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An Appraisal of Three Scoring Procedures as Discriminators between Good and Poor Problem Solvers

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AN APPRAISAL OF THREE SCORING PROCEDURES AS DISCRIMINATORS BETWEEN GOOD AND POOR PROBLEM SOLVERS.

by

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I. Introduction

The last twenty years, and especially the last decade, have witnessed a tremendous interest in a particular area of cognition, namely the problem solving situation. These attempts to qualitatively describe and quantitatively evaluate the problem solving situation have led researchers to employ various instruments and techniques.

The Loyola Psychometric Laboratory has, since its inception, been deeply concerned with this area of research. Here several instruments have been developed, as well as various methods of quantitatively evaluating performance on these instruments.

The present author has been fortunate enough to assist in much of the recent research conducted at the Loyola Psychometric Laboratory. It was through this contact that the particular problem to be discussed had its genesis.

The research presented in this paper concerns itself with a specific type of instrument and with three different scoring techniques developed and used by Dr. Rimoldi and his staff for the analysis of problem solving performance.

II. Definition of the Problem

Hand in hand with the development of any instrument must coincide the development of a technique to evaluate performance on that instrument. In the present situation such a technique was not lacking. As a matter of fact, several different techniques or scoring procedures were born in an attempt to analyze performance on this type of problem or instrument. The next point of concern, given the problem and several methods of evaluation, is which method best evaluates or discriminates performance in the problem. It is on this last point that the present research focuses.

Of the various techniques available for evaluating performance on this instrument, three which had recently been gaining prominence were selected for investigation and critical appraisal.

The specific aim of this research, then, is to analyze the three scoring procedures and determine which is the best discriminator between good and poor problem solvers.

At this point, it is important to note that this evaluation of good or poor problem solving ability is based on the process of the individual problem solver and not the accuracy of his solution. Each of these methods, then, attempts to characterize quantitatively the process of a problem solver using this type of instrument. The question, then, is which quantitative method of characterizing the process best discriminates between good and poor problem solvers.

In the foregoing definition of the problem a subtle point has seemingly been overlooked, i.e., whether the instrument measures problem solving ability. To make the research more meaningful it must be assumed that it does. Otherwise, the research would only indicate which of the scoring procedures best discriminates performance of two groups on a particular instrument, the latter measuring what it may. However, the assumption is not actually a dangerous one, having much evidence supporting its tenability.

It was necessary to introduce this latter consideration because in the design, the subjects will be divided into two groups, an upper and lower, on the basis of criteria purported to measure problem solving ability. Granting the above assumption then would allow a judgment as to which scoring procedure would best distinguish the two groups and, thus, be the best discriminator between good and poor problem solvers.

III. Review of Related Literature

A. General Considerations:

As early as 1926 Ruger (24) had made investigations in the problem solving area by his study of the dynamics of multidimensional mechanical puzzles. He was interested in the method used by subjects in arriving at skillful behavior with these puzzles. His results indicated that for the most part the subjects operated in a random fashion. No efforts were attempted in the direction of quantitative evaluation other than the length of time spent at various levels in the solution of the puzzle.

A short time later Waters (29) also devoted attention to the solution of a puzzle type problem. He was interested in the differential effect of different types of instruction on the solution of a problem. Therefore he was interested in the training aspect of solving a problem. His method of evaluation was descriptive as a result of his observations. In short, he found that a concrete suggestion as to the principle involved in the solution of the puzzle was more beneficial than demonstration of correct procedure or letting the subject discover the principle by his own errors.

Doyle (4) makes use of the learning curve concept from learning theory as a helpful technique in the analysis and comparison of performance in various types of problems. He complemented his use of the learning curve with descriptive protocols by which he distinguished performance in terms of inductive discovery and trial and error.

About 1945 the work of Max Wertheimer in the field of problem solving began and this ignited a renewed and vigorous interest in the topic. For him a problem situation has a goal, obstacles to the goal, and no clear perception of the means to reach the goal. An individual's approach to the problem determines whether he is a productive or reproductive thinker. Wertheimer (30) describes reproductive thinking as a mere reproduction of past experience. It is mostly passive in nature. Productive thinking, on the other hand, is active. It demands a mental struggle, a recentering, reorganizing, and restructuring. This last concept, it will be seen later, the pulling-out method attempts to account for. The results of productive thinking, then, is a new product, not just a reproduction of past learning. Wertheimer's approach was a qualitative one. He did not attempt quantification in characterizing the process.

Duncan (5) has a related idea of the problem solving process. He too finds various possible approaches to a problem. For him, however, real problem solving differs from rote learning or conditioning. He would like to visualize a dimension with discovery at one end and conditioning on the other. Problem solving should be high on the discovery end of the dimension.

Bloom and Broder (1) presented another qualitative study. Their methods were similar to Wertheimer's in that they used retrospection and introspection, i.e., reports of the subject. They did introduce a new technique and that was the use of tests whose various solutions could specify the solver's approach or process. Through their emphasis on the process, research in problem solving was stimulated as well as the development of scoring procedures to aid in the characterization of process. Among their findings was the special ability of the successful problem solver to understand the nature of the problem and to attack it in its own terms. They found, on the other hand, that the unsuccessful problem solver lacked a sense of direction. Aptitude scores and grades in comprehensive examinations were their criteria for successful and unsuccessful problem solvers.

Earlier than Bloom and Broder, Karl Duncker (6) had studied the process of problem solving with his method of "thinking aloud" by the subjects. This method differed from introspection in that the subjects' attention was directed to the problem rather than to his own thinking processes. This, too, supposedly was an improvement on retrospection since Duncker's technique did not depend on the subject's memory of his process. This, though, was also a qualitative approach.

Heidbreder (12) had studied adults and children in the problem solving situation very early, but the main interest here was to show that thought processes in general developed differentially through various ages. A limited conclusion was possible based on the reasons offered by the subjects for their responses.

Tate, Stanier, and Harootunian (26) constructed a battery of tests to distinguish good and poor problem solvers. One of their tests was the "Thought Problems," which is one of the criteria for this research. Their criteria received empirical validation by significant differences between good and poor problem solvers in "nearly all tests where quality of response, accuracy, or judgment is required." Another finding may be interesting in the light of the different contents of the two problems used in this research. They discovered that "the more complex the task or the more restricted the requirements, the greater their superiority (the good problem solvers)." Two basic problems with four variations each are used in this study and in the light of the above remarks differential performance on the more difficult problem and variation should be observed.

B. The Instruments:

A technique similar to the one employed here was utilized by Bryan (2) and by Glaser, Damrin, and Gardner (9). Both were employed in the area of electronic trouble shooting.

Bryan's technique, called Automasts, offers choices of answers to the problems at different intervals. The result is that the obtained data does not give a true picture of the process as it takes place in the subject. An evaluation was made in terms of correct solutions, times, number of steps, use of clues, and guesses. This, therefore, is not really an evaluation of process.

Glaser, Damrin, and Gardner's method is referred to as the Tab Item Technique. This is applicable, also, beyond the area of electronic trouble shooting. The subject is presented with a malfunction, a series of possible check procedures, and the answers which are covered by tabs. Scoring methods for this device have not been clearly defined. One suggestion is the number of checks employed. Another was to weight the check procedures according to their relevance in isolating the defective unit. This last bears some resemblance to the techniques described in the next chapter, without, however, their more complete development.

The instrument used in this research was devised by Rimoldi (17) for the study of the diagnostic process in medical students. The focus was on the process of diagnosis rather than on the final diagnosis itself. This was accomplished, in general terms, by recording the information requested by the testee in his attempt to reach a solution. Several follow-up studies resulted: Rimoldi (18) on the process, Rimoldi, Devane, and Haley (19) on approaches to characterizing the process, and a summary of the whole medical study by Rimoldi, Haley, and Fogliatto (21).

The next step was the application of the technique in fields other than the medical. Examples of this are: Tabor (26); Mohrbacher (16); Gunn (11); Rimoldi, Meyer, Meyer, Fogliatto (23); Fogliatto (8); and Rimoldi, Haley, Fogliatto, Reyes, Erdmann, and Zacharia (20). These other areas include such fields as Rorschach interpretation, organic pathology in child guidance and appraisal of personality parameters. A great deal of work has also been done with the instrument for the purpose of training in problem solving.

The exact type of instrument used in this study is described in Rimoldi, Haley, Fogliatto, Reyes, Erdmann, and Zacharia (20). "The subject is presented with a problem and a set of cards containing questions that he may ask in order to reach a solution. The subject is free to choose any card in any order he wishes. The corresponding answer to each question is written on the reverse side of the card. When the subject thinks that he has gained sufficient information to solve the problem correctly, he stops selecting cards and gives his solution. The experimenter records the questions in the order in which they were asked. These problems have no time limit."

This study found this instrument to be valuable in distinguishing individual differences in problem solving ability (see also Fogliatto (7),) in characterizing the process of the problem solver better than final solutions which clouds any individual differences, and in various aspects of using the problem as a training device. In short the instrument provided an experimental basis for the interpretation of the problem solving process.

C. Scoring Procedures:

One of the early methods of analyzing the performance (process) of a subject on the instrument used in this research may be called the group method. This procedure, as described in Rimoldi (17) utilizes the frequency of selection of a specific question in a specific order. These frequencies are then converted into proportions. Rimoldi, Haley, Fogliatto (21) note that these proportions may be proportions of the total number of responses or of the total number of possible responses i.e., the product of the number of questions and the number of subjects in the group. This latter consideration assumes that questions not asked also give valuable information. A table of porportions may be constructed and accordingly an individual sequence of questions evaluated to obtain a single score for each individual. The group method using the total number of possible responses is one of the procedures employed in this research. This method has been found valuable when one wishes to evaluate an individual in terms of a group, or to evaluate a performance in terms of a criterion group as in Rimoldi, Haley, and Fogliatto (21).

In a 1963 Loyola Psychometric Laboratory publication, Rimoldi, Fogliatto, Haley, and Erdmann (22) a new method of scoring was introduced. This method differed from the group method in the construction of the table of proportions. Once it was established the evaluation of a sequence was identical to the group method. This technique may be referred to as the <u>schema method</u>. This method established the norms (table of proportions) on the basis of the logical relationships or structure of the problem itself. The structure or schema of the problem dictates what possible sequences may occur. Given all the possible sequences, the tabulation of the frequencies for a particular question in a particular order is straightforward, and the conversion to proportions is accomplished as above. The rationale for this technique is based on the properties of the problem alone; therefore, an individual's score is based on an objective standard and not given in terms of how the rest of the group performed. The criterion for acceptability of a normative sequence is uniqueness and conformity to the schema or structure of the problem. Uniqueness refers to both questions and the order of the question. The schema method is the second scoring procedure under investigation.

The final scoring procedure has not as yet been set forth in publication but work has been done with it in the Loyola Psychometric Laboratory, and it appears to have great promise. This technique rests on the norms that are established by the schema or structure of the problem. Therefore, the table of proportions for this technique and for the schema method would be identical. The two methods differ in their application of the norms to the individual sequence. This will be discussed at length in the next chapter. This third procedure is called the <u>pulling-out method</u>.

The literature concerning these scoring procedures is obviously limited to Loyola Psychometric Laboratory publications because these techniques have originated and been developed here and have not been available long enough to expect outside published research.

IV. Description and Application of the Three Scoring Procedures

A. Group Method

The group method was chronologically the first scoring procedure used in the evaluation of performance on the instrument used in this research. Scores based on this method evaluate individual performance in terms of a group. This group may either be the group which had attempted a solution of the problem in question or it may be an outside group which is used as a criterion group, e.g., a panel of experts. Any estimation of individual performance, therefore, must be done in terms of some group and is therefore a relative estimation.

The first step in the application of the group method of scoring is the construction of the table of frequencies. Since every card or question in a problem is numerically identified and since the sequence of questions used by each subject has been recorded, it is possible to determine the number of times each question has been selected in a particular order by the entire group. When this frequency has been computed for every question in every order utilized (the orders cannot, of course, exceed the number of questions in a given problem) then a table such as the one in Table 1 will result.

TABLE 1

TABLE OF FREQUENCIES

	Questions				
Order	1	2	3	4	Σ
1	20	3	1	1	25
2	4	16	2	0	22
3	1	4	15	0	20
4	0	0	4	13	17
0	0	2	3	11	16
Σ	25	25	25	25	100

TABLE 2

TABLE OF PROPORTIONS

	Questions				
Order	1	2	3	4	Σ
1	.20	.03	.01	.01	.25
2	.04	.16	.02	.00	.22
3	.01	.04	.15	.00	.20
4	.00	.00	.04	.13	.17
0	.00	.02	.03	.11	.16
Σ	.25	.25	.25	.25	1.00

Notice that question #1 was chosen in the first order 20 times and question #4 was neither chosen second nor third by anyone in the group. The total or sum for the first row or order indicates the number of individuals in the group, i.e., 25. This is true because for anyone to perform on the instrument he must at least choose one card or question. Observe also the row on the order dimension marked "0". The frequencies in this row indicate the number of individuals who did not select that particular question at all in their sequence. The zero order, as it is called, is included so that some recognition is made in this procedure for the questions which are not asked. This idea assumes that not only what is asked is important for the evaluation of performance, but also what is not asked. Therefore, the total responses in this table is 100 or the total number of possible responses. The number of affirmative responses was 84 and the zero order responses, 16. The total number of possible responses is equal to the product of the number of subjects in the group and the number of questions given in the problem. This number is used as the denominator for determining the proportions given in the cells of Table 2, thus accounting for the questions not asked in the ultimate evaluation of performance.

Table 2 is the conversion of Table 1 into proportions and thus becomes the norms upon which the scoring of an individual sequence depends. A single value, therefore, may be given to any sequence of questions which an individual may follow by finding the sum of the proportions corresponding to the ordered questions given by the particular sequence. For example, the sequence, 1, 2, 3, 4 would have the value .64, or .20 + .16 + .15 + .13 = .64. In the same way the sequence 3, 4, 1, 2 would give a score of .02 or .01 + .00 + .01 + .00 = .02. In this manner each subject was scored for the various problems used in this study to obtain evaluation of performance according to the group method.

In summary, this technique implies that importance should be given to the questions selected, the order of selection, and to zero order responses. Finally, this evaluation is done in terms of a group.

B. <u>The Schema Method</u>

This technique, as stated above, bases the construction of the norms or table of proportions on ideal solutions to the problem. These ideal solutions are dictated by the logical relationships within the problem which can be graphically presented by a schema, sometimes called a tree. For further explanation of this analysis see Loyola Psychometric Laboratory publication No. 28, "A Program For the Study Of Thinking" by Rimoldi, Fogliatto, Haley and Erdmann (21). Having established the ideal sequences, one considers them just as observed sequences in the group method. A table of frequencies and a table of proportions including the zero order is computed using as a basis all the ideal sequences. The scoring of an individual observed sequence, then, is accomplished exactly as in the group method with the values coming from the norms or table of proportions generated by the ideal sequences.

In this method, then, the individual's performance is evaluated according to an objective standard which has been established by the logical relationships found in the specific problem. Consideration of the zero order is included also in this technique. Theoretically, its advantage over the group method lay in the fact that a score in this method need not be viewed from a relative standpoint.

C. The Pulling-Out Method.

This technique uses the same norms as the schema method and differs from it only in the application of the norms to the individual observed sequence. This method attempts to account for any restructuring or "late" understanding of the nature of the problem by the performer. In other words the benefit of the doubt is given to the subject in the evaluation of his performance.

The procedure involves a kind of matching of the observed sequence with one of the ideal sequences. In other words the scorer determines the ideal sequence which best approximates the observed sequence and will therefore maximize the evaluation of the performance. Obviously there are certain rules according to which this is done.

The first step is to remove all the irrelevant (as far as the ideal sequence is concerned) questions from the observed sequence. It is important to maintain the order of the questions as selected by the subject.

What results may be a complete or partial ideal sequence. In order to be complete the order of the relevant observed questions must duplicate the ideal sequence. If this occurs, then one finds the value of the ideal sequence which would maximize the score for the observed sequence. This completes the second step in the determination of a final score for the pulling-out method. The third and final step is to divide the value, found at the completion of the second step, by the number of questions of the original observed sequence, i.e., before any pulling-out of irrelevant questions.

The sequence resulting from the pulling-out of irrelevant questions, however, may only partially duplicate an ideal sequence. In this case credit is given for the partial sequence. This value is again divided by the number of questions of the original observed sequence to determine the final score.

An example of the technique is in order to clarify the application. Suppose the observed sequence 1, 6, 3, 8, 2, 10. Assume that the ideal sequences of the problem are 6, 3, 10 and 10, 3, 6. Pulling-out the irrelevant questions leaves 6, 3, 10 for the observed sequence. This exactly duplicates the ideal sequence 6, 3, 10 so the final score is the value of the 6, 3, 10 sequence in the schema norms divided by 6 (the number of questions from the original observed sequence). Had the original sequence been 1, 10, 8, 3, 2, 6, then the ideal sequence 10, 3, 6 would have been duplicated with results exactly as above.

In most instances the ideal sequence will not be exactly duplicated. Assuming the observed sequence 1, 6, 7, 8, 2, 3, 5, the ideal sequence approximating it best is 6, 3, 10. However there is only partial approximation here, namely 6, 3. The final score is, therefore, the value of 6, 3 in the schema norms, divided by 7 (in this case). The remnants of the observed sequence following the pulling-out of irrelevant questions must follow the order of one of the ideal sequences so that an observed sequence without 3 and 6 in it would obtain no value at all. If either occurred at the end of the sequence only that question would contribute any value. For instance the observed sequence 1, 3, 8, 4, would have zero as a final score. The sequence 1, 3, 6, 5, 7 would have the value of 6 in the first position in the schema norms divided by 5.

This technique, in summary, works to the advantage of the subject by giving him the benefit of the doubt as far as the occurrence of restructuring or reshaping the problem is concerned. It also incorporates the advantages of the schema method and adds the feature of differentially penalizing the subject for the prodigal selection of cards.

V. Procedure

A. Subjects:

The subjects used in this study were twenty-two freshmen (male) students of Loyola University, Chicago, Illinois. All the subjects participated in the research on a volunteer basis. As will be seen from the design of the research, it was not necessary to attempt to obtain any particular sample representative of a population. All that was required was the willingness and availability of the subjects to participate.

B. Instruments

a) General description:

The instruments employed in this research are two types of problems, with four variations of each type. Therefore, a total of eight problems were administered. They were problems 31A, 31B, 31C, 31D, and 35A, 35B, 35C, 35D. All eight problems are of the type that presents a verbal definition of a problem situation together with a series of questions printed on separate cards. Each card contains a question on one side and the answer on the reverse side. The questions and answers contain information relevant to the problem situation, some of which is necessary for reaching a solution. The subject, in pursuing a solution, selects the cards he feels will give him the information needed for a solution and also records the order in which he chose to have the various questions answered. This establishes a sequence for each individual which describes his process, and, also, supplies sufficient information for the experimenter to apply the three scoring procedures.

In identifying the problems, the number refers to a particular type of schema or framework or set of logical relationships upon which is superimposed various contents, identified by the letters. "A" presents the problem in concrete every-day situations. "B" presents the problem in abstract language or by means of letters that represent symbolically, non-specified concrete objects. In "C" the letters are presented in a negative manner. In all three of these forms of the one structure or schema, the answers are given in numbers. "D" is similar to form "B" in that letters stand for non-specified concrete objects in the questions, but, the answers are given in letters. The idea of quantity is, therefore, algebraic rather than numerical in this last form.

One will notice also that two different types of problem structure, namely 31 and 35, are used. The two structures represent a rather simple (31) and somewhat more complex type of problem (35).

It is possible, on the basis of the foregoing, to define two levels of difficulty. One, called intrinsic, refers to the level of difficulty describing the complexity of the structure or logical relationships of the problem. The other refers to the content superimposed on the structure and describes its level of familiarity. This latter is called extrinsic difficulty.

Since it is not the express purpose of this research to study extrinsic and/or intrinsic difficulty, one may wonder why examples representing the various possibilities were included. The answer lies in the attempt to study the sensitivity of the three scoring procedures in a situation which would reflect the various instruments to which they might be applied. Therefore, the analysis of the findings will not be focused expressly on the two structures and their forms but on their interaction with the scoring procedures.

b) Administration:

Each of the eight problems were administered to the twenty-two subjects individually. They received the tests in numerical-alphabetical order, beginning with problem 31A. This problem represents the simplest structure and form (content) of the group. Each individual had as much time as he wished for each problem and only as many problems were administered at one session as could be comfortably handled by the subject in one hour. The testing continued at intervals of a week until all eight problems had been administered to each individual.

c) Methodology and design:

The twenty-two subjects were divided into an upper and lower group with an equal number in each. The division was made using as criteria, the Raven's Progressive Matrices Tests and Thought Problems, Part I. Some provision was attempted, therefore, for both reasoning and problem solving ability in the separation into two groups. Each subject was ranked according to a simple composite of the two criteria and the highest eleven formed the upper group with the others comprising the lower group. Since, according to the design, the two groups did not have to be significantly different - no check was necessary on the method of division. This formation of the groups was done subsequent to the collection and scoring of the data so as to introduce no bias in those processes.

The performance of each subject, as indicated by his sequence of questions, was scored in each of the three procedures under investigation.

For each subject, then, there was a total of 24 scores, 8 for each procedure since he had taken 8 problems. Further, this means that each problem for any one subject had three scores, one reflecting the evaluation for each method. For each group there were 264 scores. This represented the performance of 11 subjects in 8 problems being scored three different ways.

At this point a four-way classification of the analysis of variance was computed for each group to determine possible significance for the main effects and pertinent interactions. The main effects, rows, columns, blocks, and squares, were subjects of a group, forms of a problem, the two structures, and the three scoring procedures respectively. The row dimension was an irrelevant dimension since it involved individual differences and these were not of interest as such in the research. The variance involved in this dimension, of course, proved quite valuable when considering the error estimate for measures of significance.

The finding of a significant variance for the main effect scoring procedures (squares) would further indicate that a "t" test for differences between the two groups on each scoring procedure would be meaningful. To distinguish the relative discriminative ability of each scoring procedure, it would not be necessary to find significant differences between the upper and lower groups but only to observe differences between these groups and assess the magnitude of these differences for each procedure.

Finally, the various interactions were graphed to describe the differential sensitivity of the scoring procedures with the simple and complex structures under the various forms A, B, C, and D.

VI. Analysis and Discussion of the Findings

A. Results of Analysis of Variance:

In general the results of the analysis of variance for both groups indicate that the variance attributable to the scoring procedure dimension (squares) is highly significant in each case. This indicates that for both the upper and lower group, evaluations of performance by the three scoring procedures would differ widely.

Specifically, the relevant information relating the results of the analysis of variance for the upper and lower group, is presented in tables 3 and 4, respectively. Table 3 indicates significant variance for the main effects, forms of the test (columns), and scoring methods (squares), both beyond the .001 level of significance. This indicates that for the upper group, performance is sensitive to the various forms of these tests, and suggests the possibility of successful differentiation of performance by these forms at both levels of intrinsic complexity as defined by the two schemata. As alluded to above, the high significance demonstrated by the scoring procedures dimension shows that a different description of performance may be expected by the application of the various methods to this data. The "F" ratio for the two types of schemata (blocks) did not approach any significant level, however, and thus suggests that for this superior group no differentiation by means of tests can be expected between these different levels of intrinsic difficulty. This is very interesting in the light of the findings for the inferior group where the "F" ratio was found to be significant, thus implying differentiation for the performance of this group between the two intrinsic levels of difficulty. Otherwise, the main effects of the lower group showed results similar to the upper group, except that in the lower group the levels of significance only reached the .01 level for the forms (A, B, C, D) dimension, suggesting that perhaps poorer performance on the various forms tends to be more homogeneous than better performance which may be more sensitive to differences in extrinsic difficulty.

TABLE 3

RESULTS OF ANALYSIS OF VARIANCE FOR UPPER GROUP

Source	Sum of Squares	df	Variance Estimate	F Ratio	Level of Significance
Main effects:					
R(Subjects	.01445	10	.00144		
C(forms A,B,C,D)	.05752	3	.01917	17.4273	.001
B(Schemata)	.00007	1	.00007	.1014	none
S(Scoring Procedures)	.56737	2	.28368	578.9388	.001
Two-way Interaction:					
RC	.03311	30	.00110		
RB	.00693	10	.00069		
RS	.00972	20	.00049		
CB	.03688	3	.01229	7.2722	.001
CS	.08303	6	.01350	36.4865	.001
BS	.02872	2	.01436	57.44000	.001
Three-way Interaction:					
RCB	.05082	30	.00169		
RCS	.02224	60	.00037		
RBS	.00494	20	.00025		
CBS	.06082	6	.01014	23.58140	.001
Four-way Interaction:					
RCBS	.02587	60	.00043		

TABLE 4

RESULTS OF ANALYSIS OF VARIANCE FOR LOWER GROUP

Source	Sum of Squares	df	Variance Estimate	F Ratio	Level of Significance
Main Effects:					
R(Subjects)	.03700	10	.00370		
C(forms A,B,C,D)	.01831	3	.00610	5.0833	.01
B(Schemata)	.01244	1	.01244	17.2778	.01
S(Scoring Procedures)	.64442	2	.32221	315.8922	.001
Two-way Interaction:					
RC	.03596	30	.00120		
RB	.00717	10	.00072		
RS	.02035	20	.00102		
CB	.02690	3	.00900	7.6271	.001
CS	.06990	6	.01165	29.1250	.001
BS	.06215	2	.03108	55.5	.001
Three-way Interaction:					
RCB	.03553	30	.00118		
RCS	.02421	60	.00040		
RBS	.01126	20	.00056		
CBS	.05066	6	.00844	22.2105	.001
Four-way Interaction:					
RCBS	.02312	60	.00038		

Returning to the analysis of the upper group we find significant variances for all the relevant interactions beyond $p < .001$. Remember that the subjects dimension (rows) involved individual differences and that, therefore, the relevant main effect (rows) and interactions were not of concern for this analysis. The forms by structures (columns x blocks) interaction indicates differences between the two sets of forms, one set for each schema or structure. The interaction is significant because the forms for one structure do not maintain a parallel relationship with the forms of the other structure. Provided all other things were equal except the intrinsic difficulty of the structure, one would expect this parallel relationship between the two structures with the various forms. However, training seems to play an important part here in that, as seen from the means of table 5 and corresponding graph in figure 1, the first acquaintance with the B form seems to have caused much more difficulty than the second meeting in 35B. As a matter of fact, performance on 35B and 35D were both better than performance on the previously experienced but simpler problem structure 31B and 31D. It thus appears that training overcame the increased level of intrinsic difficulty for the two schemata. This same phenomenon is similar in the lower group where significance is found for the forms by schemata (C X B) interaction also at the .001 level. But, as seen in table 6 and figure 2, the parallel relationship is almost maintained except for form B where the situation is like the upper group. Here, however, the difference in group ability seems to have precluded the better performance in the D form (35D) at the second acquaintance with this form. In general, considering both groups together, performance seems to be better on the less complex level of intrinsic difficulty, as would be expected from the nature of problem construction.

TABLE 5

MEANS OF THE INTERACTIONS OF FORMS (A,B,C,D) BY SCHEMATA (31,35) FOR THE UPPER GROUP

	Forms			
Schemata	A	B	C	D
M31	.10144	.04249	.10399	.08808
M35	.06999	.07708	.09668	.08810

TABLE 6

MEANS OF THE INTERACTIONS OF FORMS (A,B,C,D) BY SCHEMATA (31,35) FOR THE LOWER GROUP

	Forms			
Schemata	A	B	C	D
M31	.09799	.06154	.10666	.09482
M35	.06447	.08095	.08122	.07945

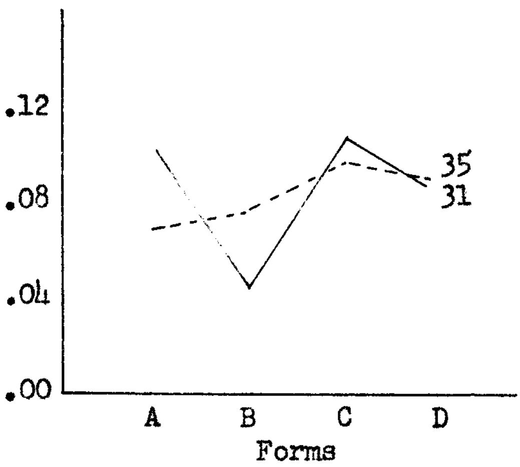

FIGURE 1

FORMS BY SCHEMATA INTERACTION FOR THE UPPER GROUP

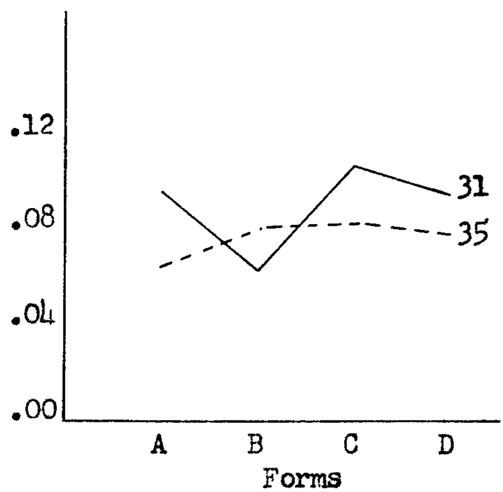

FIGURE 2

FORMS BY SCHEMATA INTERACTION FOR THE LOWER GROUP

The interaction forms of the structure by scoring procedures (C X S) also, had a significant "F" ratio for both groups beyond $p. < .001$. Here the interaction as seen in table 7 and figure 3 for the upper group, and in table 8 and figure 4 for the lower group, seems to be quite similar. The obvious exception is the performance on form B of the lower group as described by the group method. This finding seems to lend credence to the interpretation of the lower level of significance for the forms (columns) dimension where it was suggested that poorer performance would be more homogeneous than better performance. Since the group technique involves scoring according to the group performance, individuals in a poorer, more homogeneous group would receive higher scores because of the homogeneity of the group. The homogeneity of the poorer group may also be expected to increase as the difficulty (extrinsic) increases. This, then, may be suggested as the explanation for the continuous ascending curve of the poorer group according to the group method.

In general, in the forms by schemata interaction, the schema method and the pulling-out method tend to react very similarly. The fact that the pulling-out method is represented by flatter curves for both groups is merely an artifact of the scale in that each unit of difference in a score is more meaningful because of the division by the number of questions in the sequence. The majority of the interaction is accounted for by the different interpretation of performance by the group method among the various forms. A plausible explanation was offered for this above.

The third relevant interaction, structures by scoring procedures (B X S) is also significant beyond the .001 level for both groups.

TABLE 7

MEANS OF THE INTERACTION OF SCORING METHODS (GROUP, SCHEMA, PULLING-OUT) BY FORMS (A,B,C,D) FOR THE UPPER GROUP

Scoring Methods	Forms A	B	C	D
MG	.11093	.10113	.14646	.17759
MS	.11308	.06649	.12243	.07544
MP	.03313	.01174	.03210	.01123

TABLE 8

MEANS OF THE INTERACTION OF SCORING METHODS (GROUP, SCHEMA, PULLING-OUT) BY FORMS (A,B,C,D) FOR THE LOWER GROUP

Scoring Methods	Forms A	B	C	D
MG	.11264	.12434	.14141	.17748
MS	.10499	.07551	.11689	.07170
MP	.02606	.01389	.02353	.01223

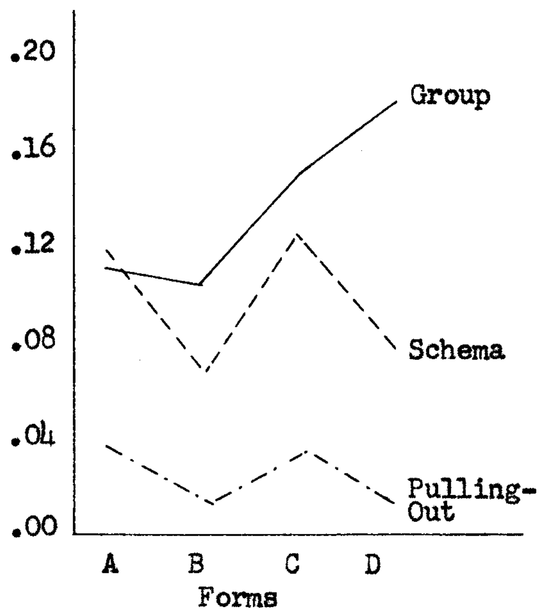

FIGURE 3

FORMS BY SCORING PROCEDURES INTERACTION FOR THE UPPER GROUP

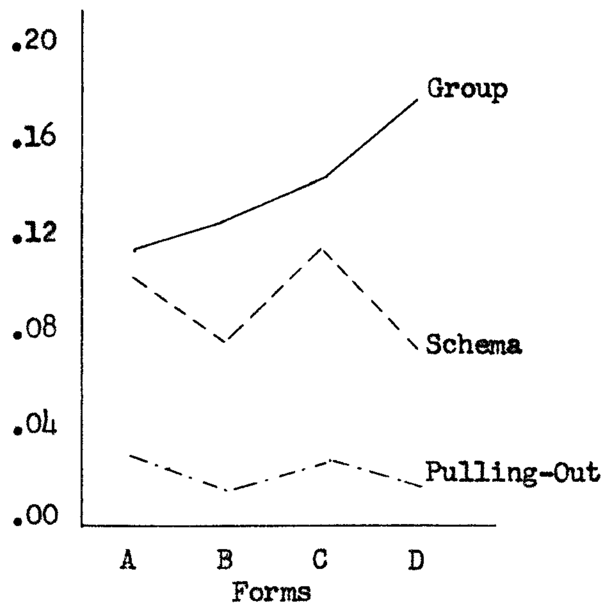

FIGURE 4

FORMS BY SCORING PROCEDURES INTERACTION FOR THE LOWER GROUP

TABLE 9

MEANS OF THE INTERACTION OF SCORING METHODS (GROUP, SCHEMA, PULLING-OUT) BY SCHEMATA (31,35) FOR THE UPPER GROUP

Scoring Methods	Schemata 31	35
MG	.14701	.12105
MS	.08181	.10690
MP	.02317	.02093

TABLE 10

MEANS OF THE INTERACTION OF SCORING METHODS (GROUP, SCHEMA, PULLING-OUT) BY SCHEMATA (31,35) FOR THE LOWER GROUP

Scoring Methods	Schemata 31	35
MG	.16707	.11087
MS	.08465	.09989
MP	.01904	.01882

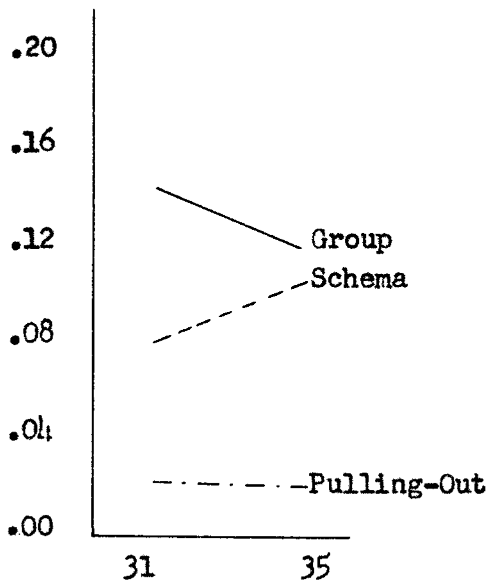

FIGURE 5

SCORING PROCEDURES BY SCHEMATA INTERACTION FOR THE UPPER GROUP

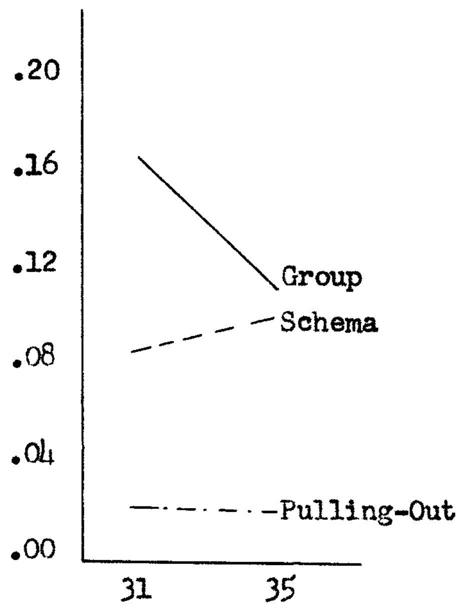

FIGURE 6

SCORING PROCEDURES BY SCHEMATA INTERACTION FOR THE LOWER GROUP

Table 9 and figure 5, and table 10 and figure 6 present the analysis of this interaction for the upper and lower groups respectively. The same type of relationship prevails for both groups. The group and pulling-out techniques both indicate lower performances for the more complex structure. The schema technique indicates the opposite result. In terms of what has been said formerly regarding the group technique, this may appear contradictory. However, it must be remembered that previously the analysis was for extrinsic difficulty whereas now the question revolves around intrinsic difficulty only. Here all differences due to forms have been suppressed because of the collapsing of the forms dimension. Before, in the forms by scoring methods (C X S) interaction, all differences due to structures had been suppressed because of the collapsing of the schemata dimension. Because of these considerations one would expect the phenomenon of homogeneity of poorer performance in the various forms to be suppressed. This occurs because the variance due to the forms of a schema does not contribute to this interaction (B X S). The picture presented by the schemata by scoring methods (B X S) interaction now limits the phenomenon of homogeneity of poor performance to a particular level of intrinsic difficulty. Perhaps familiarity with the structure may also account for some of the homogeneity.

There also remains the differences between the three techniques for the two structures. The dissenting description is offered by the schema method which imposes no penalty for the number of irrelevant questions asked. One would expect more irrelevant questions to be employed by the subjects in a structure of greater difficulty and if such is not considered by the technique this could easily account for the discrepancy found.

The remaining interaction, a three way interaction, is also significant at the .001 level of confidence for both groups. As with almost all three-way interactions, interpretation is well nigh impossible and at the least dangerous and prone to error. Suffice it to say that a significant variance is found for the triple interaction of forms of the test, the two structures, and the three scoring techniques. Table 11 and figure 7 and table 12 and figure 8 present the data of this triple interaction.

B. Results of the "t" test.

To return to the express purpose of this study, a significant variance was attributable to the squares (scoring techniques) dimension. It was therefore meaningful, since they differed among themselves as evaluators of performance, to determine which is the most sensitive to differences between the two groups. For this purpose a one-tailed "t" test of significance was run between the two groups on each scoring procedure to determine and assess differences according to the particular procedure. The formula for "t" applied was that applied in the case of the difference of means for uncorrelated groups. The error estimate utilized was obtained from the variance estimates of the subjects by scoring methods interaction in the analysis of variance as suggested by McNemar (14).

The results are shown in Table 13 below where it can be seen that the pulling-out technique is the procedure which is most sensitive discriminator between the upper and lower groups, as established by the criteria of selection.

TABLE 13

MEAN DIFFERENCES, "t" VALUES, AND LEVELS OF SIGNIFICANCE FOR THE THREE SCORING METHODS

Methods	Mean Differences	"t" Values	Levels of Significance
Group	-.03950	-3.214	none
Schema	.01670	1.359	none
Pulling-Out	.02497	2.032	$p < .05$

TABLE 11

MEANS OF THE INTERACTION OF THE SCORING METHODS (GROUP, SCHEMA, PULLING-OUT) BY FORMS (A,B,C,D) BY SCHEMATA (31,35) FOR THE UPPER GROUP

	Schemata							
	31				35			
	Forms				Forms			
Scoring Methods	A	B	C	D	A	B	C	D
MG	.13121	.08930	.14345	.22409	.09065	.11297	.14948	.13110
MS	.12727	.03409	.12727	.03863	.09889	.09889	.11760	.11225
MP	.04583	.00409	.04124	.00151	.02042	.01939	.02296	.02094

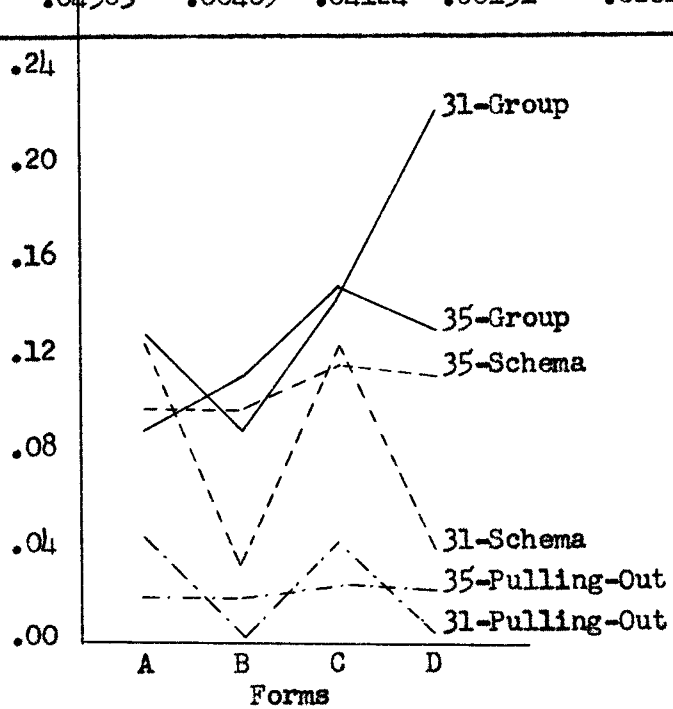

FIGURE 7

FORMS BY SCHEMATA BY SCORING PROCEDURES INTERACTION FOR THE UPPER GROUP

TABLE 12

MEANS OF THE INTERACTION OF THE SCORING METHODS (GROUP, SCHEMA, PULLING-OUT) BY FORMS (A,B,C,D) BY SCHEMATA (31,35) FOR THE LOWER GROUP

	Schemata							
	31				35			
	Forms				Forms			
Scoring Methods	A	B	C	D	A	B	C	D
MG	.14069	.12921	.16241	.23595	.08460	.11947	.12040	.11900
MS	.12045	.04545	.12954	.04318	.08953	.10557	.10423	.10022
MP	.03283	.00996	.02803	.00533	.01929	.01782	.01902	.01913

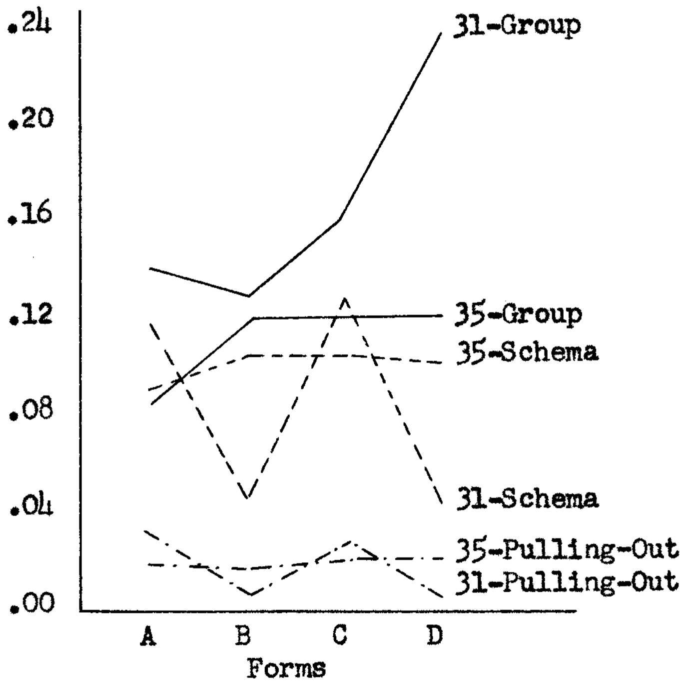

FIGURE 8

FORMS BY SCHEMATA BY SCORING PROCEDURES INTERACTION FOR THE LOWER GROUP

The pulling-out technique shows a significant difference between the groups in the expected direction with the .05 level of confidence, and almost reaches the .025 level. The schema method shows a difference in the expected direction without, however, being significant. Its "t" value of 1.359 just misses the value 1.725 needed for the .05 level.

The group method does not even show a difference in the expected direction. As a matter of fact, it indicates that the lower group should really be called the superior group.

These results then, indicate that use of the group method should be confined to those situations when one is interested in evaluating the performance of individuals in one group in terms of the performance of another group or a criterion group.

Finally, the results of this research indicate that, under the limitations imposed by this sample, the pulling-out method of scoring discriminates best among the three procedures between good and poor problem solvers as defined by the specified criteria.

VII. Summary

The purpose of the research was to investigate three scoring procedures as discriminators between good and poor problem solvers.

Twenty-two undergraduate males (freshmen) from Loyola University, Chicago, participated in the study. This sample was divided into two equal groups, an upper and a lower. The assignment to groups was done by means of two criteria, the Raven's Progressive Matrices test and Thought Problems Part I, tapping reasoning and problem solving ability respectively. Two structures with four variations in content each, a total of eight problems, were administered to both groups in identical circumstances. The performance of each subject in each problem was then scored according to the three procedures.

An analysis of variance, four-way classification was then employed on the data for each group. Significant "F" ratios were found for both groups in the squares (scoring procedures) dimension beyond the .001 level of confidence. Significant variances were also found for the remaining relevant main effects and interactions of both groups with the exception of the block main effects (the two structures) for the upper group. Interpretations of the interactions involving scoring procedures, content variations, and structures were offered to provide a more complete analysis of the scoring techniques.

Finally, a "t" test was used to determine and assess the magnitude of differences between the two groups with respect to each scoring procedure. The group method showed a difference between groups but it was in the wrong direction as defined by the criteria. The schema method differentiated the groups in the expected direction but not at any commonly accepted level of significance. The pulling-out method did discriminate between the groups at the .05 level of confidence and approached the .025 level.

It was concluded that the pulling-out technique, under the limitations imposed by the sample, was the best of the three procedures in discriminating between good and poor problem solvers as defined by the specified criteria when employing the described instruments.

The group technique, though in terms of this study not valuable as a discriminator between good and poor problem solvers, retains its usefulness as a relative measure or a measure in terms of another criterion.

The schema method is the method on whose usefulness doubt is cast; but it will be remembered that the norms for this method are the same as for the pulling-out method, and that it is only in terms of the application of the norms to the sequence that they differ. Therefore, the usefulness of the application of the schema norms in the schema method is called into question by this study. The group method and the pulling-out method both have fruitful possibilities for future investigation.

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Problem 31 A

Instructions and Corresponding Questions and Answers

At Spencer High School the annual fall dance is about to be held. A dance committee has been selected to make the necessary arrangements. Both boys and girls are on the committee. A part of the committee is to take care of the refreshments for the evening and another part will look after the sale of the tickets for the dance. The list of the girls on the dance committee involved in the sale of tickets has been lost. From the other information available, which you will find in the questions, your object will be to discover the number of girls involved in the sale of tickets.

Questions	Answers
1. Is Spencer High School the only co-educational school in the city?	1. No.
2. How many boys attend Spencer High?	2. 240 boys attend Spencer High
3. How many boys are on the dance committee?	3. 10.
4. Are there more girls than boys at this school?	4. Yes.
5. How many students on the dance committee are assigned to supplying the refreshments?	5. 14.
6. What is the total number of students on the fall dance committee?	6. 25.
7. How much time would the committee as a whole spend in preparation for the dance?	7. 275 hours.
8. How much time would the average committee member contribute?	8. 11 hours.
9. How many boys on the committee are involved in the sale of tickets?	9. 6 boys.
10. How many girls are on the refreshment part of the dance committee?	10. 10 girls.

Solution: 5 girls

Problem 31 B

Instructions and Corresponding Questions and Answers

We have a certain number of objects, M, a part of which, for lack of a better name, will be called C's. The C's are composed of B's and G's. No B is a G and vice versa. Some of the C's also are R's and some others are T's. No R is a T and vice versa. How many G's are also T's?

Questions	Answers
1. Are there C's that are not B's and G's?	1. No.
2. How many B's are C's?	2. 30.
3. How many B's are M's?	3. 120.
4. How many C's are R's?	4. 35.
5. Are there more G's than B's among the M's?	5. Yes.
6. What is the value of k times the C's?	6. 550.
7. What is the total number of C's?	7. 50.
8. How many B's that are C's are also T's?	8. 10.
9. How many G's that are C's are also R's?	9. 15.
10. What is the value of k?	10. 11.

Solution: 5 G's.

Problem 31 C

Instructions and Corresponding Questions and Answers

Assume that X, A, D, P, and S, represent properties among F objects. Not-X, not-A, and so on represent lack of these properties. Out of F objects some of them are X's and some not-X's. The not-X's are formed by not-A's and not-D's. A not-A can not be a not-D and vice versa.

Some of the not-X's also are not-P's and some others are not-S's. A not-P can not be a not-S and vice versa.

How many not-D's are also not-S's?

Questions	Answers
1. Are there not-X's that are A's and D's?	1. No.
2. How many not-A's are F's?	2. 100.
3. Are there more not-D's than not-A's among the F's?	3. Yes.
4. How many not-A's are not-X's?	4. 14.
5. What is the total number of not-X's?	5. 40.
6. How many not-X's are not-P's?	6. 24.
7. What is the value of 1 times the not-X's?	7. 440.
8. What is the value of 1?	8. 11.
9. How many not-D's that are not-X's are also not-P's?	9. 20.
10. How many not-A's that are not-X's are also not-S's?	10. 10.

Solution: 6 not-D's.

Appendix I

Problem 31 D

Instructions and Corresponding Questions and Answers

From R objects L have been selected. These objects are formed by A and B objects. No A can also be a B and vice versa. Some of the L objects are also M and some others N. No M can also be an N and vice versa.

How many N's are also B's?

Questions	Answers
1. How many A's are R's?	1. W.
2. What is the total number of L's?	2. E+F+H+I = X+Y = P+Q = L
3. How many L's are M's?	3. E+F = X
4. How many A's are L's?	4. E+H = P
5. Are there more B's than A's among the R's?	5. Yes.
6. Are there L's that are not B's and A's?	6. No.
7. How many B's that are L are also M?	7. F.
8. How many A's that are L are also N?	8. H.
9. What is the value of k?	9. T.
10. What is the value of k times the L's?	10. Z.

Solution: I

Appendix I

Problem 35 A

Instructions and Corresponding Questions and Answers

A college choral group is composed of freshmen, sophomores and juniors. The chorus has three voices or parts which are high, medium, and low. The questions and answers below give vital information concerning the group. From these facts you are to find the number of juniors singing the middle or medium part.

Questions	Answers
1. How many juniors are in this college?	1. 1567.
2. How many freshmen are in the chorus?	2. 23.
3. How many sophomores are in the middle voice?	3. 10.
4. How many chorus members are there?	4. 76.
5. How many girls are in the chorus?	5. 45.
6. How many sophomores are in the chorus?	6. 28.
7. How many juniors sing the high voice?	7. 7.
8. How many freshmen are in this college?	8. 1848.
9. How many freshmen sing the high voice?	9. 8.
10. How many low voice members are there?	10. 28.
11. How many sophomores sing the high part?	11. 9.
12. How many pianos does the chorus have?	12. 3.
13. How many freshmen sing the low voice?	13. 9.
14. How many chorus members sing the high voice?	14. 24.
15. How many juniors are in the low voice section?	15. 10.
16. How many freshmen sing the middle voice?	16. 6.
17. How many sophomores sing the low part?	17. 9.

Solution: 8 juniors.

Problem 35 B

Instructions and Corresponding Questions and Answers

T objects are composed of M, N, and P types. Each of these latter three types may or may not also be Q's, R's and S's. From the questions and answers you can discover the various relationships of these objects. Make use of this available information to determine how many T objects are N's and also S's.

Questions		Answers	
1.	How many S's are A's?	1.	350.
2.	How many Q's are there among the T's?	2.	19.
3.	How many G's are there among the T's?	3.	43.
4.	How many R's are also N's?	4.	8.
5.	What is the total number of T objects?	5.	63.
6.	How many P's are there among the T's?	6.	21.
7.	How many R's are there among the T's?	7.	24.
8.	How many Q's are also M's?	8.	5.
9.	How many R's are also M's?	9.	10.
10.	How many S's are also M's?	10.	2.
11.	How many Q's are A's?	11.	400.
12.	How many R's are also P's?	12.	6.
13.	How many Q's are also N's?	13.	3.
14.	How many S's are also P's?	14.	4.
15.	How many M's are among the T's?	15.	17.
16.	How many Q's are also P's?	16.	11.
17.	How many H's among the A's?	17.	2.

Solution: 14 T objects are N's and also S's.

Problem 35 C

Instructions and Corresponding Questions and Answers

A class of objects is distinguished by calling some B's and some others not-B's depending on the possession or non-possession of a certain property. The not-B's are further distinguished into not-X's, not-Y's, and not-Z's. Each of these latter may also be a not-D, not-E, or not-F. From the accompanying questions and answers you can discover the relationships that exist between these objects. Make use of the information available to determine how many not-B objects are not-Y's and also not-F's.

Questions	Answers
1. How many not-D's are not-A's?	1. 150.
2. How many not-F's are also not-X's?	2. 7.
3. How many not-E's are there among the not-B's?	3. 15.
4. How many not-G's are there among the not-B's?	4. 30.
5. What is the total number of not-B's?	5. 45.
6. How many not-E's are also not-Y's?	6. 6.
7. How many not-D's are there among the not-B's?	7. 6.
8. How many not-F's are not-A's?	8. 100.
9. How many not-E's are also not-Z's?	9. 5.
10. How many not-D's are also not-Y's?	10. 2.
11. How many not-F's are also not-Z's?	11. 9.
12. How many not-X's are there among the not B's?	12. 12.
13. How many not-D's are also not-Z's?	13. 3.
14. How many not-H's are there among the not-A's?	14. 2 log cos 30°
15. How many not-E's are also not-X's?	15. 4.
16. How many not-Z's are there among the not-B's?	16. 17.
17. How many not-D's are also not-X's?	17. 1.

Solution: 8 not-B objects are not-Y's and also not-F's.

Problem 35 D

Instructions and Corresponding Questions and Answers

A group of L objects taken from a larger group of M objects is composed of objects of the kind A, B and C. If an object is an A, it can not be a B or C. If an object is a B, it can not be an A and/or C. If an object is a C, it can not be a B and/or A. That is, A, B, and C are mutually exclusive. The same L objects also have properties D, E and F which are mutually exclusive.

From the questions below you are to find how many of the B's are also F's.

Questions	Answers
1. How many F's are in J?	1. U.
2. How many L's are D's?	2. M + N + O = X.
3. What is the number of L's?	3. M+N+O+R+Q+P+S+T+V = X+Y+Z = G+H+I = L.
4. How many E's are B's?	4. Q.
5. How many L's are K's?	5. W.
6. How many D's are in M?	6. X - M + C.
7. How many L's are E's?	7. R + Q + P = Y
8. How many F's are A's?	8. S.
9. How many E's are A's?	9. R.
10. How many D's are A's?	10. M.
11. How many L's are C's?	11. O + P + V = I.
12. How many F's are C's?	12. V.
13. How many L's are A's?	13. M + R + S = G.
14. How many D's are C's?	14. O.
15. How many U's are M's?	15. U - J.
16. How many D's are B's?	16. N.
17. How many E's are C's?	17. P.

Solution: T of the B's are also F's.

APPROVAL SHEET

The thesis submitted by James B. Erdmann has been read and approved by three members of the Department of Psychology.

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the Degree of Master of Arts.

Jan. 30, 1964
Date

Paul J. von Ebers
Signature of Adviser