1963

A Study of the Relationship between Complex Problem Solving Ability and a Measure of Scholastic Aptitude

Robert G. Riedel
Loyola University Chicago

A Study of the Relationship Between Complex Problem Solving Ability and A Measure of Scholastic Aptitude *

By

Robert G. Riedel

A thesis Submitted to the Faculty of the Graduate School of Loyola University in Partial Fulfillment of the Requirements for the Degree of Master of Arts

*The work in this thesis was partially supported by grant number G-19844 from the National Science Foundation.

June

1963

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of his Adviser Dr. H. J. A. Rimoldi, on this thesis. Acknowledgment is also due to Hermelinda Fogliatto, John Haley, and the other members of the Psychometric Laboratory. The author would also like to acknowledge his debt to the Rev. V. V. Herr, S.J., the Chairman of the Psychology Department. Lastly, acknowledgment is due to Miss Bernice Burris who typed the final copy.

LIFE

Robert G. Riedel was born in Chicago, Illinois March 7, 1936.

He attended the University of Illinois at Champaign for one semester in 1957. After leaving Illinois he went to Wright Junior College in Chicago where he received the Associate of Arts degree in June 1959. He then attended Loyola University, Chicago, where the Bachelor of Arts degree was conferred February 7, 1962.

He spent a year as Assistant to Dr. H. J. A. Rimoldi, on a project concerned with Mathematical ability. He is now a graduate fellow teaching at Loyola University.

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Introduction

The problem of the relationship between problem solving ability and intelligence, though not extensively mentioned in the literature, is an important and vital topic for psychology. The present thesis represents an initial attempt to understand more about this relationship. The present study is similar in some parts to others that have appeared in the literature in the past. The major exception to this similarity is the use of a new technique for studying the processes involved in problem solving that have been developed by H. J. A. Rimoldi and associates at the Loyola Psychometric Laboratory, Loyola University, Chicago, Illinois.

As one reads this thesis he will probably be disappointed to find that it asks more questions than it answers. This is not necessarily a sign of failure for it does point the way to a number of fruitful ideas for possible future research. This ability to provoke questions seems to be a constant companion of the method used to study the processes since not only has it led to significant findings but it has also opened new avenues of approach with each new application. The bibliography at the end of this thesis is actually a very exciting history of a scientific tool and it's evolution from a germ of an idea to a valuable tool for research on mental testing. Even the method of scoring the problems in terms of process that has developed along with this technique, has been improved from publication to publication. In the first few studies, where the diagnostic processes used in medicine were the subject of the research, a method based on group performance and the popularity of the individual questions was used. Later on, when methods were developed which allowed the experimenter to control the content and the structure of the problems, scoring was based on an apriori analysis of the logical relationships that the experimenter had built into the problem. This latter method had the advantage of being based on the logical structure of the problems rather than on the responses of the group taking the test. It also allowed the experimenter to be aware of the inherent difficulty of the problems and the most logical approach that could be used in solving them even before the research was begun.

Other methods of scoring and other types of problems than those that will be seen in this thesis have been developed and applied in different ways. It should not be assumed that because they do not appear here that they are in any way inferior or not applicable to this problem. They do not appear because there has been a conscious effort on the part of the present author to limit this paper in order that it be kept to a reasonable length.

The important attribute of this method of analyzing problem solving which we have mentioned is that while it does give the person testing, the information available from other more common forms of tests, e.g., right and wrong answer or solution, it also gives additional information. This additional information concerns the process or the tactic used by the subject in reaching his end-product or solution. In general those processes that are in agreement with the logical structure of the problem lead to correct solutions while those processes which depart from the logical structure lead to incorrect solutions. This however is not the full story. These tactics indicate the ability of the subject to plan his attack, and his ability to change when one line of attack appears inappropriate. It allows us to have some insight into the versatility of the subjects.

It should not be inferred from the language used in this study that the processes per se, of the subjects, are the direct object of the study. What is being studied is a manifestation of the thought processes involved in solving the problem as represented in the overt process of selecting questions which give information germaine to the problem. While this is not a study of the thought process itself it is much closer than methods which infer the characteristics of the response using merely the solution of the problem. It is also a gain in objectivity over methods such as introspection and "thinking aloud", since the interpretation of these latter methods is necessarily subjective and qualitative while the interpretation of the present method is to a great extent objective and its scoring techniques are quantitative.

Review of Related Literature

The classical monograph by Duncker (7) represents one of the first important attempts to study the processes involved in solving problems. He had his subjects think out loud while they were solving problems, and thus he could check the quality of their tactics. Bloom and Broder (1) using this thinking out loud technique, correlated the quality of their subjects' tactics in solving problems with tests of aptitude and achievement. It can be seen that the study by Bloom and Broder will be similar in some respects to the study presented in this thesis. The primary point of difference is that the technique for studying the tactics the subjects used is the one that has been briefly discussed in the Introduction.

The technique used by Bryan (3) and by Glaser, Damrin and Gardner (8) is very similar to the present one but it's application was primarily to the analysis of troubleshooting ability in electronics. It should also be said that this technique was developed as much as a training aid, as it was for a test. The authors suggest that any type of diagnostic situation could be covered by the technique which they call the "tab-item" technique. The method developed by Rimoldi and associates at Loyola University, Chicago, Illinois, has found application in many different areas outside of diagnostics where it was originally developed. Some of these applications will be mentioned below. Another major difference between the "tab-item" technique and the method developed by Rimoldi and associates is that in the former the answer is made by way of choosing the correct answer from a number of possible answers. In other words, after the subject had received the answer to a few of the items, he could guess which component was faulty, and lift the tab over this component and receive his answer. In the Rimoldi technique the answer must be constructed by the subject from the information obtained in the form of answers to the questions that the subject asks. In other words there is little chance for the subject to guess.

The present technique was first developed as a measurement and research device in connection with the skills involved in the medical clinical diagnostic process. The development and applications of the technique in this form are reported in a number of articles (5, 6, 10, 14, 15, 19, 22, 24, 25, 26). It has also been used to study personality appraisal in terms of process by Gunn (9). Rimoldi presented papers in which he made the initial applications to the study of processes involved in complex reasoning and problem solving (11, 12, 13, 18, 20, 23). Rimoldi and Majewska (21) presented a research proposal for the study of decision processes involved in mathematical thinking. Rimoldi and Devane (16) and Rimoldi, Fogliatto, Haley, Reyes, Erdmann, and Zacharia have presented research related to the training of problem solving ability, using this technique. Tabor has presented research on the processes involved in the interpretation of the Rorschach using this technique (29).

Procedure

A. Purpose

The immediate purpose of this thesis is to characterize the problem solving processes of a group of individuals who have high scholastic aptitudes, and a group of individuals who have low scholastic aptitudes, as measured by the Differential Aptitude Test. From these analyses the characterization of mental processes in relation to aptitude should be highlighted. This represents an advance over other techniques which have been used in the past, which have been anchored in the end-solution, and were unable to characterize the processes involved in reaching it. The two sub-scales, abstract and verbal, of the Differential Aptitude Test, will be analyzod to see if the difference between the two groups, in terms of them, is also significant. Other tests which fall into this general category of aptitude tests will be noticed also for a further characterization of the high and the low groups. These latter tests were administered as pre-tests to these subjects as part of a larger project.

B. Population: Description of Sample

Two Chicago-area Catholic high schools were chosen as the site for the work which provided the material for this thesis. One of these schools was on the north side of the city while the other was on the south side. The entire junior class of each school was tested on the pre-test devices, and the data from the Illinois Statewide Testing Program were made available by the schools. The differential aptitude test was included in the Illinois Statewide High School Testing program battery. From a total population of 532, for which this battery of tests was available, the upper ten per cent and the lower ten per cent were selected in terms of their raw scores on the Differential Aptitude Test. The Illinois Statewide High School Testing Program battery was administered to all the students at each school at the same time as a group by the schools themselves, so the conditions under which the test was taken were roughly the same for all students.

This selection yielded ninety-two subjects; 45 in the upper group, and 47 in the lower group. Since the experiment lasted for more than a year, and there were a number of students who dropped out of school in this time, coupled with the fact that absences could not be controlled, the number of students taking any particular problem may vary considerably. The mean score for the upper group on the Differential Aptitude Test was 85.47 while the corresponding score for the lower group was 39.59. The standard deviation on this test for the entire class was 13.08, and the mean score for the entire class was 63.26. The upper group was 22.00 points above the class mean while the lower group was 23.67 below the entire class mean.

The Differential Aptitude Test has two sub-scales; verbal and abstract reasoning. It can be seen from the following that the characterization by the total test is in agreement with the characterization by the sub-scales. The mean for the upper group on the verbal sub-scale was 40.71 while the mean for the lower group on this test was 15.45. The mean for the total group for this sub-scale was 26.68. The abstract sub-scale yielded a mean of 44.76 for the higher group, and a mean score of 24.15 for the lower group. The mean for this total group for the sub-scale was 36.58.

In the pre-testing session the Ravens Progressive Matrices and the Sequential Tests of Educational Progress (STEP), Mathematics, were administered to the subjects. The scores on these tests were in general agreement with the scores on the Differential Aptitude Test. The mean for the lower group on the Ravens test was 48.12 while the mean for the upper group was 55.61. This may seem to be a small difference in this case but the standard deviation of this test was only 4.27 for the total group. The population mean for this test was 51.50. The mean for the upper group on the STEP test was 38.71 while the mean for the lower group was 20.21. The mean for the total group on this test was 28.36.

It can be seen from the above that the upper and the lower groups are characterized as high and low, as groups, by any of the tests that were administered. The data discussed in the foregoing paragraphs are summarized in Table I below.

C Description of the Problems Used

When this type of research was first initiated at the Loyola Psychometric Laboratory it was in regard to skills in medical diagnosis. After five years of research on this type of problem the basic method was altered to fit many other situations as described briefly in the review of related literature that appears at the beginning of this thesis. In the beginning problems were made up from real life examples and had no other formal properties than the fact that they were all problems of such a nature that they

Table I

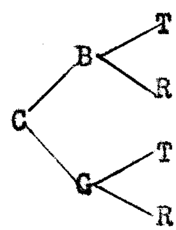
	Total N	Total M	Total S	Upper N	Upper M	Upper S	Lower N	Lower M	Lower S	t	p
DAT	465	63.26	13.08	45	85.47	3.34	47	39.59	7.63	36.691	.001
Verbal	465	26.68	8.06	45	40.71	3.15	47	15.45	4.74	18.173	.001
Abstract	465	36.58	7.07	45	44.76	2.48	47	24.15	8.90	24.213	.001
Ravens	502	51.50	4.27	45	55.61	2.51	43	48.12	4.78	8.990	.001
STEP	500	28.36	6.85	45	38.71	6.12	42	22.14	5.15	13.389	.001

could be solved by asking questions about the problems to gain information that would enable the subject to solve the problem; in this case to reach a diagnosis.

In the last year a method has been developed which permits the experimenter to apriori build into his problems any type of relationship he wishes and to vary the complexity and the abstractness of the problems at will. This is done by developing what has been called schema, and building the problems on the logical relationships contained in them. An example of the type of schemata that have been developed would be those that have been called "tree type schemata." In Figure 1, an example of this type of schemata is presented.

Figure 1

Example of a "Tree Type Schemata"



The letters could represent anything the experimenter wished, and could be presented in language of different degrees of abstractness. An example of a concrete problem built on this schemata would be to let C stand for a dance committee at a high school. The B could stand for the boys on this committee, and the G could stand for the girls that are on this committee. The T could be used for those who were responsbile for the selling of the tickets, and the R could be used for those that are handling the sale of the refreshments. We could then vary the amount of information available to the subject and ask him to find out the number of individuals in one of the groups. The difficulty of the problem can be increased both by increasing the number of the relationships used and by which position in the schemata we ask the subject to identify. Another method whereby the difficulty can be controlled is by the information we make available to the subject in terms of the questions, both their content and the way in which they are worded. An example of how we would present this problem to a subject would be to ask him how many girls were selling tickets. By excluding the possibility of asking some questions, especially the direct question, it would be easy to describe the best logical attack that could be used to solve this problem a priori. Problems of the "A" denotation in this thesis are concrete problems built in a manner similar to this. In the second degree of abstraction with this same schemata as a basis we could let letters stand for the different positions, but still present the subject with answers that were numbers. In this case we would let the letters stand for themselves in the example shown in Figure 1. Problems of the "B" category in this thesis are problems built in a manner similar to this. If we wanted to make the problems even more abstract we could present the answers as numbers in the above example, but present the questions in the form of negatives. For example we could phrase the questions as to how many are not-g's and how many are not-t's. Problems of the "C" category in this thesis are constructed in this manner. In the final degree of abstraction that appears in this thesis we could present the questions and the answers in terms of letters so that the solution would be a letter or a series of letters. The ordinary rules of algebra would apply to the manipulation of these letters. Problems of the "D" category are constructed in this manner.

It can easily be seen that the number of the relationships and their complexity can be varied depending on the type of schemata developed in the initial stages of problem construction. It can also be seen that the schemata can be developed to fit the other types of relationships which would be desired in this type of context. The problems for these schemata could be developed in much the same way as the ones presented above. This method of constructing problems has been discussed by Rimoldi, et al., elsewhere (28) at length and the interested reader is directed to that source.

The presentation of the problem to the subject is done by printing the problem and the questions on separate three by five index cards. The problem itself is presented on the first card (s) and the questions are presented each on a separate card on the cards following the first. The answers appear on the back of the index cards along with a repetition of the questions, so the subject, after asking the question, does not have to refer back to the other side in order to remember the question. In order to ask a question the subject merely turns the card over and places it to the side so that he may refer back to the information contained at later stages in the solution of the problem. Questions which are irrelevant to the problem or are at best useless are presented along with the other questions which are germaine to the solution of the problem. It should be noted at this point that once a subject chooses a particular mode of attack, all questions, even though they may contain useful information if the problem were attacked in a different manner, can now be considered as useless to the subject. That is to say that if a subject begins to find the number of people in a certain point in the "tree-type" schemata he may either find the number of objects in the total group and attempt to eliminate all others or he may go about it by determining how many are in a sub-group and proceed to add up those cases until he has the solution. It can be seen that once he starts in either of these directions, to stop and go along another would be wasteful.

The subject is presented the index cards in a deck with the problem appearing as the first card and the questions presented on the following cards. The subject is instructed to read the problem carefully and then to read all the questions. After reading all the questions he is to pick the question that he wants answered first, and then turn over the card on which it is printed and read the answer. He then repeats this operation until he feels he has enough information to offer the solution to the problem.

D. Scoring Methods

A number of scoring methods were used in this thesis. They are described at greater length elsewhere (28). The basic rationale and procedures for each method will be given here but for a fuller analysis the reader is directed to the above source. The specific scoring methods used in this thesis were: (a) number of questions asked, (b) correct answers to problems, both for the group on each problem and for the average number of correct solutions on all the problems for each group, (c) schemata norms,

(d) plateaux, or number of questions which had no value in the position they were asked or were irrelevant to the solution of the problem, (e) convex sets. A description of each method will be found below.

(a) Number of questions asked

Since the properties of each problem are known it can be calculated in advance how many questions are needed to solve the problem. Once this is known anyone exceeding this number has either asked irrelevant questions or has not realized that he has enough information to offer a solution to the problem. This should then provide a sensitive index as to whether the subjects have proceeded at an efficient rate or not. It would follow from this that the poor problem solvers, being less efficient and perhaps not proceeding in the best logical manner as dictated by the properties of the problem, would require more questions to solve the problem than would the good problem solvers. The mean number of questions for each group on any given problem should then be an index of which group is more efficient at problem solving.

(b) Correct Solutions

This is the customary method of scoring items in a test and if problem solving ability using the present technique is scored in this manner we have the similar information to that which is yielded by more conventional tests. Indeed the items on most intelligence tests are similar to these problems in many cases except that they are of shorter length, contain all the information in the presentation of the problem, and are quite often of the multiple-choice variety. We would expect that people who were low in intelligence, in this case in scholastic aptitude, would not get as many problems correct as those who were high in intelligence, if problem solving and intelligence are as highly related as we have claimed. We would also expect that any particular problem in the battery would be solved correctly more often by the group high in intelligence than by the group which is low in intelligence.

(c) Schemata Norms

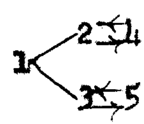
The foregoing methods of scoring the problems are useful but they do not take into consideration the order in which the questions are asked by the subject. In earlier applications of this technique the total number of times a question was asked by a group, i.e., its popularity, was used as an indicator of the value of that question for the solution of the problem. The value assigned to this popularity was called the question's utility index. This method was especially useful in testing medical diagnostic skill where questions cannot be judged on any qualitative basis for their ability to contribute to the solution of the problem in many cases. In this case the solution to the problem would be a diagnosis. This was the primary method until the development of schemata to build problems upon was used. The development of problems based on schemata where the logical relationships were known by the experimenter and indeed were under his control allowed norms to be developed which were based on the problems themselves. It can easily be seen that a scoring method based on the inherent difficulty of the problem and its logical relationships is far superior to any that depend on the performance of the group which will vary in quality depending on the group under consideration. This allows for cross group comparisons to be made against some norm which is not dependent on the groups under consideration.

In a problem of the "tree type", described earlier in this thesis, the knowledge of the relationships allows us to determine the correct order in which the questions should be asked and what questions are necessary and sufficient for the solution of the problem. As an example of this the relationships inherent in a sample schemata are presented in Figure 2.

Figure 2*

Example of Relationships

In a "Tree Type"Schemata



A B C

* A indicates first order, B second, and C third.

In the example presented in Figure 2, question one should be asked first in all the tactics. Question one may be followed by any of the other questions but the choice of the second question determines what the third must be. If question two is asked in the second position then question four must follow; if question four, then question two; if question three then question five, and if question five then question three. The four possible tactics that can be used in this example are presented in summary form in Table II below.

There are a number of ways these questions could be assigned weights and only the method of scoring employed in this thesis is explained here.

Anyone interested in further weighting techniques should consult Rimoldi, et al., (28). Rather than to assign an equal weight to all of the possible responses it was decided to weight each response inasmuch as it was a proportion of the total number of possible responses in all the tactics. In the case listed there are twelve possible responses considering both the question and the order in which it may be asked. To make the example more meaningful in terms of the types of problems actually used in this thesis, assume that there are ten questions in the example problem and that the remaining questions, e.g., questions six through ten, are all questions which are irrelevant to the solution of the problem. The next step is to arbitrarily impose the value of one for the total number of entries in the table. Next add up the total number of times any given response appears in a given order and divide this by the total number of possible tactics. In the example above, question one appeared in the first position four times and divided by the total possible number of tactics, four, a value of 1.00 is obtained. Dividing this result by the total number of questions in the problem, a weight of .10 is obtained for the first question in this position. Since the other questions will have a weight of .50 in any column, yet, since they can appear in either order, they end up with a weight of .025.

Table II*

Possible Tactics in the Example Schemata Problem

Tactics	Questions				
	1	2	3	4	5
a	1	2		3	
b	1	3		3	
c	1		2		3
d	1		3		2

* (The entries represent order of choice)

If a subject asked four questions on our sample problem; one, three, five, and eight, in that order, he would be scored as follows: he would receive a value of .100+.025+.025+.000 or a total of .150. It can be seen that this can be scored as a cumulative value and that an individual performance curve which is representative of the agreement with, or the departure from the schemata norms for the problem under consideration, can be drawn. This type of analysis has been made in other publications but has not been attempted here (16, 28). It can also be seen that the curve obtained from this type of cumulation is an observed value score. If each observed score is corrected by the amount, it is expected by chance alone, the resulting curve is called the Observed minus the Expected. The theoretical values for a question being asked in any given position as a function of the total number of questions possible is given in a paper by Rimoldi and Georgas (17). The amount of separation that occurs between the two lines is also an indication of the quality of the process that the subject has used in attempting to solve the problem.

(d) Plateaux

It can be seen from the foregoing section that some of the questions asked by the subject may have a zero value for this type of scoring system where irrelevant questions are used and the position in which the question is asked are taken into consideration. Since the number of these zero responses is an indication of the quality of the process itself, an analysis in terms of them might prove useful. In this thesis the zero responses are referred to as plateaux. The mean number of zero questions asked by each subject for each group on each problem is an indication of the number of valueless or irrelevant questions that each subject in a given group asked on any problem. This is referred to as the mean length of plateaux in this thesis. The proportion of the total number of responses that are valueless on any given problem for each group can also be calculated. This will be an indication of the amount of the subjects' total responses in the group that are contributory to the problem and those that are not. This score is also given in the section on results for each group and for each problem.

It should be emphasized that zero responses can be obtained by either asking questions which are irrelevant to the problem or by asking questions in a sequence which does not agree with the schemata norms. This could occur in two ways, either the subject could merely ask a question that has value in another position or another sequence or he could begin a sequence only after asking irrelevant questions. In this second case the questions although in the proper order would not be in the proper position since they would have been forced back a number of positions equal to the number of irrelevant questions that were chosen.

(e) Convex Sets

If the two points, the observed (O) and the observed minus the expected (O-E) are plotted for the final cumulative value for a subject, we find that we can plot these points on a graph such that the quality of his process is indicated by his position on the graph. This can be done for all the subjects in each group and by having points represent one group and crosses represent the other group, we can make comparisons of the two groups in regard to where their members appear on the graph. This graph is constructed so that the values on the abcissa represent the O values while the values on the ordinate represent the O-E values. Those subjects in the upper right-hand corner will be those whose process is in closest agreement with the schemata norms while those in the left lower corner will be those subjects whose performance departs the most from the schemata norms. Any point in between these extremes will indicate more or less agreement with the schemata norms according to its position. The maximum and the minimum scores for each group can be connected with a line which will show the boundaries for the two groups. The amount of common space shared between the two resultant figures so constructed indicates the types of processes which were common to the two groups while the space not shared indicates those processes which were unique to one group.

RESULTS

A. Number of Problems Correctly Solved.

The upper group had thirty-eight subjects who completed all the problems. The lower group had twenty-eight who completed all the problems. The difference between the number of completions for the two groups was due mainly to absences on the day of testing. The thirty-eight subjects in the upper group solved a total of 288 problems of those administered while the lower group solved 136. The total number of possible solutions for the upper group was 342 while the corresponding number for the lower group was 252. The mean number of problems solved correctly per subject in the upper group was 7.579. The corresponding figure for the lower group was 4.857. These means were found to be significantly different at greater than the .01 level.

The number of subjects who solved each problem correctly was also analyzed and a chi square test was performed on the correct and the incorrect solutions for each group for each problem. The result of the chi square analysis is shown in Table III. It can be seen that for all the problems where there was a proportion large enough that a chi-square could be run, the difference between the two groups is significant at either the .01 level or the .001 level in each case. The differences between the number of correct and incorrect solutions for problems Nos. 41B, 39A, 43A, and 43B were not significant according to Fisher's Exact Probability.

It can be seen from the foregoing that some of the tests were able to differentiate between the two groups while others could not. It is suggested that if an item analysis were made on the items of the Differential Aptitude Test the results would also indicate that there were items which were answered correctly by a large number of both groups.

Table III

Chi-Square Analysis of Correct and Incorrect Solutions*

35A	35B	35C	35D	39A
9.38**	17.63***	18.00***	27.90***	.138****
39B	41A	43A	43B	
8.22**	11.16***	.107****	.123****	

* Chi-square values corrected for small sample.

** Significant at greater than the .01 level

***Significant at greater than the .001 level

****Not significant-Fisher's Exact Probability

It can be seen from Table IV that very few of the subjects were unable to solve the problems that are not significant in Table III. This would lead one to hypothesize that these problems were too easy for this group of subjects and therefore did not discriminate between the two groups. The number of correct solutions for each group and number of incorrect solutions for each group is presented in Table IV. It can be seen from this Table that even the number of completions for each group on any given problem is quite different.

It would seem from the foregoing that any analysis of right and wrong answers is in agreement with the Differential Aptitude Test, at least at the group level. That is to say that the high group is characterized by high scores on both tests and that the low group is characterized by low scores on both tests. In both cases the upper group is superior to the lower group and in both cases this difference is highly significant.

Table IV

Number of Correct and Incorrect Solutions

	35A		35B		35C		35D		39A	
	+*	-*	+	-	+	-	+	-	+	-
Upper	39	2	24	18	32	10	31	10	40	2
Lower	26	11	4	35	8	25	3	30	29	5

	39B		41A		43A		43B	
	+	-	+	-	+	-	+	-
Upper	35	6	33	9	42	0	41	1
Lower	18	17	13	21	36	3	30	4

*+ = correct, - = incorrect

B Number of Questions

The analysis of the data by this method was disappointing in light of the last analysis if it is difference between the two groups that we are looking for. There seems to be no systematic difference between the two groups by this type of analysis. Table V indicates the mean number of questions asked by the upper group and the lower group for each problem. It can be seen that the differences in these means are slight and that seven are in favor of the upper group while three are in favor of the lower group. The only problem which showed a significant difference was 43B. The present data would seem to indicate that for separating high and low scholastic aptitudes such as are measured by the Differential Aptitude Test, some scoring method other than the one discussed in this section would perhaps yield results more in line with what would be desired. This method has shown in the past to be an indicator of the efficiency of the subject's approach but to have very little relationship to the quality of his tactic or to the rightness or wrongness of his solution.

Table V

Mean Number of Questions for

Both Groups on Each Problem

	35A	35B	35C	35D	41A	43A	43B*	39A	39B
Upper	5.41	5.81	5.45	5.22	5.33	5.48	5.19	5.40	5.38
Lower	5.67	5.18	5.67	5.54	5.00	5.54	6.74	5.91	5.83

* The difference on this problem was significant at the .001 level. All others were not significant.

C Plateaux: Analysis of Valueless Questions

If a valueless question is asked the scoring system described earlier in this thesis in the section on schemata norms gives no score to that response. A valueless question can occur in two ways. In the first case irrelevant questions are placed in the problem and if these are chosen by the subject no score is given since they in no way contribute to the solution of the problem and indeed indicate a lack of understanding on the part of the subject as to the exact nature of the problem. The other way that a question can receive a score of zero is to be asked out of the sequence of the schemata. These responses of either type are called zero responses in this thesis since they are scored as zero with the method of scoring used here. A number of these responses occurring in the same problem constitutes what has been called a plateaux (28). A plateaux may vary in length from one question to the total number of questions that a subject asks. A plateaux can be said to indicate the number of questions that were used which were of no value in solving the problem or were not properly in the sequence demanded by the logical structure of the problem. The length of a plateau is the same as the number of questions asked that were of no value. Table VI shows the mean length of plateaux for the upper and the lower groups on problems 35A, 35B, 35C, 35D, and 41A. The other four problems mentioned elsewhere in this thesis were not analyzed in terms of schemata norms because these norms had not been developed when this thesis was written. The outline stated that one problem of each type would be analyzed in this manner and this has been done.

Table VI

Mean Length of Plateaux for the Upper and the Lower Groups

	35A	35B	35C	35D	41A
Upper	1.66	2.40	1.40	1.80	1.98
Lower	3.05	2.41	2.80	4.10	2.74
t Values	2.46	.001	2.71	4.98	5.24
Sig.	.01	0.7	.005	.0005	.0005

It can be seen from Table VI that the difference is significant in favor of the upper group on every problem but problem 35B. This difference seems to increase both as a function of the difficulty of the problem and of how late in the study it was presented to the students, since the order in the Table is the same order in which the subjects received these particular problems.

Since the number of zero responses is not only a function of the type of question asked and the order in which it is asked, but also of the total number of questions asked, the present author feels that a more sensitive measure would be the proportion of the total number of responses for each group that were scored as zero responses. These data are summarized in Table VII. The difference between the two groups is made even greater by this type of analysis. This may be accounted for by the fact that some students in the lower group asked only two or three questions and then gave up and attempted to guess at the answer to the problem without the necessary information. This occurred more often the more difficult the problem was on which they were working. This was quite often the reason why the lower group's mean number of questions was as low as it was on many of the difficult problems. It seems that the lower group was not motivated to seek out the proper solution of the problem after having received only partial information.

Table VII

Proportion of Total Responses That Were Scored As Zero *

Upper	.31	.41	.25	.34	.36
Lower	.54	.44	.53	.73	.57
Chi Square Value	24.46	1.97	25.91	62.78	12.18
Significance	.001	.2	.001	.001	.001

*Chi-square was derived from the number of zero responses and the number of value responses in a four fold contingency table.

D Convex Sets

The data in this section actually represent a special application of the schemata norms that were discussed earlier. If a graph is drawn on which the observed (O) values are represented on the abcissa and the observed minus the expected (O-E) values are drawn on the ordinate, a figure is generated which has been called a convex set in earlier publications (e.g. 28). Each subject is represented by a single point on the graph. Those scores in the upper right hand area of the figure represent those subjects whose approach was in closest agreement with the schemata norms. Those points which represent the furthest departure from the schemata norms will be found in the lower left hand area of the graph. It is impossible because of the inherent proporties of the scoring method that any points appear in the upper left hand corner since this would make the corrected value higher than the uncorrected value. Points which are to the right of the graph but which are lower than the extreme represent subjects who asked questions in the proper order but then continued to ask questions which were, of course, then beyond the limits of the of the schemata norms and were thus scored as zero. It seems logical that a subject who has enough insight into the structure of the problem to ask the questions in the proper order would also have sufficient insight to know when he had enough information to solve the problem. Since there are tactics of this type at all it seems that research on the personalities involved would be interesting and rewarding. Perhaps this type of performance is related to some trait such as compulsivity. Any point between the upper right and the lower left can be said to be in agreement with or a departure from the schemata norms inasmuch as it is close to either extreme. In Figures 3 through 6, the upper group is represented by dots while the low er group is represented by crosses. The extremes for both groups are connected in each of the graphs. The solid line indicates the extremes for the upper group while the broken line indicates the extremes for the lower group. The space enclosed by these lines indicates the types of tactics that were shared by the two groups where the area is common to both groups. The area which is not shared on the graphs is an indication of the processes that were unique for one group and did not appear in the other group. The graphs for problem 35B and 35D show the greatest amount of difference between the two groups. The tactics represented by the area that is common to the two graphs which indicates tactics common to the two groups is of extreme interest. On all of the other tests and methods of scoring represented in this thesis there is evidence to support the fact that these are two extremely different groups. Yet in this mode of interpretation there is a considerable amount of overlap between the two groups. It would be interesting to see if the correlation with grades were higher for the

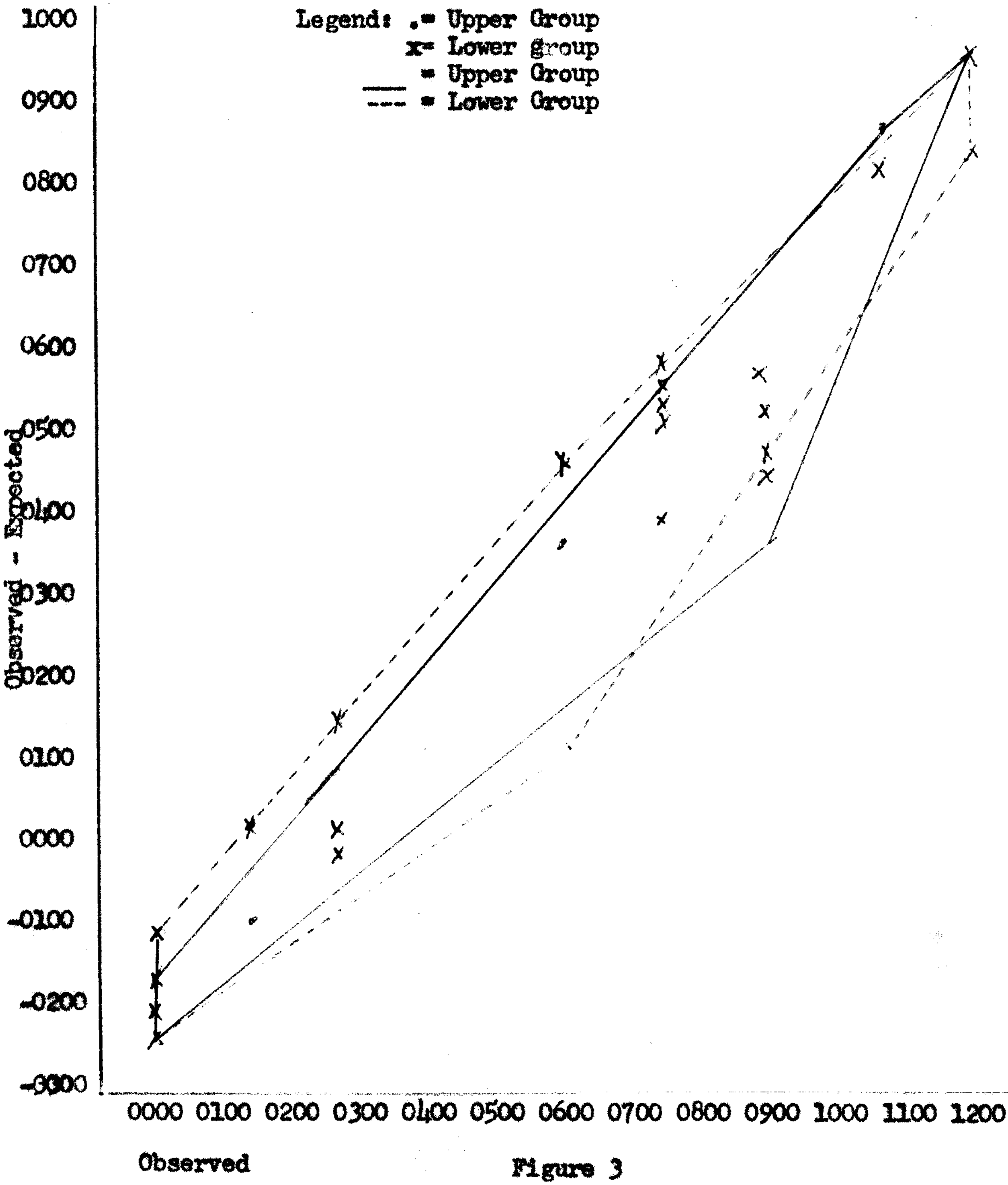


Figure 3

Convex Set for 35 A

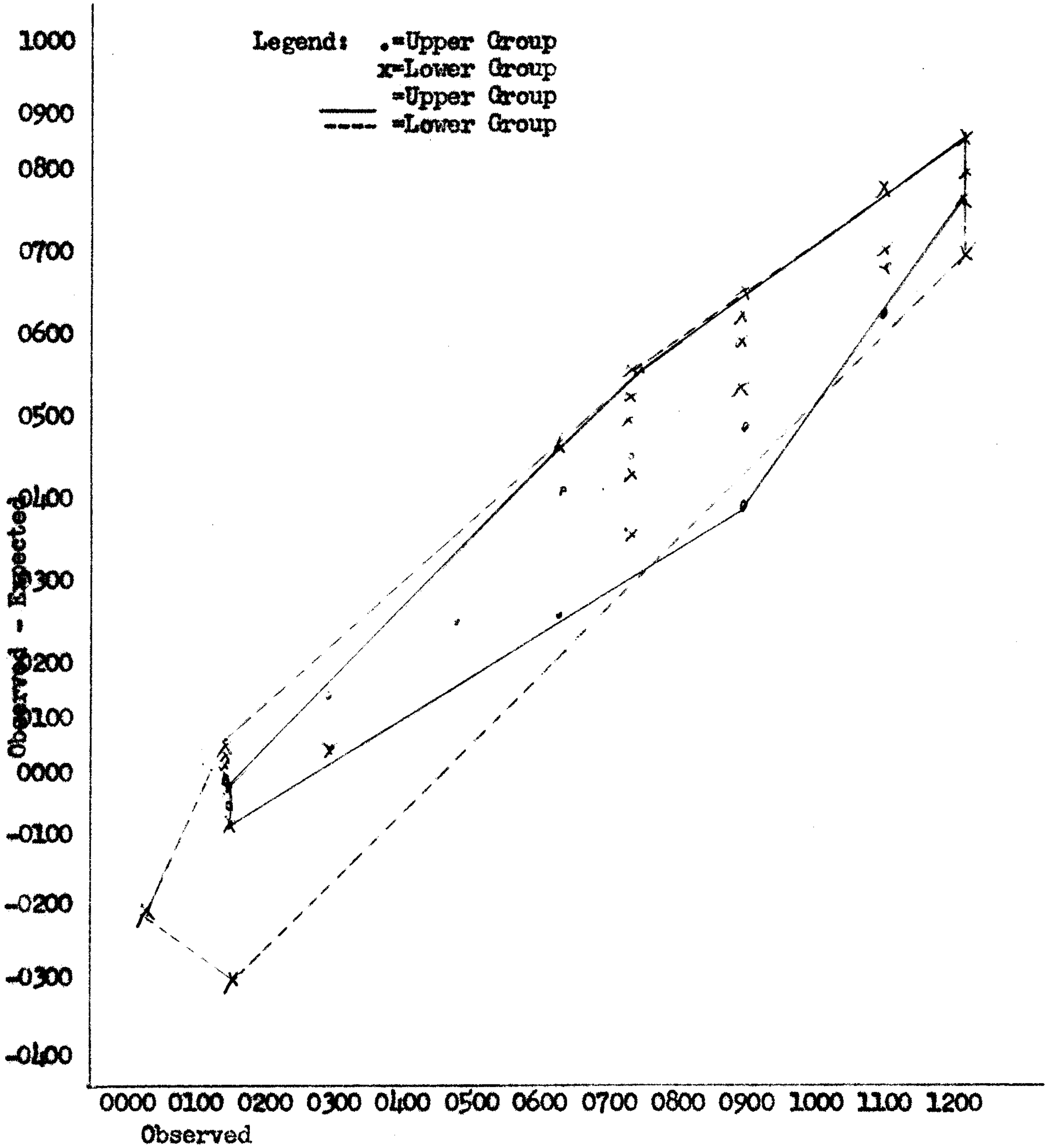


Figure 4

Convex Set for 35 B

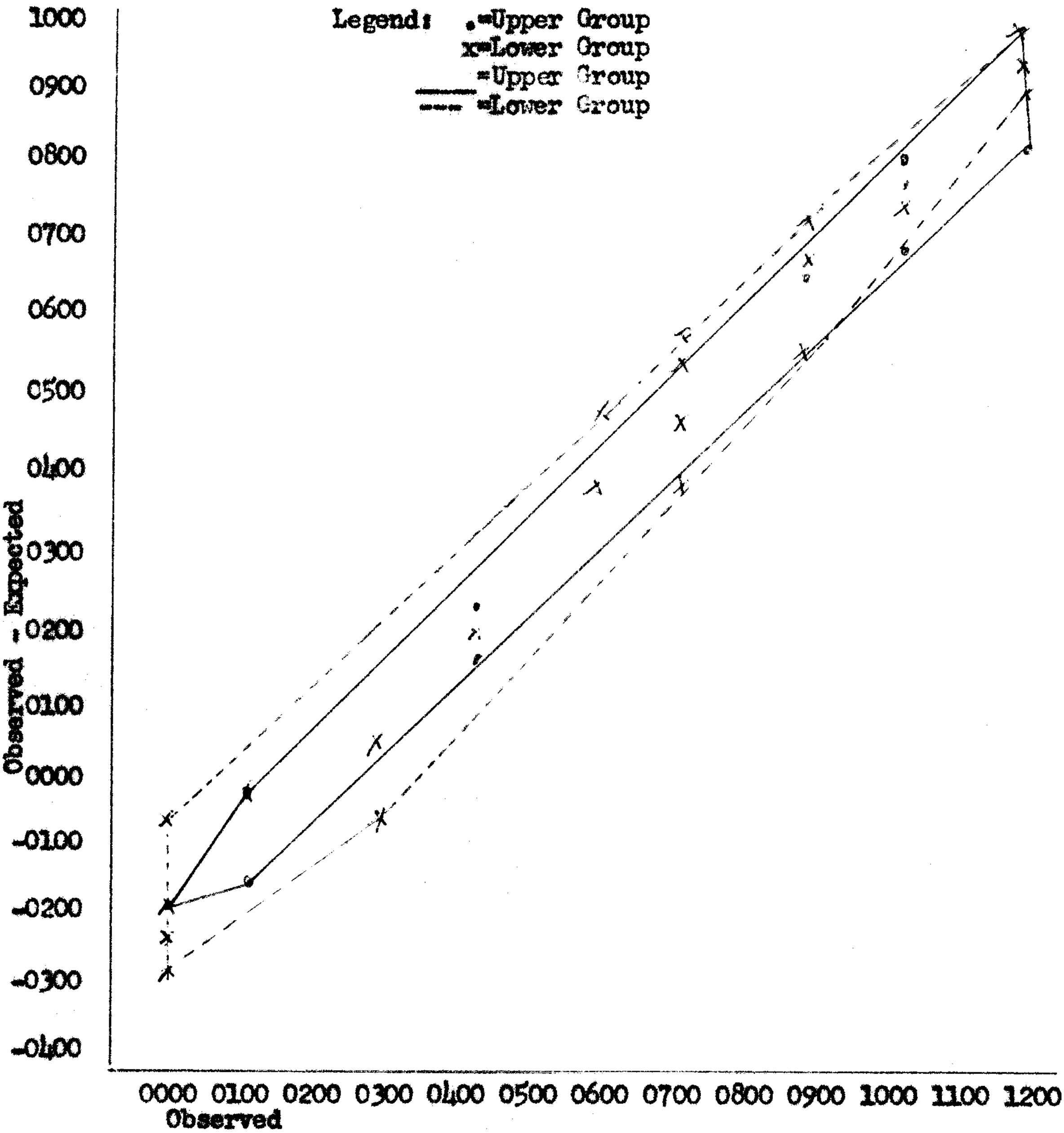


Figure 5

Convex Set for 35 C

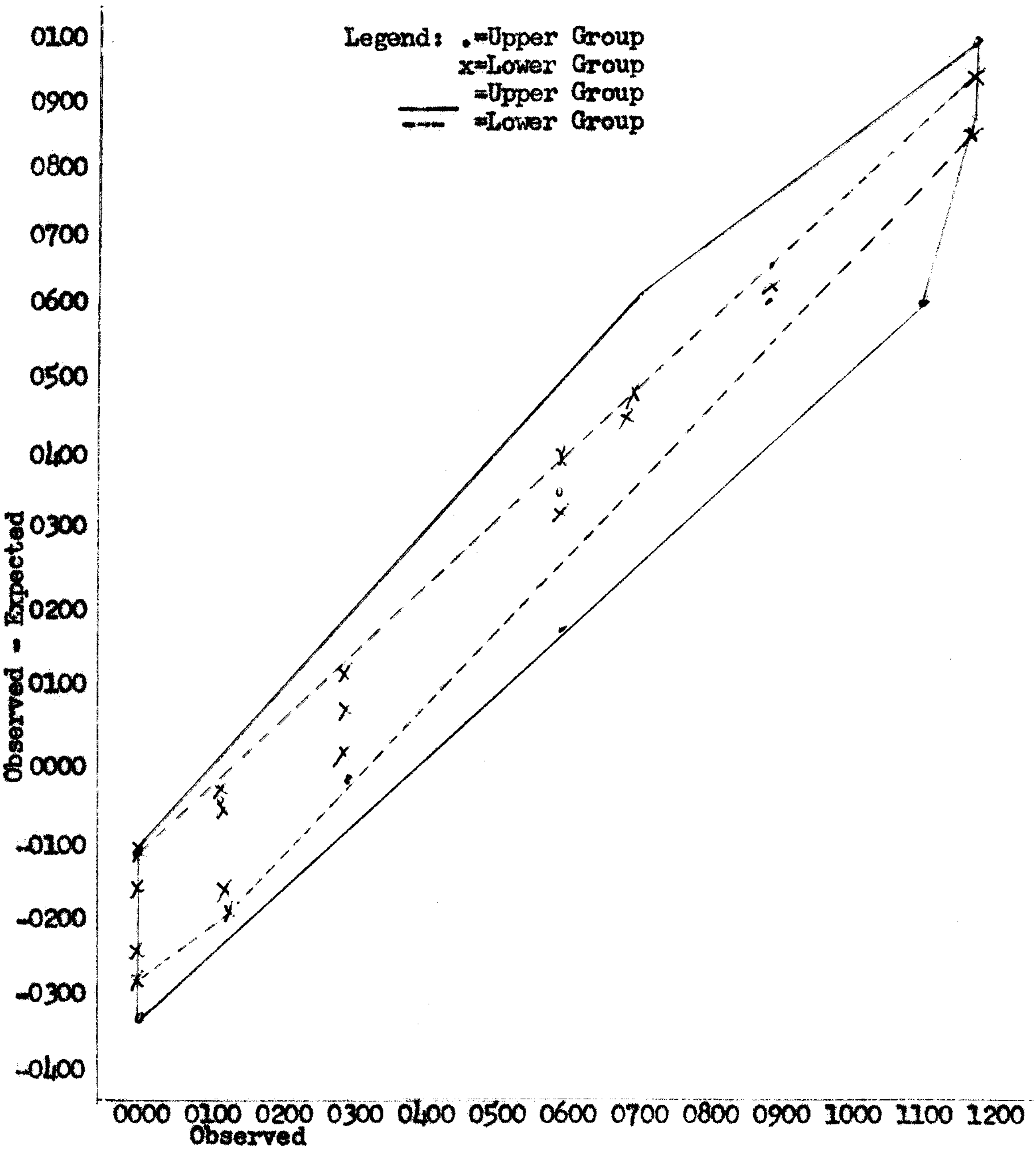


Figure 6

Convex Set for 35 D

number indicated on this graph by a point or for the score on the Differential Aptitude Test.

Since this method of representing the group's performance seems to indicate that there is much overlap between the two groups, it would seem that a study which would isolate the value of this method of scoring as a predictor of scholastic performance would perhaps yield valuable results. Not only have we represented the quality of the subject's performance on these graphs but we have indicated his departure from chance. It would seem that additional research is warranted on this topic. There is some indication from earlier research on training in problem solving (28) that this ability to solve problems with a process that is in agreement with the schemata norms, or more clearly, in line with the logical structure of the problem is related to grades in certain subjects. Perhaps further research would clarify this relationship and indicate the possibility of using this method of studying problem solving as a test for prediction or selection of students for honors or accelerated classes where creativity and the ability to think rather than to do rote memorization and reproduce is the important criterion.

SUMMARY

From a group of 532 Chicago area high school juniors a group that scored high on the Differential Aptitude Test and a group that scored low on the same test were selected. These groups were given nine problems of the type developed by Rimoldi and associates at the Loyola Psychometric Laboratory. A number of scoring methods were applied to the problems to determine the differences that existed between the two groups in relation to this type of test. The interesting thing about analyzing problem solving in this manner is not only does it allow the conventional analysis of the right and wrong answers but allows the experimenter to study the processes or tactics used by the subject to reach that end-product.

The upper group got more of the problems right than did the lower group. The score for the number of problems right for each subject was higher for the upper group than the corresponding score for the lower group. The differences between the mean values for these scores was found to be significant in both cases. The mean number or zero, i.e., worthless, items asked by the upper group and the proportion of the total number of questions asked that were zero, was less for the upper group than for the lower group on each of the problems analyzed in this way. The mean number of questions asked for each problem was less for the upper group than for the lower group on seven of the nine problems, while the relationship was reversed on the other two problems.

It was shown that by plotting a point on a graph that was representative of the quality of the process an individual had used to solve the problem, interesting differences between the two groups could be

observed. It was stated that this type of analysis suggested that further research along these lines would prove rewarding. It was also suggested that a study be made attempting to find the relationship between this type of test and grades in school, with the hope that this type of test could prove useful as a selection device and for the discovery of creativity and talent.

It can be seen from the foregoing analysis that there are great differences in the ability to arrive at the correct solution of a complex problem between a group that is high on the Differential Aptitude Test and a group that is low on the same test. This difference becomes very slight, however, when the processes utilized to arrive at this solution are analyzed. These processes are called tactics in this thesis. From the material in this thesis it can be seen that the information obtained from the problem solving approach developed by Rimoldi and associates not only gives us the information available from conventional testing methods but gives us additional information about the tactics the testee used to arrive at his answer.

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APPENDIX

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 other 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 ane 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 + O
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

Problem 39 A

Instructions and Corresponding Questions and Answers

A man wished to buy an automobile. After investigating all of the makes available, he found three types of automobile, A, B, and C, that were suited to his needs. In choosing among these three he decided to buy the one that would cost the least. Which type of automobile did he buy, A, B, or C?

Questions	Answers
1. What was the total cost of car A?	1. 2000 pounds
2. What was the total cost of car B?	2. 8000 francs
3. What was the total cost of car C?	3. 250,000 pesos
4. What is the value of a pound in United States currency?	4. $2.50
5. What is the value of a pound in French currency?	5. 10 francs
6. What is the value of a pound in Spanish currency?	6. 250 pesos
7. What is the value of a franc in United States currency?	7. $ .25
8. What is the value of a franc in English currency?	8. .1 pound
9. What is the value of a franc in Spanish currency?	9. 25 pesos
10. What is the value of a dollar in English currency?	10. .4 pound
11. What is the value of a dollar in French currency?	11. 4 francs
12. What is the value of a dollar in Spanish currency?	12. 100 pesos
13. What is the value of a peso in United States currency?	13. $ .01
14. What is the value of a peso in English currency?	14. .004 pound
15. What is the value of a peso in French currency?	15. .04 franc

Solution: Car B

Problem 39 B

Instructions and Corresponding Questions and Answers

There are three objects, X , Y, and Z. Each object has a value that can be stated in terms of a, b, c, or d. From the following questions select those that you consider necessary to determine which of the three objects has the smallest value.

Questions	Answers
1. What is the value of X?	1. 100a
2. What is the value of Y?	2. 400b
3. What is the value of Z?	3. 12,500d
4. What is the value of "a" stated in terms of "c"?	4. 2.5c
5. What is the value of "a" stated in terms of "b"?	5. 10b
6. What is the value of "a" stated in terms of "d"?	6. 250d
7. What is the value of "b" stated in terms of "c"?	7..25c
8. What is the value of "b" stated in terms of "a"?	8..1a
9. What is the value of "b" stated in terms of "d"?	9. 25d
10. What is the value of "c" stated in terms of "a"?	10..4a
11. What is the value of "c" stated in terms of "b"?	11. 4b
12. What is the value of "c" stated in Terms of "d"?	12. 100d
13. What is the value of "d" stated in terms of "c"?	13..01c
14. What is the value of "d" stated in terms of "a"?	14..004a
15. What is the value of "d" stated in terms of "b"?	15..04b

Solution: Y

Problem 41 A

Instructions and Corresponding Questions and Answers

As a textile factory in a small town the telephone system connecting the various factory offices is rather primitive. However, communications between offices is greatly aided by the network since the offices are considerably separated.

Basically, the factory has a north wing comprising offices A, B, and C, and a south wing in which are offices D, E, F, H, and G. At the time the phones were installed only seven were available and consequently office G is without one. Because of the way in which the phones have been wired certain limitations have been placed on their use. The limitations are these:

1) There is not a single phone from which all the other offices with phones may be called.
2) The fact that one office can call another does not necessarily mean that the last office can call the first.

With this present confusion in the telephone network a worker in office B would like to contact someone in office H. What is the most efficient way in which this can be accomplished?

Questions	Answers
1. Is there a line from any office in the North wing to H?	1. No
2. Which office can issue outgoing calls to the greatest number of other offices?	2. Office E
3. What offices can office C call?	3. Offices D&E
4. Can office A call office H?	4. No
5. From which offices in the south wing can office H receive calls?	5. N
6. What offices in the north wing can call offices in the south wing?	
7. Can every office in the north wing call every office in the south wing?	7. No
8. Can office B call Office A?	8. Yes
9. What offices in the north wing can call office C?	9. Only Office B
10. Can office C call office B?	10. No
11. What offices can office H call?	11. None
12. Can every office in the south wing call every office in the north wing?	12. No
13. What offices can office E call?	13. Offices A, B, C, D, and F
14. Can office B call Office H?	14. No
15. Can any office in the south wing call any office in the north wing?	15. Yes, only Office E

Solution: B C D H

Problem 43 A

Instructions and Corresponding Questions and Answers

A man owns some race horses. One of his horses won a race yesterday. Your problem is to determine which of his horses won the race.

Questions	Answers
1. How many race horses does the man own?	1. He owns four horses, Magic Realm, Prince Jet Secessionist, and Lethal.
2. Does he ever run all of the horses on the same day?	2. No
3. Does he ever run three horses on the same day?	3. No
4. Does he ever run two horses on the same day?	4. Sometimes
5. Are there any days when he only runs one horse?	5. Yes, on some days
6. Does Magic Realm ever race alone?	6. No
7. Does Prince Jet ever race alone?	7. No
8. Does Secessionist ever race alone?	8. No
9. Does Lethal ever run with Prince Jet?	9. No
10. How many of his horses ran yesterday?	10. One
11. Does Magic Realm ever run with Prince Jet?	11. Yes whenever Magic Realm races, Prince Jet also races.
12. Does Magic Realm ever run with Secessionist?	12. No
13. Does Magic Realm ever run with Lethal?	13. No
14. Does Prince Jet ever run with Secessionist	14. Yes, sometimes
15. Does Prince Jet ever run with Lethal?	15. No.
16. Does Secessionist ever run with Lethal?	16. No
17. Does Prince Jet ever run with Magic Realm?	17. Yes, sometimes
18. Does Secessionist ever run with Magic Realm?	18. No
19. Does Secessionist ever run with Prince Jet?	19. Yes, whenever Secessionist runs, Prince Jet also runs
20. Does Lethal ever run Secessionist?	20 No

Solution: Lethal

Problem 43 B

Instructions and Corresponding Questions and Answers

A man selected one object from a number of objects. Before he could select that object it had to be displayed before him. Each object could be displayed with any other object or objects. Although there were some displays that never occurred. Your task is to discover which object the man selected.

Questions	Answers
1. How many objects are there?	1. Four: A,B,C, and D
2. Do all of the objects ever occur in the same display?	2. No
3. Do three objects ever occur in the same display?	3. No.
4. Do two objects ever occur in the same display?	4. Yes, sometimes
5. Is one object ever displayed alone?	5. Yes, sometimes
6. Does A ever occur alone?	6. No
7. Does B ever occur alone?	7. No
8. Does C ever occur alone?	8. No
9. Does D ever occur with B/	9. No
10. How many objects were displayed?	10. One
11. Does A ever occur with B?	11. Yes, A always occurs with B
12. Does A ever occur with C?	12. No
13. Does A ever occur with D?	13. No
14. Does B ever occur with C?	14. Yes, sometimes
15. Does B ever occur with D?	15. No
16. Does C ever occur with D?	16. No
17. Does B ever occur with A?	17. Yes, sometimes
18. Does C ever occur with A?	18. No
19. Does C ever occur with B/	19. Yes C always occurs with B
20. Does D ever occur with C?	20. No

Solution: D

Table I *

Values Corresponding to Each Group According to the Scoring Method
Based on the Schemata for Problem No. 35 A

Order	Questions 2	3	4	6	7	10	14	15	16
1.			0588						
2.	0147			0147		0147	0147		
3.	0147			0147		0147	0147		
4.		0147			0147			0147	0147
5.		0147			0147			0147	0147

* All questions which do not appear in this Table receive a score of zero.

Table II *

Valess Corresponding to Each Group According to the Scoring Method
Based on the Schemata for Problem No. 35 B

Order	Questions 2	4	5	6	7	10	13	14	15
1.			0588						
2.	0147			0147	0147				0147
3.	0147			0147	0147				0147
4.		0147				0147	0147	0147	
5.		0147				0147	0147	0147	

* All questions which do not appear in this table receive a score of zero

Table III *

Values Corresponding to Each Group According to the Scoring Method
Based on the Schemata for Problem No. 35 C

Order	Questions 2	3	5	6	7	10	11	12	16
1.			0588						
2.		0147			0147			0147	0147
3.		0147			0147			0147	0147
4.	0147			0147		0147	0147		
5.	0147			0147		0147	0147		

* All questions which do not appear in this Table receive a score of zero.

Table IV *

Values Corresponding to Each Group According to the Scoring Method
Based on the Schemata for Problem No. 35 D

Questions

Order	2	3	4	7	8	11	12	13	16
1.		0588							
2.	0147			0147		0147		0147	
3.	0147			0147		0147		0147	
4.			0147		0147		0147		0147
5.			0147		0147		0147		0147

* - All questions which do not appear in this Table receive a score of zero.

APPROVAL SHEET

The thesis submitted by Robert G. Riedel 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.

April 1, 1965
Date

Signature of Adviser