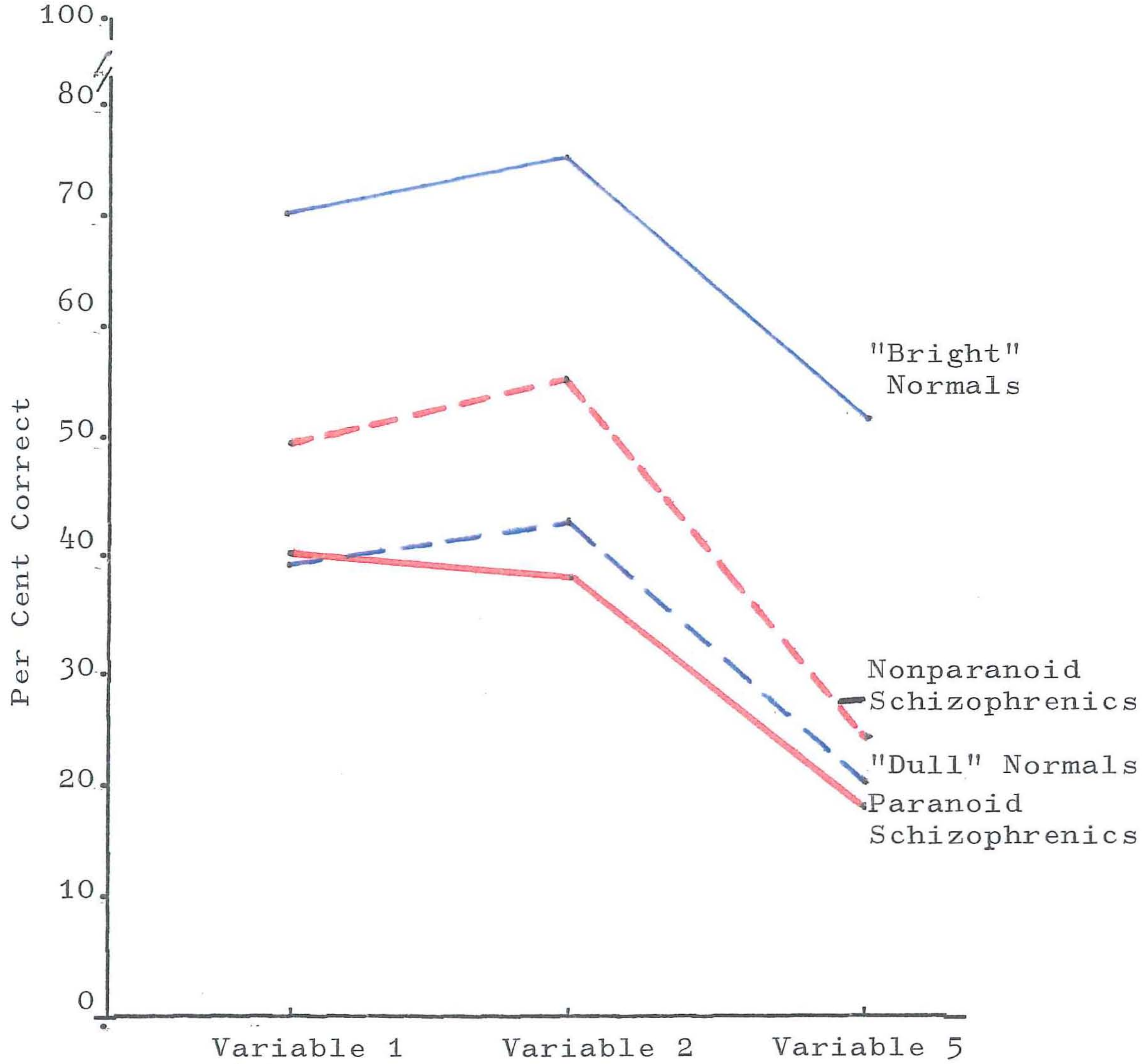
20. Also important, but not as conspicuous is the fact that the nonparanoid schizphrenics are separated from groups 1 and 4 by 10. It can be seen from both Table 4 and Graph 1 that there is no difference between the paranoid schizphrenics and the "dull"normals.

On variable 2, the "Raven-minus-alternatives" task, the same overall pattern is obtained, this time with slightly higher differences between the groups. (On Graph 1, this is shown by the groups showing the same pattern but being more spread out over this variable.) Again, the greatest difference is between Group 2 and the other groups; the difference between Group 2 and the closest of the other groups is 21. The nonparanoid schizophrenic group is again separated from the "dull" normal group and from the paranoid schizophrenic group, this time by 18 and 14 respectively. Thus, the groups are more differentiated from each other on this variable than they were on variable 1, although the difference between the paranoid schizophrenic group and the "dull" normals is, while greater here, still rather insignificant.

Regarding variable 5, the Series Induction test, Group 2 has spread out even more from the other groups.

GRAPH 1

MEAN SCORES OF THE FOUR RESEARCH GROUPS
ON VARIABLES 1, 2, AND 5



The largest difference between groups 1, 3 and 4 is 7, while the difference between Group 2 and the closest of the other groups is 27.

The mean scores of the four groups on the two similarity perception variables (variables 3 and 4) are outlined in Table 5, and can be seen diagrammatically on Graph 2.

TABLE 5

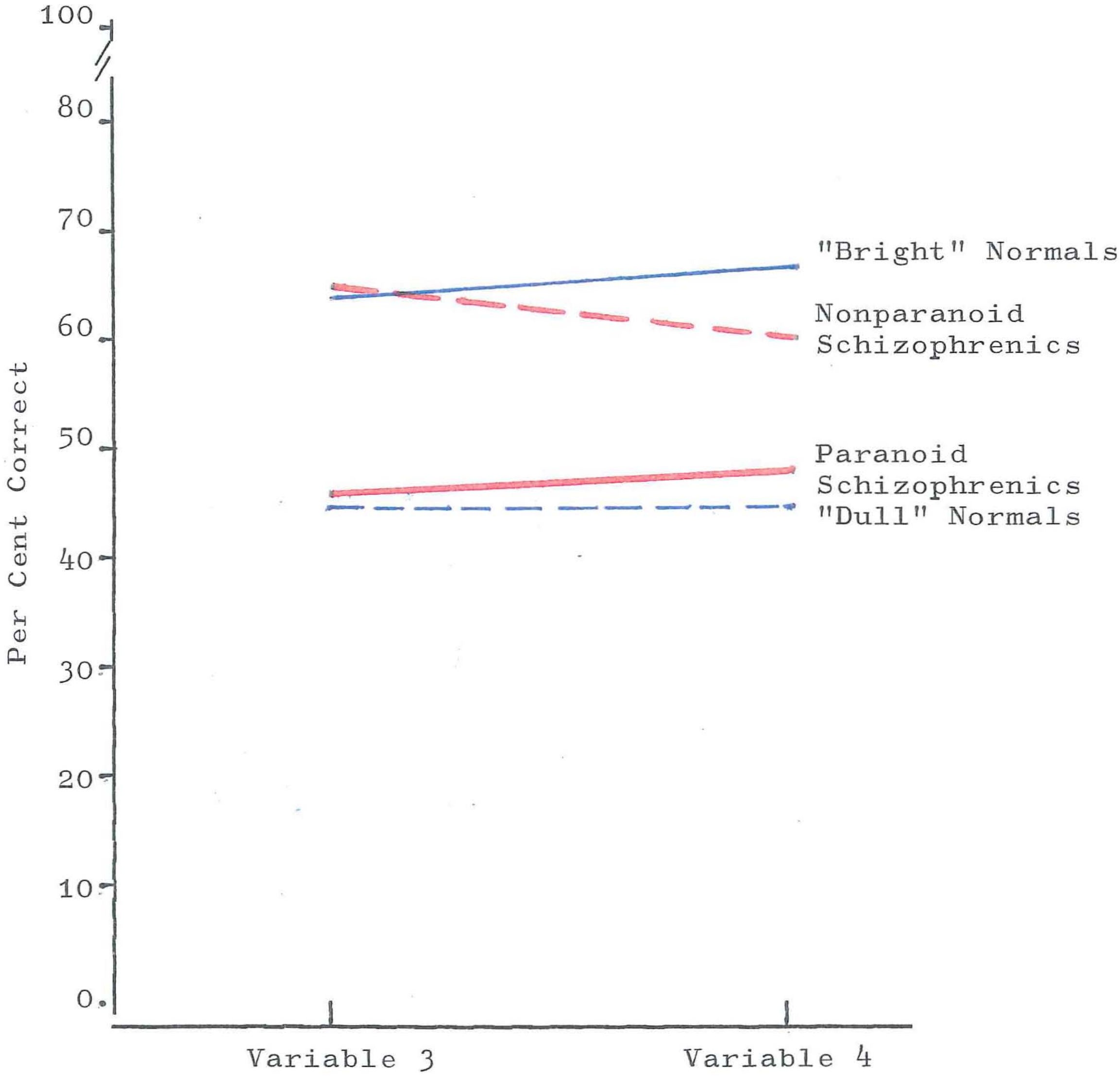
GROUP MEANS FOR VARIABLES 3 AND 4

Research Groups	Variables 3	Variables 4
Paranoid Schizophrenic - 1	46.82	48.30
"Bright" Normals - 2	63.51	67.50
Nonparanoid Schizophrenic - 3	64.57	60.00
"Dull" Normals - 4	45.82	45.85

With variable 3, as Graph 2 shows most clearly, there is no differentiation between groups 1 and 4, or between groups 2 and 3. That is, the paranoid

GRAPH 2

MEAN SCORES OF THE FOUR RESEARCH GROUPS ON VARIABLES 3 AND 4



schizophrenics and the "dull" normals are clustered together, as are the nonparanoid schizophrenics and the "bright" normals. However, there appears to be a marked difference between these two clusters; the difference is 17. The mean scores of the groups on variable 3, then, indicate a separation between the two clusters, but do not indicate such a separation taking the groups individually.

On variable 4, the second of the similarity perception tasks, the scores are spread out slightly more than on variable 3. The "dull" normals and paranoid schizophrenics are separated by only 3, but the other groups are separated by 7 and 12. Thus, the mean scores do indicate that there is slightly more separation of the groups on this variable than on variable 3.

Thus, an analysis of the mean scores indicates that it was the variables involving series induction that most influenced the separation obtained by the discriminant function analysis. Using group means, it appears that it was on variable 5 that the most differentiation of the groups occurred. Also, the group means were separated more clearly on variable 2 than on variable 1 - i.e. the means were separated more clearly on the Raven task where similarity cues had been removed. The overlap of paranoid schizophrenic patients and "dull" normals was again noted, and these groups were most separated on variable 2.

As outlined above, a better separation of the groups using mean scores appeared to occur on the series induction variables - 1, 2, and 5. These variable are discussed individually below. The tables show raw scores for all subjects in the four groups and the group means, on these three variables. (Raw scores for all subjects on all variables may be seen in Appendix 4). The accompanying scatter diagrams show the range of scores obtained by the subjects. By examining the results in this way, it will become more obvious how these variables have contributed to the separation of the groups that was obtained by the discriminant function analysis.

TABLE 6

RAW SCORES FOR ALL SUBJECTS, AND GROUP MEANS, ON VARIABLE 1

Subjects	Groups			
	1 Paranoid Schizophrenics	2 "Bright" Normals	3 Nonparanoid Schizophrenics	4 "Dull" Normals
1	10	15	8	4
2	9	13	4	7
3	3	6	16	11
4	13	11	5	6
5	5	12	8	7
6	8	15	8	5
7	10	8	7	4
8	4	4	7	4
9	3	11	7	8
10	3	8	9	5
11	5	9	11	10
12	4	13	6	5
Group Means:	6.4	10.4	8.0	6.3

An analysis of the group means alone supported the notion that "bright" normals were differentiated from the other groups, but as Figure 1 shows, the individual scores are so scattered that a meaningful analysis of trends is not possible with such small numbers. Group 2 ("Bright" Normals) show some trend toward the high end of the scatter, but scores are widely dispersed along the length of the scale. Overall, it would not appear that this variable contributed significantly to the separation found in the discriminant function analysis, when one views the scatter of individual scores.

FIGURE 1

SCATTER DIAGRAM: RANGE OF SCORES FOR ALL SUBJECTS ON VARIABLE 1

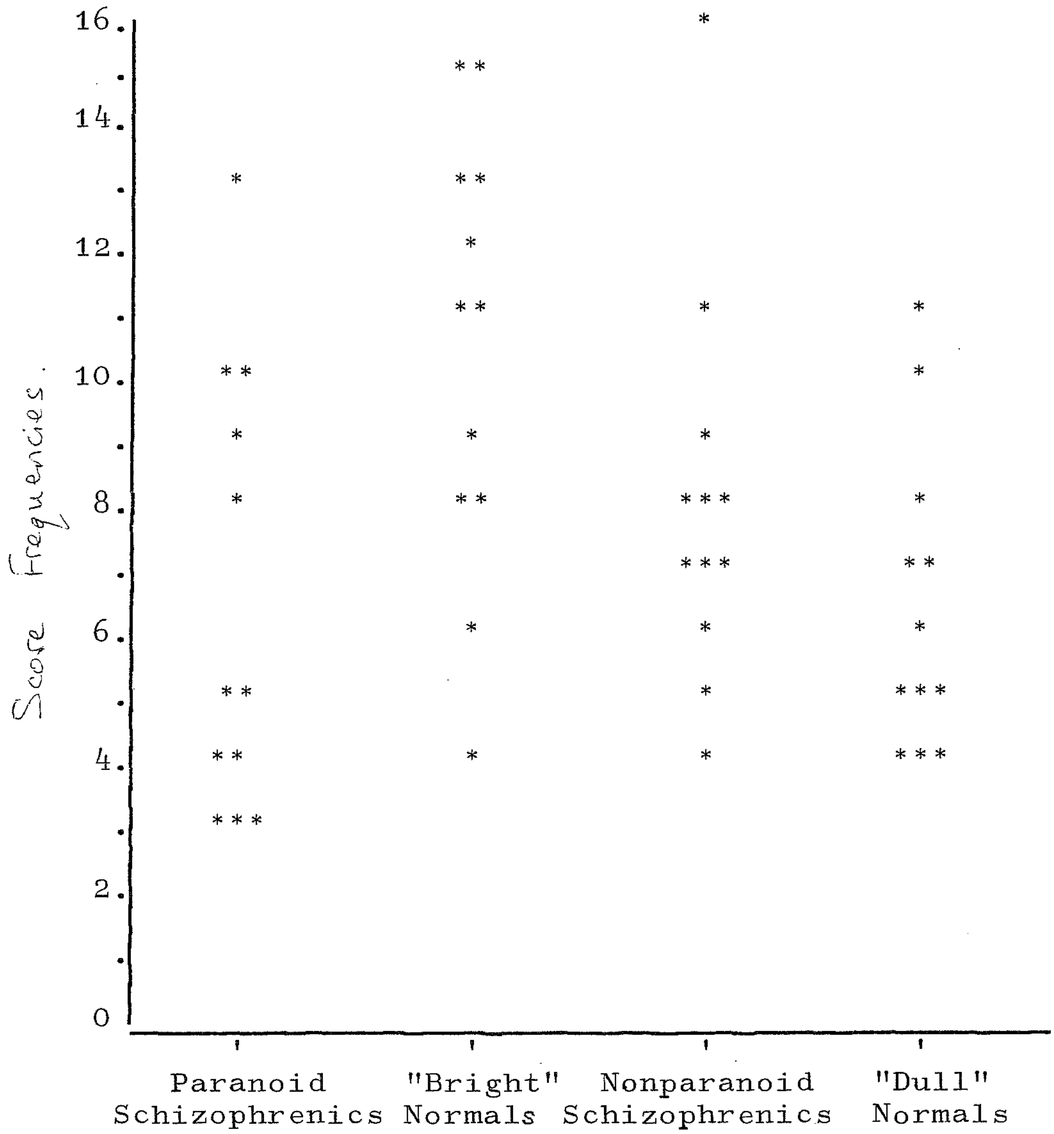


TABLE 7

RAW SCORES FOR ALL SUBJECTS, AND GROUP MEANS, ON VARIABLE 2

Subjects	Groups			
	1 Paranoid Schizophrenics	2 "Bright" Normals	3 Nonparanoid Schizophrenics	4 "Dull" Normals
1	10	13	8	5
2	5	13	5	9
3	2	9	15	10
4	10	11	4	7
5	7	15	9	6
6	6	14	9	6
7	14	11	7	2
8	6	14	7	4
9	4	14	10	9
10	2	11	13	8
11	4	11	10	10
12	3	12	11	6
Group Means:	6.1	12.3	9.0	6.8

On variable 2, more of a scatter of individual scores was obtained than on variable 1. It can be seen that the "bright" normals are completely separated from the "dull" normals, with the exception of one subject - this particular subject having the lowest intelligence raw score of the "bright" normal group. However, a high degree of overlap obtains regarding the "dull" normal and paranoid schizophrenic groups.

FIGURE 2

SCATTER DIAGRAM: RANGE OF SCORES FOR ALL SUBJECTS ON VARIABLE 2

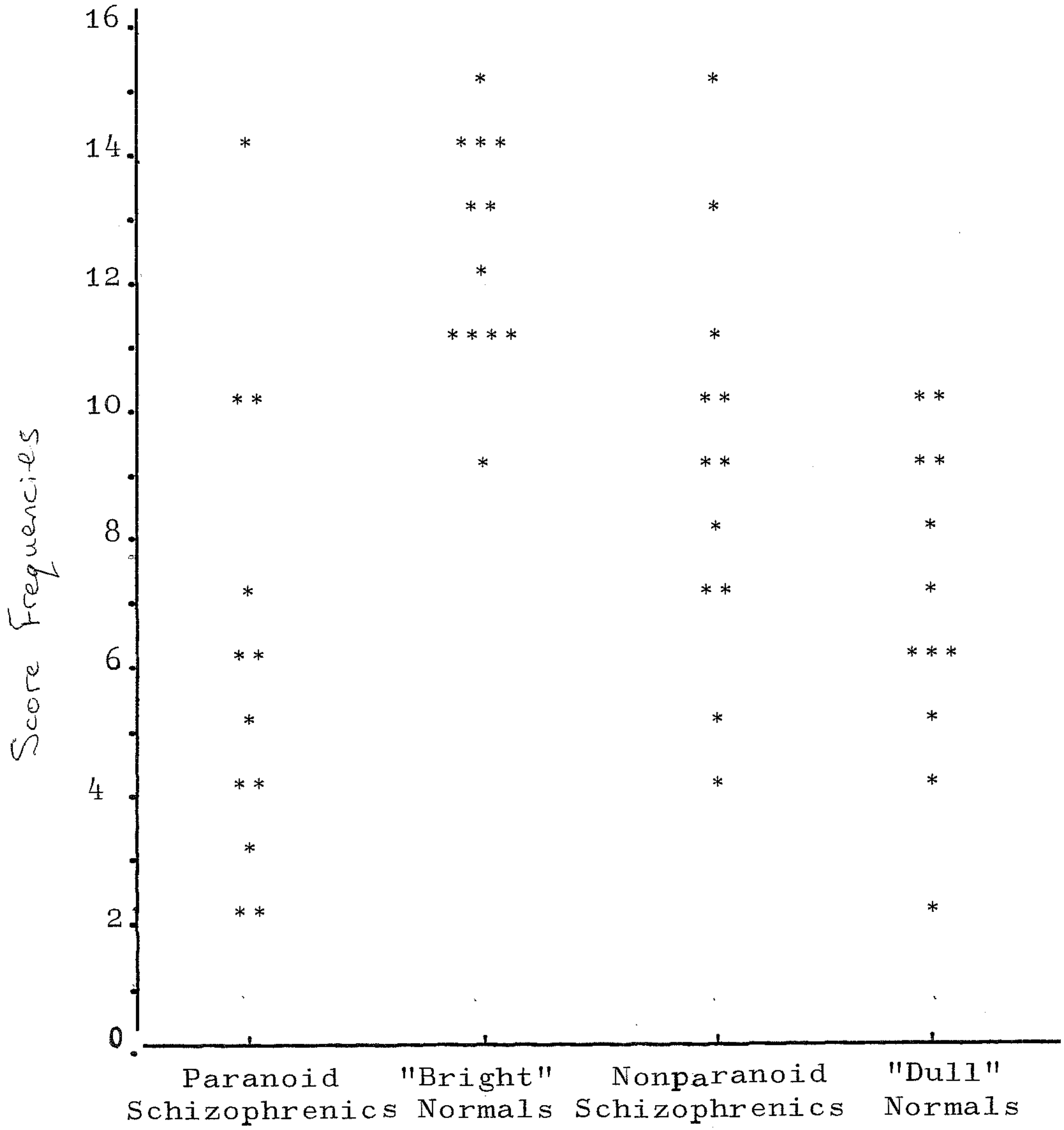


TABLE 8

RAW SCORES FOR ALL SUBJECTS, AND GROUP MEANS, ON VARIABLE 5

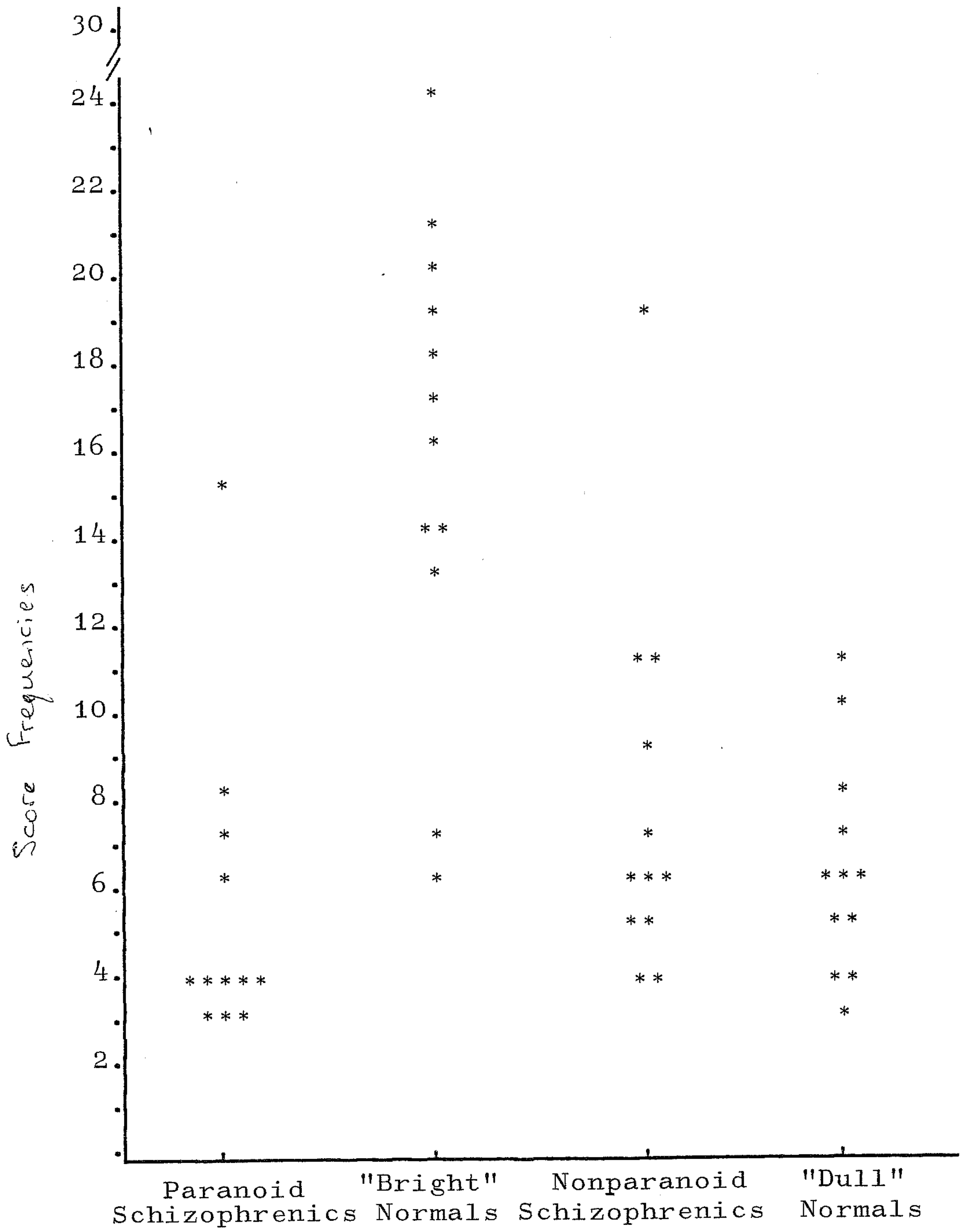
Subjects	Groups			
	1 Paranoid Schizophrenics	2 "Bright" Normals	3 Nonparanoid Schizophrenics	4 "Dull" Normals
1	7	20	4	4
2	4	24	6	8
3	4	14	19	10
4	8	14	6	11
5	4	19	11	7
6	6	21	7	6
7	15	13	4	4
8	4	18	5	6
9	3	17	6	5
10	3	6	9	3
11	3	7	5	6
12	4	16	11	5
Group Means:	5.4	15.8	7.8	6.3

On variable 5, as an analysis of Figure 3 shows, most of the "bright" normals separate out reasonably clearly from the other three groups. Two of these subjects are, however, embedded in among the other three groups. These "bright" normal subjects have in fact been classified as "dull" normals in the discriminant function analysis.

It can be seen that Groups 1, 3 and 4 show a mixed scatter of scores at the lower end of the scale, with two exceptions. One paranoid schizophrenic subject's score is amongst those obtained by "bright" normals, and this subject was classified as being a "bright" normal in the discriminant function analysis. Again, the nonparanoid schizophrenics are all at the lower end of the scale, except for subject 3, of this group. This subject was also classified in the discriminant analysis as being a "bright" normal. The group of "dull" normals all achieved scores at the low end of the scale.

FIGURE 3

SCATTER DIAGRAM: RANGE OF SCORES FOR ALL SUBJECTS ON VARIABLE 5



Overall, then, the most consistent separation occurred on variable 5, and this variable probably accounted for much of the separation between the groups. It is also noted that there appears to be more separation occurring on variable 2 than on variable 1.

CHAPTER V

DISCUSSION AND CONCLUSION

The broad aim of this investigation was an attempt to gain a partial answer to the question: what are the processes involved in the task of completing Raven's Progressive Matrices (1938) ? The specific aims were : (a) to discover, by undertaking an exploratory factor analysis, whether there was any evidence of a second factor involved in the battery of tests; (b) to see if the battery given to the research subjects significantly differentiated between them; and (c) to discover where the differentiation, if found, occurred within the battery. By these means, it was hoped to discover whether tasks involving similarity perception were involved in the process of completing the standard Progressive Matrices items.

The exploratory factor analysis suggested the presence of a small second factor in the battery of tests, derived from the similarity perception variables. As was outlined in Chapter IV, the research was not conducted in a way to make factor analysis strictly appropriate, and so this result must be viewed as being only suggestive. However, it does appear that the task involved in the similarity perception variables is somewhat different than that involved in the series induction tasks; other abilities do seem to be involved in the completion of the similarity perception variables.

In the discriminant function analysis, on the basis of the five measures employed in the research, the four research groups cannot be considered to have come from the same group centroids. That is, the groups are differentiated at a highly significant level. The clearest differentiation occurs with the "bright" normal group. This was to be expected: the "bright" normal group was extreme on both intelligence and "sanity". In the case of the paranoid schizophrenic patients, an overlap occurred with the "dull" normals. What seems to have contributed to this are the scores the subjects obtained on variables 1 and 2 (the "standard Raven items", and the "Raven-minus-alternatives", respectively) as was outlined above.

Thus, the discriminant analysis fails to identify correctly the group membership of various individuals. The most plausible interpretation of this fact is that the groups are imprecisely and inadequately defined, and the discriminant analysis has picked this up. (This is precisely what discriminant analysis is capable of, among other things.) Psychiatric classification (for the patient groups) and performance on a quick, verbal measure of intelligence (for the normal groups) were used as the starting point for selecting subjects, but these classifications are themselves suspect. Using a verbal intelligence test as an index for the classification of normal subjects for tasks involving non-verbal performance would appear inappropriate, and iterative revision of the psychiatric classifications by means of repeated use of the discriminant analysis seems to be needed.

Regarding the means of the research groups, it would appear that it is the series induction variables that have most influenced the separation obtained by the discriminant function analysis. It seems variable 5 has had the most influence, with variable 2 having more influence than variable 1. When one views the individual raw scores, however, it is noted that on all variables, wide individual subject differences occurred in each group, mostly as a function of intelligence.

The fact that the research groups are more clearly differentiated on the series induction variables than on the similarity perception variables, does suggest that series induction is the better discriminator of the two. The finding that more differentiation occurs on variable 2 than on variable 1 tentatively suggests that the standard Progressive Matrices items may be compounding series induction and similarity perception tasks, and that it is a better discriminator without the alternative solutions, i.e. without the similarity cues. Obviously, a more detailed statistical analysis than was carried out in this research would be desirable. In particular, the variances of the obtained scores are required, and would be incorporated in any study on a larger sample. As none of the variables are standardized, comparisons between variables are tentative in this sense.

However, it does appear that Progressive Matrices (1938) has similarity perception features included in it. The test appears to be attenuated by these features. That is, the similarity perception features in the test are obscuring the supposed nature of the task - series induction. It is suggested that Progressive Matrices (1938) is confounded with, or weakened by, the superimposed similarity perception tasks. Thus, it appears that using the test simply as an induction task (i.e. uncomplicated by the similarity judgements to be made among the offered alternatives) discriminates better than using the standard form of the test.

Implications for Further Research.

Findings from the research suggest that:

1. The experiment could be repeated using substantially the same method, but with a larger sample of subjects than was possible in the present study. Definite limitations

were imposed on the treatment of the data by the small sample size of this study. A larger sample would enable more meaningful conclusions to be reached.

2. Any investigation following the lines of the present study would need to use more sophisticated, quantified ways of measuring similarity as perceived e.g. Gregson (1969), Höijer (1969), and Sjöberg (1966).

3. It is suggested that iterative revision of the subcategories of schizophrenia is needed, and research on this could be carried out by repeated use of the discriminant analysis.

4. The pattern of results obtained demonstrate that further studies need to be done in an effort to gauge the effect of the similarity perception features that seem to be embedded in the standard form of Raven's Progressive Matrices (1938).

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APPENDIX 1

(a) MATCHING DATA FOR AGE AND INTELLIGENCE

Criterion	Measure	Groups			
		1	2	3	4
Intelligence	Mean	40.5	65.6	43.9	36.4
	Range	14-72	50-76	20-72	21-48
	Std.Deviation	14.14	8.25	13.23	9.02
Age	Mean	35.5	33.3	31.9	35.4
	Range	22-48	20-48	19-45	27-48
	Std.Deviation	9.8	8.61	9.73	7.72
		PS	BN	NPS	DN

(b) SUMMARY OF ANALYSIS OF VARIANCE FOR AGE

Source	SS	df	MS	F
Treatments	109.896	3	36.63200	.419 N.S
Error	3847.084	44	87.43372	
Total	3956.98	47		

(c) SUMMARY OF t-TESTS FOR INTELLIGENCE

Comparisons of intelligence in the four research groups as measured by the W.A.I.S. Verbal subtest; tested for significance by the appropriate 't' test.

1 & 2 Paranoid - "Bright" Normal		1 & 3 Paranoid - Nonparanoid		1 & 4 Paranoid - "Dull" Normal	
t	Sig	t	Sig	t	Sig
5.04	.01	.581	N.S.	.968	N.S.

2 & 3 "Bright" Normal - Nonparanoid		2 & 4 "Bright" Normal - "Dull" Normal		3 & 4 Nonparanoid - "Dull Normal	
t	Sig	t	Sig	t	Sig
4.56	.01	7.91	.01	1.71	N.S.

APPENDIX 2

(a) STIMULI USED IN EACH EXPERIMENTAL MEASURE

Task 1. (Standard Progressive Matrices items)(1)

Set	Item Number
A	5, 8.
B	6, 10.
C	3, 6, 8, 11.
D	1, 5, 7, 10.
E	1, 5, 8, 12.

Task 2. (Arrays only, without alternatives)(1)

Set	Item Number
A	6, 7.
B	7, 9.
C	4, 5, 9, 10.
D	2, 4, 8, 9
E	2, 4, 9, 10.

Task 3. (Alternative solutions only)(1)

Set	Item Number
A	-
B	7.
C	4, 9.
D	2, 5, 8, 10.
E	5.

Task 4. (Individual pieces from Progressive Matrices arrays)(1)

Set	Item Number
A	-
B	6, 9.
C	3, 5.
D	1, 4, 7
E	1, 4, 9

(1) All items in each subtest of the battery were presented in the order in which they appear in Raven's Test booklet (1960).

Appendix 2 (cont.)

Task 5. (Series induction test)

1) ABC DEF GHI ———

2) $\frac{1}{2}$ $\frac{1}{3}$ $\frac{1}{4}$ $\frac{1}{5}$ $\frac{1}{6}$ —

3) 100 81 64 49 36 ———

4) AAT BAT ———

5) z x v —

6) G K O —

7) 100 1 80 2 60 4 ——— ———

8) BUSY BUS ———

9) 2301 3522 4743 ———

10) 0.2 0.4 0.6 ———

11) ABY BCZ CDY ———

12) 5 TENDE 3 END 1 ———

13) 10 100 9 81 ——— ———

14) M N A B O ——— ———

15) SPATE PATE ATE ———

16) 3150 450 90 ——— ———

17) GKM FIJ EGG ———

18) 1 8 32 64 ———

19) FINISH END BEGINNING ULTIMATE LAST ———

20) 12345678 DAUGHTER 18'x'4 DRAG 6'x'8 ———

21) A25 C16 E ———

Appendix 2 (cont.)

22) Give next but one member of the series:

2.7, 4.79, 6.88, 8.97, ———

23) The fifth member is missing below. What is it ?

8 16 26 40 — 100

24) 3ozs. 15ozs. 4lb 11ozs. ———

25) 1 2 4 7 —— ——

26) 0.3 0.6 0.9 —— ——

27) 1 6 30 120 —— ——

28) The difference between 8 and ——

is equal to twice the sum of their ——

minus 141.

29) CHARMED 74635 DREAM 467 ———

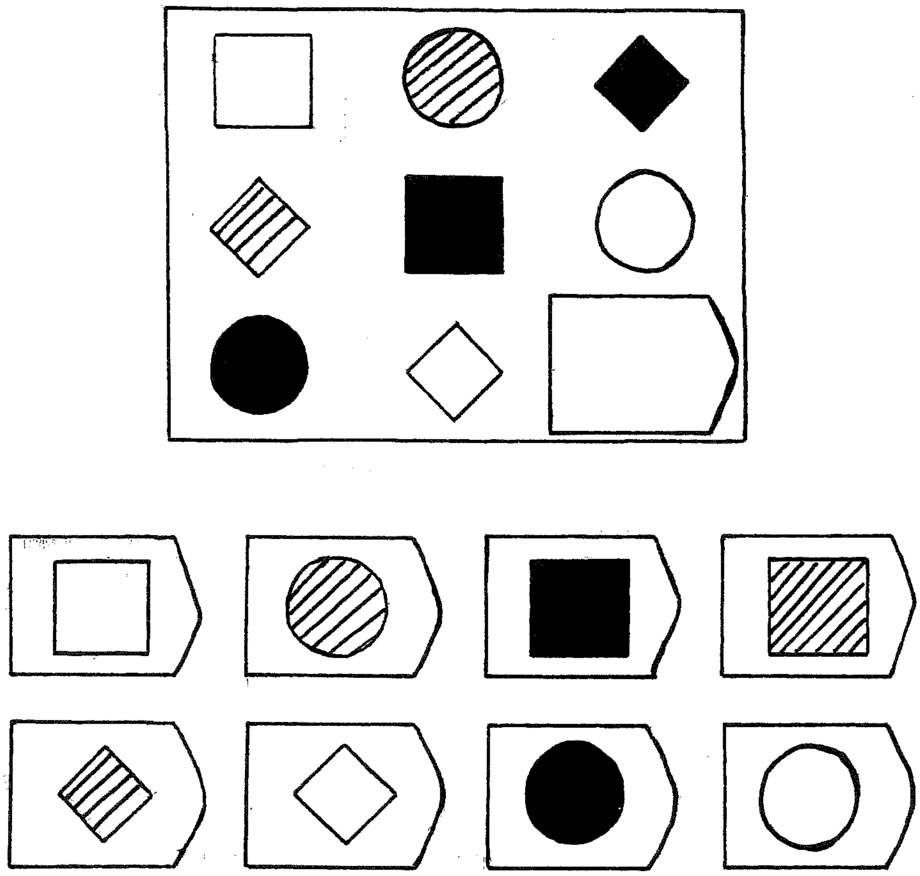
30) 2F 6I 18L 54 ——

APPENDIX 2(cont.)

(b) SCORING PROCEDURE FOR TASKS 3 AND 4.

The logical structure of each item was first determined. The manner in which this was done can be illustrated by the example below.

DIAGRAM 1.*



* This item was used in Task 3.

Appendix 2 (cont.)

In this example, the constituent pieces vary on only two dimensions: shape; and shading. To convert each piece to axiomatic form, shape may be called A, and shading B. Thus, a square becomes A_1, a circle = A_2, and a diamond = A_3. For shading, similarly - blank = B_1, lined = B_2 and black = B_3. For the pieces in the above item, then, the logical structure can be represented as follows:

TABLE 1

MATRIX

1	A_1	B_1
2	A_2	B_2
3	A_3	B_3
4	A_3	B_2
5	A_1	B_3
6	A_2	B_1
7	A_2	B_3
8	A_3	B_1
	A_1	B_2

TABLE 2

ALTERNATIVES

1	A_1	B_1
2	A_2	B_2
3	A_1	B_3
4	A_1	B_2
5	A_3	B_2
6	A_3	B_1
7	A_2	B_3
8	A_2	B_1

Appendix 2 (cont.)

Having obtained the logical structure of each constituent piece in an array, a logical ordering of similarity to the solution piece can be obtained. In this manner, for each piece making up the array, it can be seen how far removed it is from the solution item; that is, whether it is in some dimension the same as the solution item, or whether it is different on all dimensions. Thus, in the present example, the logical ordering of the pieces of the array in terms of their similarity to the solution item would be any combination of 1, 2, 4 and 5, followed by any combination of 3, 6, 7, and 8, since the first four pieces all share one dimension with the solution item, while the others are different on both dimensions.

The logical structure of all items used in Tasks 3 and 4 are outlined in Tables 3 and 4 respectively.

Appendix 2 (cont.)

TABLE 3

THE LOGICAL STRUCTURE OF ITEMS USED IN TASK 3

1. (B_7)*

1)	A_1	B_1
2)	A_2	B_2
3)	A_1	B_2
4)	A_3	B_2
5)	A_3	B_1
6)	A_4	B_1

2. (C_4)

1)	A_1	B_3
2)	A_2	B_2
3)	A_3	B_2
4)	A_2	B_3
5)	A_3	B_1
6)	-	B_4
7)	A_1	B_1
8)	A_3	B_3

3. (C_9)

1)	A_2	B_1	C+
2)	A_2	B_2	C+
3)	A_1	B_0	C+
4)	A_2	B_3	C+
5)	A_3	B_3	C+
6)	A'	B_1	C+
7)	A_1	B_1	C+
8)	A_1	B'_1	C+'

4. (D_2)

1)	A+	B+	C-
2)	A+	B=	C-
3)	A-	B-	C+
4)	A-	B+	C-
5)	A-	B-	C'
6)	A+	B-	C+
7)	A'	B-	C+
8)	A-	B'	C-

* Subscripts refer to item numbers in Raven's test booklet (1965).

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Appendix 2 (cont.)

Table 3 (cont.)

5. (D_5)

1)	A_2	B_2	
2)	A_2	B_3	
3)	A_1	B_1	
4)	A_3	B_2	
5)	A_0	B_1	B_2
6)	A'	B_2'	
7)	A''	B_1''	
8)	A_3	B_3	

6. (D_8)

1)	A_1	B_1
2)	A_2	B_2
3)	A_1	B_3
4)	A_1	B_2
5)	A_3	B_2
6)	A_3	B_1
7)	A_2	B_3
8)	A_2	B_1

7. (D_{10})

1)	B_1	B_3	
2)	A_2	B_1	
3)	A_1	B_3	
4)	A_3	A_2	
5)	A_2	B_3	B_1
6)	A_1	B_2	
7)	A_2	B_3	
8)	B_1	B_2	

8. (E_5)

1)	A+	B-	C-	D-
2)	A+	B+	C+	D+
3)	A+	B-	C-	D+
4)	A'	B-	C+	D-
5)	A--	B-	C-	D+
6)	A-	B-	C+	D-
7)	A-	B-	C+	D+
8)	A+	B+	C-	D-

APPENDIX 2 (cont.)

TABLE 4

THE LOGICAL STRUCTURE OF ITEMS USED IN TASK 4

1. (B_6)*			2. (B_9)		
1)	A_1	B_1	1)	A_1	B_1
2)	A_2	B_2	2)	A_1	B_2
3)	A_1	B_4	3)	A_2	B_1
—	A_2	B_3	—	A_2	B_2

3. (C_3)		4. (C_5)		5. (D_1)	
1)	1	1)	1	1)	A
2)	2	2)	2	2)	A
3)	3	3)	3	3)	A
4)	2	4)	2	4)	B
5)	4	5)	3	5)	B
6)	6	6)	4	6)	B
7)	3	7)	3	7)	C
8)	6	8)	4	8)	C
—	9	—	5	—	C

* Subscripts refer to the item numbers in Raven's test booklet (1965)

Appendix 2 (cont.)

Table 4 (cont.)

6. (D_4)

1)	A_1	B_0
2)	A_1	B_1
3)	A_1	B_2
4)	A_2	B_0
5)	A_2	B_1
6)	A_2	B_2
7)	A_3	B_0
8)	A_3	B_1
	A_3	B_2

7. (D_7)

1)	A_1	B_1
2)	A_2	B_2
3)	A_3	B_3
4)	A_2	B_1
5)	A_3	B_2
6)	A_1	B_3
7)	A_3	B_1
8)	A_1	B_2
	A_2	B_3

8. (E_1)

1)	1
2)	2
3)	12
4)	3
5)	4
6)	34
7)	13
8)	24
	1234

9. (E_4)

1)	A_1	B_1	C_1	D_1
2)	A_1	B_2	C_1	D_2
3)	A_2	B_1	C_2	D_1
4)	A_1	B_1	C_2	D_2
5)	A_1	B_2	C_2	D_2
6)	A_2	B_1	C_2	D_2
7)	A_2	B_2	C_1	D_1
8)	A_2	B_2	C_1	D_2
	A_2	B_2	C_2	D_1

10. (E_9)

1)	A_1	B_1
2)	A_2	B_2
3)	A_2	B_1
4)	A_4	B_3
5)	A_3	B_4
6)	A_3	B_3
7)	A_4	B_1
8)	A_3	B_2
	A_3	B_1

APPENDIX 3

TABLE 1

FACTOR ANALYSIS DATA

CORRELATION COEFFICIENTS

Row 1.	1.00000	0.85543	0.46968	0.60475	0.77828
2.	0.85543	1.00000	0.53601	0.56204	0.79667
3.	0.46968	0.53601	1.00000	0.64954	0.52840
4.	0.60475	0.56204	0.64954	1.00000	0.59009
5.	0.77828	0.79667	0.52840	0.59009	1.00000

EIGENVALUES

3.56523	0.71671	0.35533	0.23271	0.13000

CUMULATIVE PERCENTAGE OF EIGENVALUES

0.71305	0.85639	0.92745	0.97400	1.00000

FACTOR MATRIX (5 FACTORS)

VARIABLE 1	0.89139	-0.31516	0.08360	-0.20552	-0.23845
VARIABLE 2	0.90046	-0.28575	-0.12509	-0.16463	0.25448
VARIABLE 3	0.73552	0.57191	-0.35513	-0.04759	-0.05949
VARIABLE 4	0.79725	0.39744	0.44956	0.01439	0.06414
VARIABLE 5	0.88499	-0.22516	-0.06677	0.40111	-0.02709

APPENDIX 4

SEX, AGE, INTELLIGENCE, AND RAW SCORE DATA FOR ALL SUBJECTS ON ALL TESTS

Paranoid Schizophrenics	Sex	Age*	I.Q*	Test Scores* 1	2	3	4	5
1	M	24	49	10	10	6	6	7
2	M	22	28	9	5	2	5	4
3	M	45	25	3	2	5	3	4
4	M	23	50	13	10	5	5	8
5	M	48	35	5	7	4	5	4
6	M	41	50	8	6	4	6	6
7	F	35	72	10	14	5	4	15
8	F	40	38	4	6	4	7	4
9	F	46	39	3	4	4	6	3
10	F	30	40	3	2	2	3	3
11	F	25	14	5	4	0	2	3
12	F	47	46	4	3	4	6	4

* See Key Page 97

Appendix 4 (cont.)

"Bright" Normals	Sex	Age*	I.Q.*	Test Scores* 1	2	3	4	5
1	M	30	72	15	13	7	9	20
2	M	20	68	13	13	5	8	24
3	M	38	50	6	9	3	4	14
4	M	45	51	11	11	3	4	14
5	M	20	67	12	15	6	9	19
6	M	39	71	15	14	8	10	21
7	F	30	65	8	11	7	6	13
8	F	29	72	4	14	5	8	18
9	F	48	76	11	14	6	7	17
10	F	30	68	8	11	3	4	6
11	F	30	55	9	11	3	4	7
12	F	40	72	13	12	5	8	16

* See Key Page 97

Appendix 4 (cont.)

Nonparanoid Schizophrenics	Sex	Age*	I.Q.*	Test Scores* 1	2	3	4	5
1	M	41	49	8	8	3	7	4
2	M	43	52	4	5	3	4	6
3	M	24	53	16	15	8	8	19
4	M	19	20	5	4	5	6	6
5	M	21	30	8	9	3	4	11
6	M	42	32	8	9	5	3	7
7	F	23	33	7	7	5	7	4
8	F	40	39	7	7	5	6	5
9	F	30	48	7	10	7	7	6
10	F	45	50	9	13	6	8	9
11	F	35	72	11	10	6	6	5
12	F	20	49	6	11	6	6	11

* See Key Page 97

Appendix 4 (cont.)

"Dull" Normals	Sex	Age*	I.Q.*	Test Scores* 1	2	3	4	5
1	M	27	21	4	5	4	3	4
2	M	41	46	7	9	6	5	8
3	M	48	47	11	10	3	4	10
4	M	37	48	6	7	4	5	11
5	M	31	37	7	6	3	6	7
6	M	32	28	5	6	3	5	6
7	F	27	26	4	2	3	5	4
8	F	44	37	4	4	6	4	6
9	F	35	38	8	9	2	5	5
10	F	31	30	5	8	3	4	3
11	F	47	48	10	10	3	5	6
12	F	25	31	5	6	4	4	5

* Key: Age = Age in Years

I.Q.= Raw Score Total on W.A.I.S. Vb. subtest

Test Scores = 1. Standard Raven items
2. "Raven-minus-alternatives"
3. Similarity Perception using Alternatives
4. Similarity Perception using Arrays
5. Series Induction Task